BIOGRAPHICAL MEMOIRS

John Burns Brooksby. 25 December 1914 –– 17 December 1998: Elected FRS 1980

R. F. Sellers

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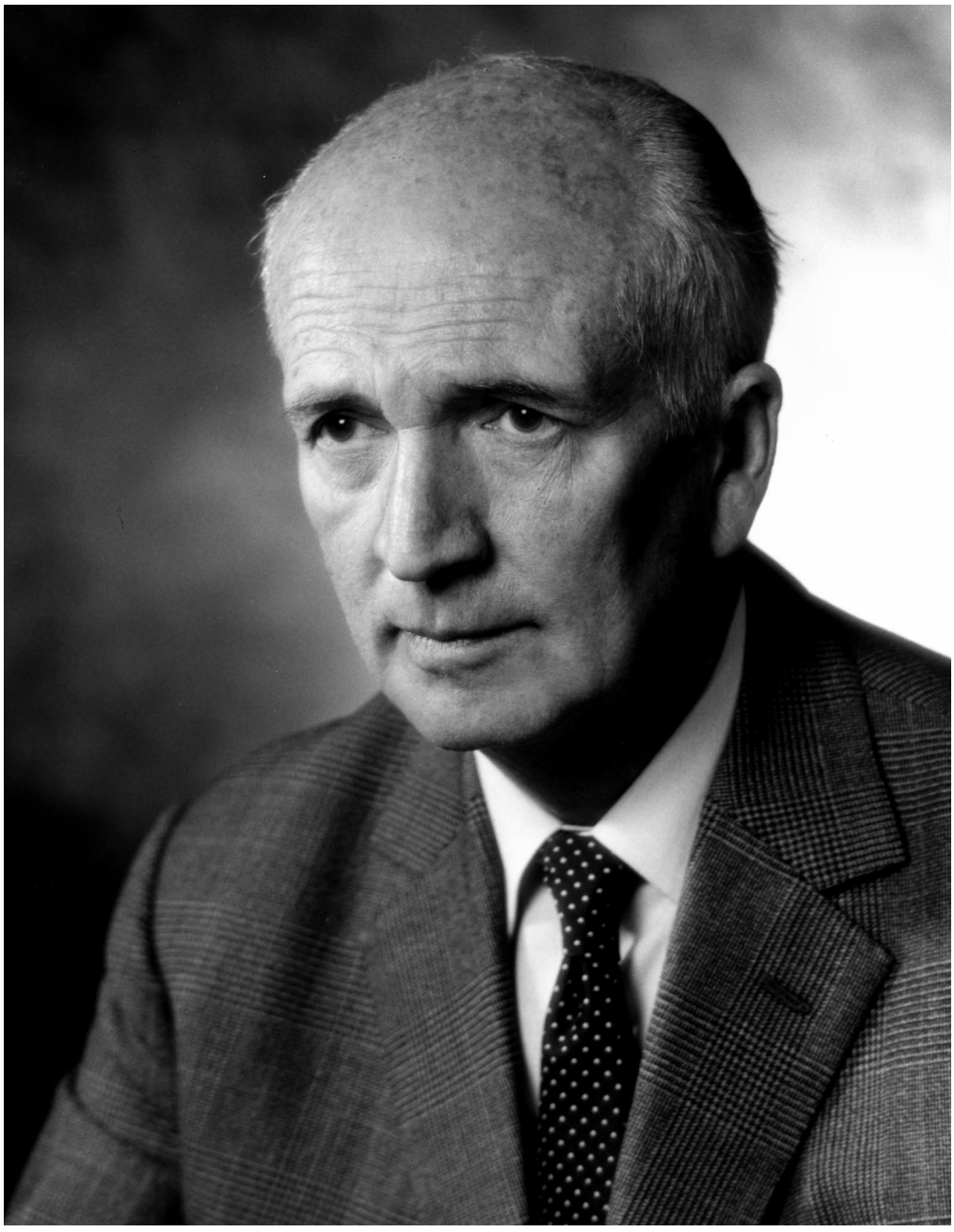

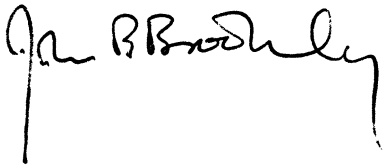

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John Brooksby was an outstanding veterinary virologist, who worked at the Animal Virus Diseases Research Institute, Pirbright, for 40 years, for 16 of which he was Director of the Institute. He will be remembered for his contributions to the diagnosis of foot-and-mouth disease, for his discovery of four new types, for the classification of subtypes and for fundamental studies of the virus. As Deputy Director and Director he was responsible for programmes on fundamental investigations of foot-and-mouth disease virus and other viruses exotic to the UK and for the application of the results both in the UK and worldwide. His advice on the distribution and the control of foot-and-mouth disease was sought by international organizations and by individual countries and was responsible for reducing the risk of spread of disease.

EARLY YEARS

John Burns Brooksby was born in Hyndland, Glasgow, on Christmas Day 1914. He was the son of George Bagnall Brooksby, an organ builder, and Elizabeth Brodie Brooksby (*née* Burns). He attended Hyndland School from the age of 5 years until he was 16 years old. His uncles on his mother's side were farmers in Renfrewshire, and John spent many happy summer holidays on the different farms learning about farming. At school John originally decided to study physics, but at that time Professor Whitehead, the Principal of the Glasgow Veterinary College, visited schools in Glasgow to recruit students. John decided to change from physics despite his parents' wishes but with the support of his mother's parents, who said that a vet in the family would be a good idea. He therefore chose to enter the Glasgow Veterinary College. The course to become a veterinary surgeon lasted four years at the time, so that although John passed the final examination for MRCVS in 1935 he was not put on the Register of the Royal College of Veterinary Surgeons until he was 21 years old at the end of the year. The Glasgow Veterinary College was not part of Glasgow University at that time and John's parents thought

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he should study for a university degree. This he did by taking an external degree of the University of London, a BSc (Vet Sci), which could be attended concurrently with the MRCVS course but required an extra year at the Veterinary College. During this year he was employed as an assistant in the Department of Veterinary Physiology at the Glasgow Veterinary College and taught histology to second-year veterinary students. Among these students was his wife-to-be, Muriel Weir, who qualified MRCVS in 1939. John graduated BSc in 1936. His year in the Physiology Department, together with his experience of the problems in breeding gained from farmers and veterinary surgeons in practice, may have influenced his decision to train for research especially in animal reproduction. He applied to the Department of Agriculture for Scotland and was granted a Research Studentship for three years in 1936.

John Brooksby spent the first year at the Department of Physiology, Pharmacology and Biochemistry, University College London, under W. H. Newton, the second at the Department of Biochemistry, McGill University, Montreal, Canada, and the third under Professor F. A. E. Crewe at Edinburgh University. He published four papers, two from University College London, and two from McGill University. The papers reported the activity of hormones on the uterus and on the anterior pituitary glands of rats. These experiences demonstrated the value to John in the training received in research and in the ability to write papers and present results. Thus, in 1939 he had had experience of the practical application of findings in the veterinary course and of basic research in the laboratory. At the completion of his studentship it was planned that he would join the group under Professor John (later Sir John) Hammond FRS at Cambridge to continue the work on animal reproduction. However, with the outbreak of war the work at Cambridge was curtailed; John changed to virology and was appointed a Research Officer at the laboratory of the Foot-and-Mouth Disease Research Committee of the Ministry of Agriculture and Fisheries at Pirbright, where he remained for the next 40 years.

Pirbright years

In any consideration of John Brooksby's contribution to research on foot-and-mouth disease (FMD) it is necessary to describe the history of FMD investigations before 1939.

The introduction of FMD to the UK resulted in epidemics, the latest of which before 1939 was between 1922 and 1924. A Departmental Committee was appointed in 1924 'to initiate, direct and conduct investigations into Foot-and-Mouth Disease, either in this country or elsewhere, with a view of discovering means whereby the invasions of the disease may be rendered less harmful to Agriculture'. In the same year the Cattle Testing Station at Pirbright, which had been used for tuberculosis testing of cattle before export but had been closed down in 1921, was made available to the committee for animal experiments. During the subsequent years research on FMD was conducted at the Lister Institute for Preventive Veterinary Medicine in Chelsea, The National Institute for Medical Research at Hampstead, Manchester University and the Central Veterinary Laboratory at Weybridge as well as at Pirbright. Pirbright remained under the control of Director of the Central Veterinary Laboratory at Weybridge. Work in laboratories other than Pirbright ceased over the years, until in 1939 Dr I. A. Galloway, who had been working on FMD at Hampstead, was appointed Director at Pirbright, where all future research into FMD in the UK was to take place (Skinner 1989) (12)*.

* Numbers in this form refer to the bibliography at the end of the text.

During the years up to 1939 work had been done on the fundamental properties of the virus, on the search for susceptible laboratory animals apart from the guinea pig, initial experiments on tissue culture of virus, the survival of virus under various conditions in the environment and in meat, and the use of disinfectants. Preliminary work had been carried out on the development of vaccines. Pirbright conducted diagnostic tests on samples from outbreaks in the UK. This involved the inoculation of susceptible and immune guinea pigs to determine the type responsible. On occasions, cattle had to be inoculated. The testing in guinea pigs took time and the use of cattle was expensive.

The years 1939–56

The work John did in the war years can only be deduced from later publications and reports. To control epidemics of FMD or of rinderpest that might arise during the war, the Institute prepared vaccines and hyperimmune serum to protect against these diseases. In 1940 the new Director, Dr Galloway, initiated a research programme to develop quantitative methods for the study of FMD, including measurements of vaccine potency and of the level of antibody in hyperimmune serum. John assisted W. M. (Gregor) (later Sir William) Henderson (FRS 1976) during Gregor's development of a method for titrating FMD virus by the inoculation of virus dilutions at different sites on cattle tongues and in the testing the potency of vaccines (Henderson 1949). John's own investigations involved the measurement of the antibody of vaccinated cattle and of hyperimmune serum produced in cattle. Antibody was usually measured by the protection test in guinea pigs but, as John confirmed, variation in the response of guinea pigs to the virus strain made it difficult to compare the results of tests at different times. John adapted the Henderson method of titration of virus on cattle tongues to the measurement of antibody level in immune, vaccinated and control cattle. The neutralization test involved mixing dilutions of serum with a known dose of virus and, after a period, comparing the sites on the tongue that were protected. The test had advantages over the guinea pig protection test, in that there was no need to adapt the virus to a new host, the range of dilutions could be wider and the result could be obtained in 24 hours (5). However, after the finding in 1951 of the susceptibility of the unweaned mouse to FMD virus (Skinner 1951), neutralization tests were carried out in mice. John also collaborated with Gregor Henderson on the survival of FMD virus in meat and offal. They confirmed the results of workers before 1939 that virus survived in bone marrow after slaughter but was inactivated by pyruvic and lactic acids in muscle and went on to show that virus also survived in the offal and lymph nodes (1). This work was important in emphasizing the danger to livestock of meat imports from affected countries and in determining the origin of outbreaks in the UK. John was awarded the PhD in 1947 for his investigations on serological tests.

John's main contribution was the development of the complement fixation test for use in FMD. The test involved incubating complement (proteins in blood plasma that combine with antibody to destroy antigen) with antibody and virus and measuring the change in the quantity of complement. Use of guinea pig antigen and antibody had been successful with FMD, but the use of bovine antigen and bovine antiserum failed. John used guinea pig antiserum and antigen from cattle and other species. He followed methods developed by Heidelberger (Mayer *et al.* 1946). Complement was used in excess, and the amount of complement remaining after the reaction was measured and compared with controls. This had an advantage with

poorly fixing systems such as FMD virus and antiserum. The amount of haemolysis was measured in a spectrophotometer and the 50% haemolysis endpoint was determined by probit transformation. John introduced the test for the diagnosis and determination of the virus type (O, A or C) responsible for an outbreak. The test eliminated the need to adapt the virus to guinea pigs or to inoculate cattle provided that sufficient antigen was present in the original sample. A result could be obtained in three hours. The precision of the test was such that it was possible to distinguish between different variants of the virus, which were classified as subtypes. Subtypes were becoming more important in the field because of both the ongoing selection and mutation of the virus and also failures in vaccination when the vaccine strain differed from the strain responsible for the outbreak although being of the same type (6). At the same time John developed the complement fixation test to distinguish between FMD and vesicular stomatitis.

At the start of the war, when John joined Pirbright, the professional staff was six. In 1942 the staff was reduced to three as a result of retirement, appointment to another position and joining the armed forces. No replacements were appointed and the work was carried out by Galloway, Henderson and Brooksby. John remembered the restrictive discipline of working in the laboratory with only one strain at a time, spending long periods in protective clothing while examining cattle, and rigorous showering and clothing changes (20). In addition there were Home Guard duties to perform. On the route to Woking Station John used to point out the bridge that he was assigned to defend. He also talked about Home Guard exercises in Brookwood Necropolis in eerie conditions in the blackout.

In 1946 Pirbright confirmed the presence of FMD in Mexico. A joint Mexican American Commission waged an intensive campaign involving quarantine, slaughter and, after several people were shot by irate Mexican farmers, vaccination of cattle. Pirbright was asked to assist, especially in examining samples from the field and the effects of vaccination. In 1948 six papers were published dealing with Pirbright's contribution (Galloway 1948). John was the senior author of three of these and demonstrated the effectiveness of the complement fixation test in diagnosing FMD and of the complement fixation test and the serum neutralization test in cattle in distinguishing between strains (2–4). He also used the complement fixation test to differentiate between FMD and vesicular stomatitis.

Pirbright also received samples from Africa for typing. In 1948, with the use of complement fixation tests and cross-immunity tests in cattle and guinea pigs John demonstrated the presence of three new types of FMD virus in addition to O, A and C, which were termed Southern African Territory types (SAT1, SAT2 and SAT3). In 1954, after receiving samples from Asia, John showed the existence of a seventh type, Asia 1 (10).

As a result of the assistance of Pirbright in Mexico, the US Department of Agriculture made equipment, including an ultracentrifuge, available to the Institute. Claude Bradish was appointed as a biophysicist; John Brooksby and he, together with visiting workers, investigated the infective and complement-fixing components of FMD virus. They demonstrated the presence of two components, the 25-micron (μm) and 7-micron particles. The 25-micron particle was infective and fixed complement; the 7-micron particle fixed complement but was non-infective. These findings were important in the analysis of the specificity of the complement fixation test and of the presence of the large particle in stimulating immunity (7). Similar studies were made with vesicular stomatitis virus. With Claude Bradish and Gregor Henderson, John performed electrophoretic studies of bovine serum and showed the initial development of β-globulin followed by that of γ-globulin in infected cattle (8, 9).

John Brooksby was head of the Serology Department and responsible for the laboratory diagnosis of FMD with the use of the complement fixation test that he had developed for typing and subtyping the virus strain. From 1948 onwards the department engaged in systematic examination and classification of samples from overseas to build up a world picture of the distribution of the types of FMD present in the different continents and countries. In 1955 proposals were put forward that there should be a Central Reference laboratory and that the laboratory should be Pirbright (Galloway 1956). In 1958 Pirbright was recognized as the World Reference Laboratory for Foot-and-Mouth Disease by the Food and Agricultural Organization (FAO) of the United Nations (Anon. 1958).

In 1952, with the expansion of the Institute and the appointment of more staff, John Brooksby became responsible for new sections on tissue culture and genetics. In 1957 John became Deputy Director of the Institute in succession to Gregor Henderson, who had been appointed Director of the PanAmerican Foot-and-Mouth Disease Center in Rio de Janeiro.

During his 17 years at Pirbright, John had experienced investigations at the fundamental level of the virus as well as the application of laboratory findings to the field. Thus he had a wide knowledge of FMD, its diagnosis and control. He also learned to get down to fundamentals in examining a problem and not be satisfied with *ad hoc* solutions, or 'adhoccery' as he termed it. He was awarded a DSc in 1957 for his publications, especially his contributions to complement fixation.

Deputy Director and Director, 1957–79

As Deputy Director John took on further responsibilities. By 1957 the expansion of Pirbright had led to results over a wide range, including attenuated vaccines (11). As a result of Skinner's discovery that FMD virus passaged in mice and chick embryos lost its virulence for cattle, Galloway decided to test the attenuated strains as vaccines in Africa. For this purpose SAT1, SAT2 and SAT3 attenuated vaccines were used, and John visited countries in Africa in the testing of vaccines (17). By this time the plant designed to produce *Frenkel* inactivated vaccine was in production and making vaccines against southern African types as a reserve in case these viruses should enter Europe.

Initially the attenuated vaccines were so successful in Africa that the Institute's activities were directed towards production rather than research. The Wellcome Foundation had taken over Cooper, McDougall and Robertson, who had production plants in South America, and Wellcome was interested in the latest developments in vaccination against FMD. Pirbright and Wellcome entered into discussion, in which John played a part and eventually decided on a joint partnership, in which Wellcome would take over production of attenuated vaccine at Pirbright and profits would be shared. Tom Pay, who had been at Pirbright until 1959, was appointed to head the Wellcome group and John was involved in the organization of production facilities.

Until 1960, SAT types had remained in Africa. However, in 1962 SAT1 was found to be responsible for FMD in the Middle East. FMD had been spreading through the Middle East and reached Turkey and Israel. Europe and international organizations were concerned that the SAT1 virus would spread to Europe and elsewhere. No suitable SAT1 vaccine was available, and inactivated vaccines had to be produced. Pirbright supplied *Frenkel* vaccine, and John was involved in the programme of vaccination and, with Wellcome, the organization of vaccine

trials. He visited Turkey several times, once damaging his knee in a car accident, which as he put it made him leery of Turkish drivers.

Galloway retired at the end of 1963 and John became Director. He had already planned the programme he would initiate. His experience in Africa indicated that the role of wild animals in the dissemination and maintenance of FMD was not known. In the late 1950s there had been an outbreak of bluetongue in the Iberian peninsula and questions had been asked in Parliament about the need for research on bluetongue because of its potential danger to the UK sheep population. He also recruited Walter Plowright (FRS 1981) to undertake investigations into African swine fever, which was causing problems in the Iberian peninsula as well as in Africa.

John also consulted colleagues on whether Pirbright should attempt to produce an inactivated vaccine by growing FMD virus in cell suspensions of BHK-21 cells. In the early 1960s Macpherson & Stoker (1962) had developed this cell line from baby hamster kidneys. Mowat & Chapman (1962) had demonstrated that FMD virus would grow in the cells to high titre, and the cells were used for the production of attenuated vaccines. Later Capstick, Telling and Garland were successful in growing BHK cells in suspension (Capstick *et al.* 1965). In addition John wanted to explore the use of acetylethylenimine (AEI) to inactivate FMD virus instead of formalin. AEI had been shown by Fred Brown (FRS 1981) and Joan Crick to inactivate FMD virus without damaging its immunogenic potency (Brown & Crick 1959). The line of research was successful and by 1967 effective vaccines were being produced.

In 1964 a new subtype of A, A_{22}, was found in the Middle East introduced from Iran, with its source probably further east. As with SAT1, Europe and international authorities feared that the new subtype would spread to Europe and elsewhere. Initial CF tests showed that an attenuated vaccine might protect against the new strain, but its use in Israel showed that it could cause lesions in high-yielding dairy cattle as well as failing to protect against the new strain. Pirbright produced inactivated *Frenkel* vaccine against the A_{22} strain for use in Turkey and Greece. John played a prominent part in advising FAO on the nature of the A_{22} strain and the use of vaccine.

The failure of the attenuated vaccines in the Middle East resulted in financial losses to the joint partnership. To reduce the losses, Pirbright added the profits made on the inactivated vaccine. However, the Public Accounts Committee of the House of Commons took note of this and Sir Gordon Cox FRS, the then Secretary of the Agricultural Research Council, had to appear before the committee. John assisted Sir Gordon in his presentation. However, the committee decided that profits on the sale of inactivated vaccines could not be applied to the joint partnership, which was then dissolved. Instead, Wellcome would be charged a rent for the buildings they occupied and for services and livestock supplied by the Institute. Pirbright would make available the new technology for producing inactivated vaccines to Wellcome, and Wellcome would take over the responsibility of producing SAT1, SAT2, SAT3 and Asia 1 vaccines as a standby. Once Wellcome was able to make the new vaccines, Pirbright would close down production of *Frenkel* vaccines and carry out research. By 1967 the production of inactivated vaccines at Pirbright had closed down and Wellcome had taken over the responsibility.

In 1965 the O_1 strain of FMD had reappeared in Europe and there were extensive outbreaks of FMD, especially in the Federal Republic of Germany and The Netherlands. On 25 October 1967 FMD was reported on a farm near Oswestry; however, in the next week FMD was reported over a widespread area in the heavily stocked counties of Shropshire, Cheshire and Staffordshire (Committee of Inquiry 1969). John had had an operation for hernia earlier in

October, but he returned to Pirbright once he had heard of the extent of spread. Hitherto Pirbright had been responsible for laboratory diagnosis and typing of the strain involved, and the State Veterinary Service was responsible for control in the field. John set in motion studies on the possible source of virus and the behaviour of the strain in cattle, sheep and pigs. Spread of virus had occurred through transport of milk, and workers from Pirbright were sent to help the investigations in the field. In addition the effect of disinfectants and the survival of virus in heat-treated milk were investigated (14). John advised the Chief Veterinary Officer on vaccines, when it was thought that the epidemic was out of control. The standby vaccine purchased was shown at Pirbright to be effective against the strain of O_1 virus involved.

The Northumberland Committee was set up in 1968 to 'review the policy and arrangements for dealing with FMD in Great Britain and to make recommendations' (Committee of Inquiry 1969). As Director, John was responsible for preparing the memoranda by Pirbright to the Committee of Inquiry. The first memorandum dealt with Pirbright's investigations on the virus, its possible sources and its behaviour in animals (Committee of Inquiry 1968*a*). The second memorandum discussed methods available for the control of FMD, including vaccines (Committee of Inquiry 1968*b*). After describing the effectiveness of present vaccines the memorandum discussed emergency vaccination and prophylactic vaccination. With emergency vaccination there was the difficulty of when to start vaccination: if too early the disease might already have been eliminated by slaughter; if too late the disease might have spread widely and supplies of vaccine might be insufficient. In addition, after disease was wiped out the vaccinated area might remain a problem because it would not be possible to move animals out for at least three months. Prophylactic vaccination would prevent primary outbreaks, and animals on any farms with disease could be slaughtered immediately. At the best, prophylactic vaccination could result in virtual freedom from the disease. At worst, primary outbreaks might occur but the possibility of a major epidemic spread as occurred in 1967 would be ruled out. The cost of prophylactic vaccination was estimated to be £5.5 million annually. Unless there was assurance that the 1967 outbreak would not be repeated, prophylactic vaccination must be considered very seriously as an alternative to the stamping-out policy. The Ministry of Agriculture, Fisheries and Food (MAFF) had always opposed vaccination. In a visit to Pirbright in 1956 the then Minister said that although he was impressed by the work on vaccines at Pirbright, the Ministry would never sanction the use of vaccines in the UK. The Northumberland Committee recommended that the slaughter policy should continue but that imports of meat from endemic countries should be restricted to boned-out beef or heat-treated offal. This was based on the work of Henderson and Brooksby (1). Prophylactic vaccination was ruled out but emergency plans for ring vaccination should be kept in constant readiness. The committee also recommended an expansion of research work in epidemiology and the formation of epidemiological teams.

During the 1967–68 epidemic the spread of disease had been attributed to airborne carriage of virus. John asked Bob Sellers to investigate. The results showed the importance of pigs as sources of airborne virus (Sellers & Parker 1969). Further work was carried out on the pathogenesis of FMD in cattle and sheep, resulting in the finding that the respiratory route was the main method by which FMD virus infected cattle and sheep with initial multiplication in the pharyngeal area (Burrows *et al.* 1981).

In 1966 a virus causing vesicular lesions in pigs was isolated in Italy. Examination at Pirbright showed that it was a porcine enterovirus. Further isolations were made from samples received from Hong Kong in 1970. In November 1972 FMD was reported in pigs in

Staffordshire. Samples sent to Pirbright showed it was not FMD but the porcine enterovirus. Further tests by electron microscopy and exposure to acid confirmed it was not FMD but the porcine enterovirus. Initial results were available on the day the samples were received but legislation had to be changed before the disease was confirmed as swine vesicular disease (SVD) (15). John took a prominent part in the discussions with the Animal Health Division, MAFF, to decide on policy and also organized staff to join the epidemiological teams in Staffordshire to carry out field investigations. Pirbright made extensive serological surveys to discover the extent of the infection in the UK (17).

John always encouraged the staff in their researches to keep themselves informed of developments in their field and encouraged cooperation between departments and cross-fertilization of ideas. Thus, as with SVD, confirmation of diagnosis of FMD involved several departments. Investigations on the structure and biological function of FMD virus in the Biochemistry Department under Fred Brown led to advances in understanding of the virus. Studies of the virus proteins emphasized the importance of the intact particle for immunization and located the site affected by neutralizing antibody. Examination of viral ribonucleic acid showed differences in serotypes of virus, and fingerprinting of ribonuclease T oligonucleotides demonstrated variation in strains of virus within a type. The Genetics Department had demonstrated recombination as well as mutation at the rate of 1 in 10 000. Electrofocusing of the protein coat showed differences between strains (Animal Virus Research Institute 1984).

John retained his interest in the mechanics of virus typing and in subtype differentiation. The use of microplates reduced the quantity of reagents required for complement fixation tests. Later the enzyme-linked immunosorbent assay (ELISA) was developed. However, with many more samples being received from different parts of the world, difficulties arose with subtyping of strains. In 1967 John redefined type and subtype (13). For complement fixation tests he used a complement fixation product (CFP), which was obtained by multiplying the two ratios of heterologous and homologous fixation. Together with serum neutralization tests the CFPs were used in the study of the epidemiology of FMD and in determining the most appropriate vaccine to use. However, the results did not always reflect the field situation. Helio Pereira of the World Influenza Centre, Mill Hill, was appointed head of epidemiology in 1974. He considered that subtype variation in FMD was a continuum similar to the production of antigenic drift in influenza (Pereira 1977). He suggested that field isolates should be related to current strains in vaccines and to reference strains from past outbreaks; John agreed that this should be adopted.

Africa

John took a great interest in the control of FMD in Africa from the time when samples were being received from that area and especially after his establishment of the SAT1, SAT2 and SAT3 virus types. Southern Africans used to control outbreaks by aphthization; that is, once the disease reached a herd, virus was given to all the animals in the herd so that the outbreak would finish rapidly. John maintained that using an attenuated vaccine would be safer, and when attenuated vaccines were no longer being produced he encouraged the use of inactivated vaccines. He was also interested in how FMD virus persisted in the area, and Bob Hedger made many visits to Africa to learn more about infection in buffaloes and wild ruminants (16). In Kenya John supported the Wellcome Institute for Foot-and-Mouth Disease Research in Nairobi by sending staff to carry out laboratory work and investigate the epidemiology of FMD in that area. He also seconded staff under Walter Plowright to the East African Research

Institute at Muguga, Kenya. Here Plowright conducted a successful programme to understand the role of the tick in the maintenance and spread of African swine fever (Plowright *et al.* 1969). John paid several visits to Africa on behalf of the British Overseas Development Organisation and international agencies to advise on FMD control.

Thus, the research programmes John initiated and his encouragement of work overseas resulted in the application of the findings to the control of FMD in the UK and worldwide. The earlier investigations on SVD led to rapid diagnosis when disease entered the UK and was subsequently found in many countries in Europe. With Pirbright as the World Reference Laboratory for Foot-and-Mouth Disease, John was constantly advising international agencies on the distribution and spread of FMD and on the type or types of virus to be included in a vaccine. He was chairman of the World Organisation for Animal Health (OIE) Commission on FMD and a member of the Research Group of the FAO Commission on FMD.

In 1964 countries free of FMD wished to import European breeds of cattle such as the Charolais. John took part in discussions to eliminate the chance of introducing FMD by setting up laboratory tests to ensure that animals held in quarantine were free of infection. This, together with tests for other diseases, resulted in the export of cattle from Europe to the UK and Northern Ireland, the Republic of Ireland, Canada, the USA, Australia and New Zealand, enabling the beef-producing qualities of European breeds to be introduced to those countries.

The pig was probably John's favourite farm animal. He investigated strains of FMD virus that affected pigs but not cattle. As part of laboratory investigations to establish a differential diagnosis he infected pigs with vesicular exanthema virus. He thought pigs intelligent, and the author remembers anaesthetizing twenty pigs with him. As they were anaesthetized the pigs were laid in rows of five. After nineteen pigs had been anaesthetized there was no sign of the twentieth. Eventually the last pig was found lying quietly at the end of one of the rows. John was very interested in the finding that in airborne spread of FMD pigs produced the most virus. The rapid diagnosis of SVD in 1972 after its discovery in pigs pleased him. Perhaps the most exotic animals studied were marsupials, at the request of the Australian government. Kangaroos, wallabies, wombats, marsupial mice and echidnas were some of the animals in the consignment from Australia. The kangaroos were noted for boxing prowess, the wombats for their ability to bite through forceps, and the echidnas for the amount of dirt that had to be mixed with their food. Only the tree kangaroo developed lesions of FMD. However, there was a serendipitous benefit to the Institute and FMD research in that Bill Snowdon, the Australian vet who accompanied the marsupials and carried out research on them, showed that monolayers of calf thyroid tissue culture were the most sensitive cells for detecting FMD virus (Snowdon 1966). Respiratory virus diseases of horses were also investigated at Pirbright, as it was thought that they were not endemic and it would be dangerous to the horse-racing industry if research were to be performed at Newmarket. Bob Burrows initiated a programme on equine herpes virus that in time showed that this infection was prevalent throughout the horse population in the UK (Animal Virus Research Institute 1984).

Buildings and disease security

John was involved in the planning of buildings in the major expansion of the Institute, between 1952 and 1956. The new animal units were close to each other and in 1958 accidental infection occurred between them. In 1960 a strain of type SAT2 (not found at this time in Europe) appeared in the neighbouring village of Worplesdon. Installation of filtration units was carried

out immediately and over the following years in all buildings where virus was handled. In 1964 John obtained a grant from the Wellcome Trust, which together with money from the Agricultural Research Council was used to construct a new laboratory with air filtration. Over the years, animal accommodation had been converted to laboratories by Pirbright staff to meet ongoing requirements. A Visiting Group commented on the considerable variety in the disease security buildings at Pirbright, to which John replied, 'Every building we have put up has taught us something new about the airborne transmission of FMD virus'. After all the efforts Pirbright had put in over the years, John was greatly chagrined at the criticism of the buildings at Pirbright that the Visiting Group made in their report.

Relations with others in the UK

As a result of its isolation and disease security precautions, Pirbright was relatively unknown in the UK. It was not until the 1967–68 epidemic that the Animal Health Division at Tolworth allowed Pirbright staff into the field during outbreaks, and this together with the formation of epidemiological teams led to better cooperation until it reached a point at which Tolworth reckoned they had more cooperation from Pirbright than from their own laboratory at Weybridge. John was always on good terms with the Chief Veterinary Officer at Tolworth. Pirbright was a grant-aided laboratory under the Agricultural and Food Research Council (AFRC) and as such it had a Governing Body. John valued the advice of the Governing Body, whose members comprised virologists as well as a lay chairman, former civil servants and veterinarians including the Chief Veterinary Officer. John's relations with the AFRC were, as one former adviser put it, 'strained' because he had the support of MAFF and the Governing Body in anything that might interfere with the role of Pirbright in controlling FMD in the UK. When the AFRC proposed that a Visiting Group should inspect Pirbright, John felt it was an insult to the Governing Body. At annual AFRC Directors' conferences John used to attend the dinner on the first night but when the meeting started the following day he usually received a telephone call (engineered) from Pirbright telling him there was a crisis overseas with FMD. During his Directorship at Pirbright there was an increase in accountability, due partly to the Rothschild Report of 1971. When he retired in 1979 John said he would miss the science but not the bureaucracy.

John was very enthusiastic in his pursuits and encouraged younger members of the staff in their careers. One former member of staff recalls that John used to visit individual laboratories on a Friday afternoon. He would appear unannounced with the unnerving injunction, 'Show me something interesting' — rather disconcerting for the newly joined members of staff but showing that he was interested in their progress. New items of equipment had to be justified. 'Tell me, did Pasteur ever need an ultracentrifuge?' he replied when he was asked to place an order. However, the purchase was approved. John took a great interest in the laboratory workshop and encouraged the staff to start a museum of examples of apparatus they had made. He also took an interest in the history of the Pirbright Institute and rescued a yoke that had been used by the cattle attendants in the early days to carry pails of water for the animals. He placed the yoke on the wall of his office as 'a symbol' (as he jocularly put it) 'of the burdens he had to bear as director'.

John was a member of several scientific societies. He was president of the Veterinary Research Club and president of the Comparative Section of the Royal Society of Medicine. He served as convener of the Virus Section of the Society for General Microbiology. He was a founding member of the board of *Research in Veterinary Science*. John served on committees

concerned with the handling of dangerous pathogens and with genetic manipulation, in which he followed the developments with great interest.

After his retirement he continued to write articles, in particular a chapter on FMD virus in the book *Portraits of viruses. A history of virology* (20). In 1981 outbreaks of FMD in Jersey and the Isle of Wight were introduced on the wind from Brittany from affected pigs. He was proud that the programme of research at Pirbright into airborne spread, together with the development of fingerprinting and electrofocusing of virus strains, had combined to show the method of introduction and the source of the virus strain concerned (King *et al.* 1981; Donaldson *et al.* 1982) (18). In 1983 he organized and edited a Royal Society Discussion Meeting, 'The aerial transmission of disease' (19). This dealt with the transmission of disease in plants and animals by infective agents and insects in the air, over long distances or in buildings. The contributions came from meteorologists, medical and veterinary workers, entomologists and plant pathologists and stimulated discussion between the different disciplines. John was proud of the interest that it provoked.

Family

In 1979, at a meeting of Brooksbys at Brooksby Hall, Brooksby, Leicestershire, John learned that his great-great-great-grandfather Thomas Brooksby had been a sergeant in the 12th Regiment of Foot. As a corporal he had kept a notebook, which tells of his marching from Winchester to Scotland, where he was involved in road building and where he married. After service, Sergeant Thomas retired and settled in Falkirk. John's great-grandfather emigrated to London, where he became an organ builder. John's grandfather and father also became organ builders, but the family returned to Scotland at the end of the nineteenth century. John was impressed with the march of Corporal Brooksby from Winchester to Scotland.

John's mother before her marriage was secretary to the Deputy Director of the Glasgow Art Galleries, and his parents encouraged his interest in art. In his visits abroad, John made a point of visiting art galleries and local art shows. In his late thirties he took up painting and was a member of the Farnham Art Society. He exhibited at the Art Society's shows and sold some of his paintings. John felt that his main talent was in watercolours. On moving to Cambridgeshire after retirement he joined a painting class at Grantchester and exhibited there. John was also a keen golfer and gardener. He married Muriel Weir in 1940 and they had two children, Elspeth and Iain. John instilled a love of poetry in his children and passed on his interest in art. Muriel accompanied John on many of his visits abroad. The children of Pirbright staff seconded to Kenya welcomed their visits for the presents they brought them. France and Italy were perhaps John and Muriel's favourite places to visit, both for their culture and for their cuisine. Roast sucking pig in Paris and *osso bucco* in Rome were his favourite dishes, which he liked to introduce to colleagues. John was active until the time of his death, which occurred the day before his 58th wedding anniversary and eight days before his 84th birthday.

Honours and awards

John Brooksby was elected a Fellow of the Royal Society in 1980. Before this, in 1968, John was elected a Fellow of the Royal Society of Edinburgh. In 1971 he received the John Henry Steel Medal of the Royal College of Veterinary Surgeons. He also received the Fellowship of the Royal College of Veterinary Surgeons by election in 1978. He was awarded the CBE in 1973. In 1981 he received an honorary DSc from the University of Edinburgh.

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The frontispiece photograph was taken in 1980 by Godfrey Argent Studio and is reproduced with permission.

References to other authors

Animal Virus Research Institute 1984 *The Animal Virus Research Institute Report, 1983*. Pirbright, Surrey: Animal Virus Research Institute.

Anon. 1958 The World Reference Laboratory for FMD. *Nature* **182**, 1417.

Brown, F. & Crick, J. 1959 Application of agar gel diffusion analysis to a study of the antigenic structure of inactivated vaccines prepared from the virus of foot-and-mouth diseases. *J. Immunol.* **82**, 444–447.

Burrows, R., Mann, J. A., Garland, A. J. M. & Goodridge, D. 1981 The pathogenesis of natural and simulated natural foot-and-mouth disease infection in cattle. *J. Comp. Pathol.* **91**, 599–609.

Capstick, P. B., Garland, A. J. M., Chapman, W. G. & Masters, R. C. 1965 Production of foot-and-mouth disease virus antigen from BHK 21 clone 13 cells grown and infected in deep suspension culture. *Nature* **205**, 1135–1136.

Committee of Inquiry 1968*a* Memorandum to the Committee of Inquiry on Foot-and-Mouth Disease by the Animal Virus Research Institute, Pirbright. The origin and development of the foot-and-mouth disease outbreak in 1967. (Copies held by the Institute for Animal Health, Pirbright Laboratory.)

Committee of Inquiry 1968*b* Second Memorandum to the Committee of Inquiry on Foot-and-Mouth Disease by the Animal Virus Research Institute, Pirbright. Methods available for the control of foot-and-mouth disease. (Copies held by the Institute for Animal Health, Pirbright Laboratory.)

Committee of Inquiry 1969 *Report of the Committee of Inquiry on Foot-and-Mouth Disease. Part One.* London: HMSO.

Donaldson, A. I., Gloster, J., Harvey, L. D. J. & Deans, D. H. 1982 Use of prediction models to forecast and analyse airborne spread during the foot-and-mouth disease outbreaks in Brittany, Jersey and the Isle of Wight, 1981. *Vet. Rec.* **110**, 53–57.

Galloway, I. A. 1948 Considerations of some important aspects of recent investigations on foot-and-mouth disease. In *Proceedings of the Fourth International Congresses on Tropical Medicine and Malaria, Washington DC, 10–18 May 1948*, vol. 2, pp. 1372–1385. Washington DC: US Government Printing Office.

Galloway, I. A. 1956 Foot-and-mouth disease. *J. R. Agric. Soc.* **117**, 64–71.

Henderson, W. M. 1949 *The quantitative study of foot-and-mouth disease virus* (Agricultural Research Council Special Report Series, no. 8). London: HMSO.

King, A. M. Q., Underwood, B. O., McCahon, D., Newman, J. W. I. & Brown, F. 1981 Biochemical identification of viruses causing the 1981 outbreaks of foot-and-mouth disease in the United Kingdom. *Nature* **293**, 479–480.

Macpherson, I. A. & Stoker, M. G. P. 1962 Polyoma transformation of hamster cell clones. An investigation of genetic factors affecting cell competence. *Virology* **16**, 147–151.

Mayer, E. M., Eaton, B. B. & Heidelberger, M. 1946 Spectrophometric standardization of complement fixation tests. *J. Immunol.* **53**, 31–35.

Mowat, G. N. & Chapman, W. C. 1962 Growth of foot-and-mouth disease virus in a fibroblastic cell line derived from hamster kidneys. *Nature* **194**, 253–255.

Pereira, H. G. 1977 Subtyping of foot-and-mouth disease. International Symposium on Foot-and-Mouth Disease, Lyon, 1976. *Dev. Biol. Standard.* **35**, 167–174.

Plowright, W., Parker, J. & Pierce, M. A. 1969 African swine fever virus in ticks collected from animal burrows in Tanzania. *Nature* **221**, 1071–1073.

Sellers, R. F. & Parker, J. 1969 Airborne excretion of foot-and-mouth disease virus. *J. Hyg., Camb.* **67**, 671–677.

Skinner, H. H. 1951 Propagation of strains of foot-and-mouth disease in unweaned mice. *Proc. R. Soc. Med.* **44**, 1041–1044.

Skinner, H. H. 1989 The origins of virus research at Pirbright. *Vet. Hist.* **6**, 31–40.

Snowdon, W. A. 1966 Growth of foot-and-mouth disease virus in monolayer cultures of calf thyroid cells. *Nature* **210**, 1079–1080.

Bibliography

The following publications are those referred to directly in the text. A full bibliography is available as electronic supplementary material at http://dx.doi.org/10.1098/rsbm.2007.0002 or via http://www.journals.royalsoc.ac.uk.

(1) 1948 (With W. M. Henderson) The survival of foot-and-mouth disease in meat and offal. *J. Hyg., Camb.* **46**, 394–402.

(2) 1948 (With W. M. Henderson & I. A. Galloway) Strains of the virus of foot-and-mouth disease recovered from outbreaks in Mexico. Identification. *Proc. Soc. Exp. Biol. Med.* **69**, 64–66.

(3) 1948 (With I. A. Galloway & W. M. Henderson) Strains of the virus of foot-and-mouth disease virus recovered from outbreaks in Mexico. Complement fixation tests. *Proc. Soc. Exp. Biol. Med.* **69**, 70–74.

(4) 1948 (With I. A. Galloway & W. M. Henderson) Strains of the virus of foot-and-mouth disease virus recovered from outbreaks in Mexico. Serum neutralisation tests. *Proc. Soc. Exp. Biol. Med.* **69**, 74–77.

(5) 1949 *The antibodies in foot-and-mouth disease* (Agricultural Research Council Special Report Series, no. 9). London: HMSO.

(6) 1952 *The technique of complement fixation in foot-and-mouth disease research* (Agricultural Research Council Special Report Series, no. 12). London: HMSO.

(7) 1952 (With C. J. Bradish, J. F. Dillon & M. Norambuena) Ultracentrifugal studies of the infective and complement fixing components in the virus system of foot-and-mouth disease. *Proc. R. Soc. B* **140**, 107–127.

(8) 1954 (With C. J. Bradish & W. M. Henderson) Electrophoretic studies of ox serum. 1. The sera of normal cattle. *Biochem. J.* **56**, 329–325.

(9) 1954 (With C. J. Bradish & W. M. Henderson) Electrophoretic studies of ox serum. 2. The sera of cattle infected with foot-and-mouth disease. *Biochem. J.* **56**, 335–341.

(10) 1957 *The virus of foot-and-mouth disease* (Advances in Virus Research, vol. 5) (ed. K. M. Smith and M. A. Lauffer), pp. 1–37. New York: Academic Press.

(11) 1958 Comparative aspects in virology. *Proc. R. Soc. Med.* **51**, 1–8.

(12) 1964 Ninth Middleton Memorial Lecture. Impact of science on the control of foot-and-mouth disease. *Agric. Prog.* **39**, 7–17.

(13) 1967 Variants and immunity: definitions for serological variation. In *International Symposium for Foot-and-Mouth Disease on Variants and Immunity, Lyon 1967* (Symposium Series Immunobiological Standards, vol. 8) (ed. R. H. Regamey), pp. 1–10. Basel: Karger.

(14) 1969 Laboratory investigations on the 1967–68 outbreak of foot-and-mouth disease in Great Britain. In *The veterinary annual, tenth year 1969* (ed. C. S. G. Grunsell), pp. 1–10. Bristol: John Wright.
(15) 1972 Swine Vesicular Disease: a statement from Pirbright. *Vet. Rec.* **91**, 681–682.
(16) 1972 Epizootology of foot-and-mouth disease in developing countries. *World Animal Rev.* **1**, 10–13.
(17) 1974 Animal Virus Research Institute 1924–1974. Booklet produced to mark the 50th Anniversary of the Institute. (Copies held by the Institute for Animal Health, Pirbright Laboratory.)
(18) 1981 Tracing outbreaks of foot-and-mouth disease. *Nature* **293**, 431–432.
(19) 1983 (Editor) *The aerial transmission of disease.* London: The Royal Society.
(20) 1988 Foot-and-mouth disease virus. In *Portraits of viruses. A history of virology* (ed. F. Fenner & A. Gibbs), pp. 124–126. Basel: Karger.