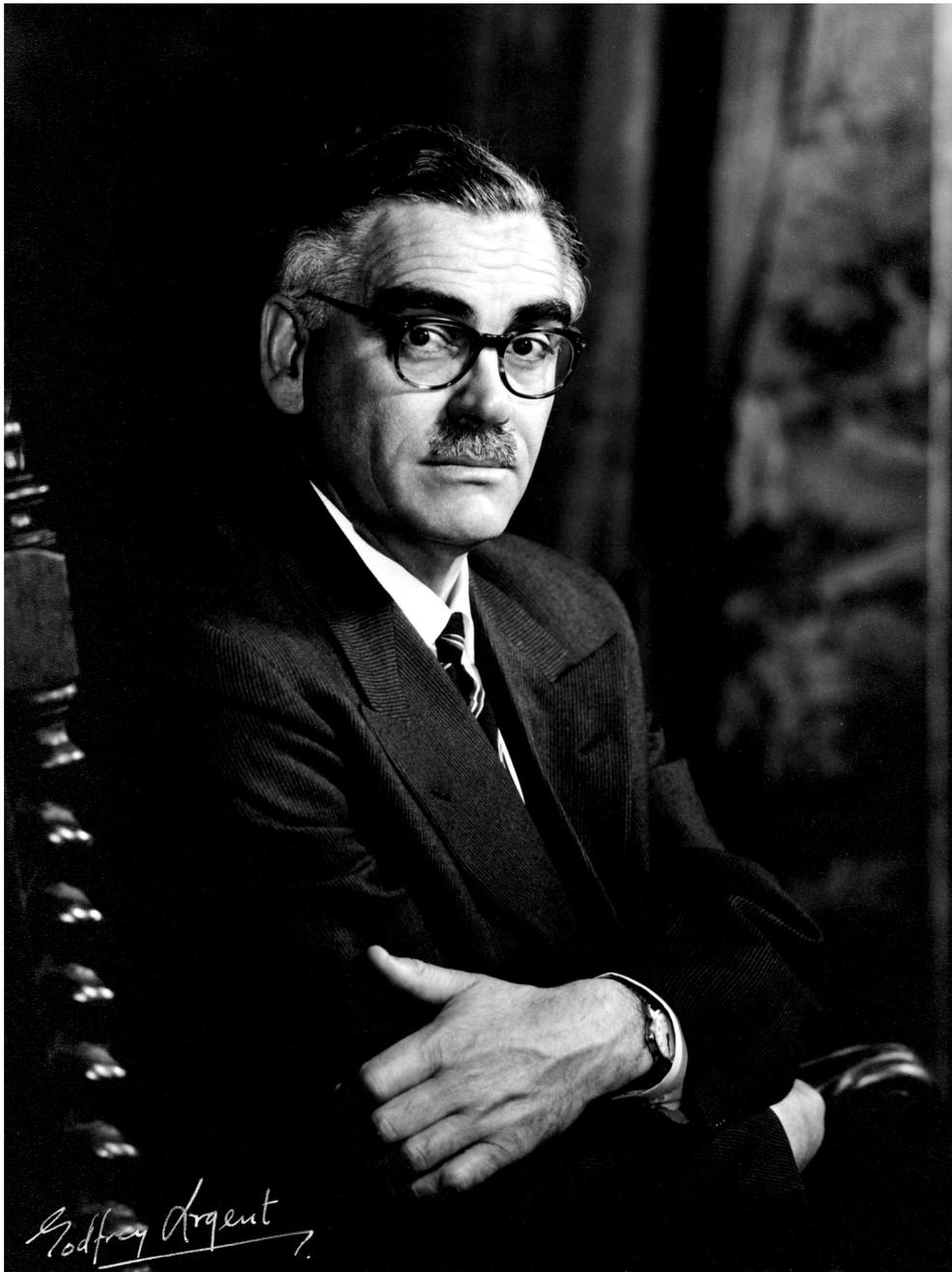


PHILLIP SADLER NUTMAN

10 October 1914 — 4 May 2004

Biogr. Mems Fell. R. Soc. **51**, 315–326 (2005)



F.S. Nutman

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Elected FRS 1968

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INTRODUCTION

Dr Phillip Nutman was a microbiologist and plant physiologist, distinguished for his research into the infection of roots of legumes by root nodule bacteria of the genus *Rhizobium*. This is a subject that is truly symbiotic, involving both leguminous host plants and free-living soil bacteria, which join in a complex, often specific interaction to produce symbiotic, nodulated, nitrogen-fixing plants. His research pre-dated the molecular genetics now available to modern researchers and used the techniques of plant physiology and Mendelian genetics to explore the mechanisms of infection, subsequent nodule development and the symbiotic fixation of atmospheric nitrogen. The research took place in the laboratories and fields of Rothamsted Experimental Station, Harpenden, Hertfordshire, where the study of nitrogen fixation by nodulated legumes first developed in the UK (Russell 1966). There were components of related research in Australia, 1953–57 (Bergersen 2001), and also in other countries during the International Biological Programme of 1966–73, in which Nutman was an active participant. He was a well-respected leader in active research during a period in which the subject underwent rapid development. In many ways his work became the basis on which more recent research has developed. He was a modest, self-effacing, scrupulously honest man who became increasingly impatient with the methods of research management that were emerging within the Agriculture and Food Research Council towards the end of his career at Rothamsted. After his retirement, in his Personal Record, he wrote critically about these matters.

EARLY YEARS

Phillip Sadler Nutman was born on 10 October 1914, the second son of John William and Elizabeth Hester (*née* Hughes) Nutman, in Lea, Malmesbury, Wiltshire. An elder brother, Dr Frederick John Nutman OBE DSc (Imperial College, London), a botanist distinguished for his work on cloves, sisal and coffee in South Africa, Kenya and Tanganyika, was born in Ledbury, Gloucestershire, in 1904. A younger brother, Samuel Richard Nutman, was born in Clyro, Herefordshire, in 1916. After taking an external BSc from the University of London, Samuel became a schoolteacher. Other siblings died in infancy. Their father, John William Nutman (1877–1920), had a tailoring business in Wiltshire and Herefordshire, specializing in making breeches for the gentry and farmers. He was also a skilled cabinetmaker, but by 1917 he was in poor health, having contracted tuberculosis of the kidneys, so the family moved to the milder climate of Teignmouth, Devonshire. Here, in 1920, his father died when Phillip was only five years old. At Teignmouth his mother opened the Clifton Hotel on the sea front but after the death of her husband she devoted herself to her family and their education. Both of Phillip's parents were sober, non-conformist Protestants but later, some years after the death of John William, his mother withdrew slightly because of emotional reasons but John, Phillip and Samuel still had to attend Sunday school assiduously.

It is clear from the records that Phillip's grandmother, Elizabeth M. Nutman (*née* Sadler) was considered by the Sadlers to have married beneath her station (that is, into 'trade') to Edwin Jethro Nutman (1850–1928), a clerk at the Great Western Railway works at Swindon. (In later years, Phillip established some interesting connections with distinguished Fellows of the Royal Society, Edward Jenner and the Maskelyne family, which included 'an extraordinary concentration of Fellows' (Phillip's Personal Record).)

SCHOOLS

Phillip's primary education was obtained at a private institution, Mr Parson's Primary School in Teignmouth. The school was run by Mr Parsons, a stern and rather remote man, and his wife, a plump and kindly woman. Few details of this phase of his education or its duration are recorded. More details of the secondary education at Teignmouth Grammar School are recorded in his personal recollections, but dates are omitted. He wrote appreciatively of the contributions to his education by several teachers, but these are not of note for the purpose of this memoir. However, in particular he mentioned that he and his wife Mary maintained contact with one of them, Mr A. S. Paton, until shortly before his death in 1990 at the age of 97 years. At this point I should mention that Phillip's secondary education was closely linked with that of Mary Stanbury, also a student at Teignmouth Grammar School, but one year his senior and thus effectively out of reach. She could not draw maps and was advised by Mr Paton to 'consult with Nutman who was good at it'. So began their friendship, culminating in their marriage in 1940.

Phillip's teenage years were influenced strongly by his elder brother, John, who was greatly admired by the two younger siblings. His influence was noted in Phillip's writings about his own schooling and during his teenage years in particular. He wrote appreciatively of his indebtedness to his brother for insights into natural history developed during extensive ramblings over Devonshire's moors and woodlands. There was a natural connection with the Boy

Scout movement, which also played an important part. The sea, swimming and sailing were also important. Phillip and his younger brother enjoyed 'messing around in boats'. This activity began with an unsatisfactory canvas-covered canoe and developed into an adventure with a 27-foot teak yacht, the *Vera*, which proved too difficult for the boys to manage and was soon sold to the Teignmouth harbourmaster. However, the interest in boats and boating persisted into later life. (With help from a graduate student, Rodney Roughley, he built a Mirror dinghy in Harpenden and sailed it during holidays from his seaside cottage in Devon in the 1970s.)

While Phillip was at Teignmouth Grammar School, his brother John was undertaking studies in botany at Imperial College, where he befriended a staff member, Dr F. G. Gregory FRS, who became a frequent visitor to Teignmouth and a firm friend of the Nutman family. Phillip was greatly impressed by Gregory's scholarly and musical accomplishments and by his ability to communicate with the younger members of the family during visits to Devonshire. He joined with them in exploring the countryside and its natural treasures and took an interest in their recreational activities, such as scouting and boating, which were important components in their young lives. He became a major inspiration in Phillip's subsequent scientific development.

UNIVERSITY EDUCATION

Phillip's secondary education was completed with the award of the Higher School Certificate in physics, chemistry, pure mathematics and geography (with Distinction), but he failed to gain an award in the County Major Scholarships Examination in which his elder brother, John, had previously been successful. In addition, Phillip's Higher School Certificate lacked the then essential applied mathematics. Thus, his intention to follow John into Imperial College was frustrated. To remedy this deficiency he enrolled as a fee-paying student at the University College of the Southwest at Exeter, studying applied mathematics, chemistry and physics and taking an examination at the end of the year to gain entrance into Imperial College. While at Exeter, he stayed in Hall during the week and cycled home at weekends so as not to forgo walks along the sea wall with Mary!

He moved to London soon after completing studies at Exeter, taking up residence with Gregory, first at his flat in Bloomsbury and later at Hampstead. Gregory introduced him to London, the delights of classical theatre and concert going.

At Imperial College, Phillip studied chemistry and geology as subsidiary subjects but his main subject was botany. He recalled with pleasure the plant physiology lectures by Professor V. H. Blackman FRS, fungal physiology taught by Professor W. Brown FRS and advanced aspects of plant physiology, taught with nervous energy by Dr Gregory, whose lectures were not easy to follow, demanding close attention and careful note taking. Phillip wrote of the formative influences of these and several other members of staff on his undergraduate studies. Honours classes were small and he benefited from close individual contact with staff. Field work at Slough and later at Swanage contributed to the value of his undergraduate studies. He graduated in 1936 with first-class honours in botany, Associateship (ARCSc) and Diploma (DIC). Postgraduate studies began immediately at Imperial College Institute of Plant Physiology, with supervisors Professor F. G. Gregory and Dr O. N. Purvis, experimental work being done at Chelsea Physic Garden (1937–39). His subject was the vernalization of cereals with particular reference to effects of temperature pretreatment on development. During this

period, Phillip developed suspected tuberculosis in a right cervical gland and he was hospitalized at Hawkmoor Sanatorium, where the gland was excised. During his recovery he was able to complete cytological drawings for the first part of his thesis, using the microscope given to him earlier by his brother John. The thesis was completed and submitted, and Phillip set about obtaining a research post.

ROTHAMSTED EXPERIMENTAL STATION, 1939–80

At the time there were few opportunities but Nutman applied successfully for the post of Research Assistant to Dr H. G. (later Sir Henry) Thornton (FRS 1941), head of the Microbiology Department at Rothamsted Experimental Station. In 1939, Rothamsted was directed by Dr E. J. (later Sir Edward) Russell FRS, who, in his historical account of agricultural science in Great Britain, later described the central role of Rothamsted in Britain, including the research on nodulation of legumes being undertaken in Thornton's department (Russell 1966, pp. 309–352). When Nutman joined the staff of Rothamsted, Thornton's research was on the decomposition of phenolics and cresols by soil microorganisms, the nodulation of legumes by *Rhizobium* spp. and symbiotic nitrogen fixation. Apart from publishing his PhD research, Nutman's collaborative work with Thornton was delayed, first by wartime direction, along with about 50 others, to Cambridge for training in medical microbiology at the Department of Pathology, Addenbrooke's Hospital. As the perceived need for such training declined, so also did attendance and Nutman returned to Rothamsted. Restricted laboratory accommodation delayed and restricted the start of his research career. In 1939 the Microbiology Department was housed in the James Mason laboratory, opposite the director's office on the ground floor. A new laboratory was under construction but wartime demands delayed its occupation by the Microbiology Department. At first it was occupied by an evacuee medical group, and later it was shared with the genetical group of Professor J. B. S. Haldane FRS, which had evacuated from University College London to escape German bombing. Professor R. A. (later Sir Ronald) Fisher FRS (a particular friend of Thornton's) and other members of the Galton Laboratory were also evacuated from the University of London. Although Nutman's laboratory work was restricted initially by crowded facilities, it benefited from the close contact with Fisher and members of the Haldane group. He recorded the formative discussions about the dimensions of populations of nodule bacteria in the root zone of clovers in the nodulation process, and how these were to be estimated. He acknowledged, in particular, contributions by Hans Kalmus and Dr A. B. Rendle FRS to his formative initial breeding work with red clover. When reflecting on this period later, he found it curious that *Rothamsted Reports 1939–45* made no mention of these important visitors and their beneficial influence on the research of the station (Nutman's Personal Record). At this time Rothamsted became involved in the discovery of the selective herbicides, and some of Nutman's research time was diverted to this. He wrote of his pleasant memories of working with staff members at the ICI laboratory at Jealotts Hill where, on Christmas Eve in 1942, about 1000 test plants set up in test tubes at Rothamsted were taken for greater security. Also housed in the Microbiology Department during the war was newly formed Soil Fermentation Unit under Dr J. H. Quastel FRS. This association later gave rise to joint work on 2,4-dichlorophenoxyacetic acid. Meanwhile, Nutman's preliminary work on nodulation proceeded under the guidance of Dr Thornton. There were unpublished studies of growth of rhizobia (a commonly used

collective term for *Rhizobium* spp.) in various culture media, followed by studies repeating and failing to confirm American work on the effects of serially re-isolating the same strain of bacteria from nodules and testing them for changes in symbiotic properties. His research became increasingly independent, and soon after the end of the war in 1945 he began the bulk of his research at the interface between plant physiology and genetics of the legume symbiosis. This research, and developments from it, continued at Rothamsted throughout his career. His work there was interrupted by a secondment to the Commonwealth Scientific Industrial Research Organisation (CSIRO) Division of Plant Industry, in Canberra, Australia (1953–56), during which he established a research group to study symbiotic nitrogen fixation by nodulated legumes (Bergersen 2001) and developed links with related research at the Universities of Sydney, Adelaide and Western Australia. From Canberra he returned to Rothamsted to succeed Dr Thornton as head of the Microbiology Department and to continue his research on nodulation until his retirement in 1979.

MARRIAGE AND FAMILY

Soon after joining Rothamsted, Phillip married Mary Meta Stanbury, eldest daughter of Leslie and Meta (*née* Webber) Stanbury, on 3 February 1940, in St James Church, Teignmouth. Mary had received her primary and secondary education at Teignmouth (see above) before being trained as a teacher at University College of the Southwest, Exeter. At the time of her marriage she was acting head of Kingsteignton School. The Nutmans made their home at Harpenden, not far from Rothamsted. Their eldest son, Robert Francis Nutman, was born in Harpenden in 1945. He later took a University of London degree in chemistry and held various posts in teaching and at Wellcome and Kodak. Now he resides in Florida. Phillip and Mary's daughter by adoption, Hester Mary, was born in 1951, began primary education in Canberra and, after completing schooling in Harpenden, took her university degree in microbiology at the University of Cardiff; she has held various posts in New South Wales. Mary and Phillip's younger son, Allen Phillip, was born in 1955 in Canberra during the secondment to CSIRO Plant Industry. After schooling, Allen took a degree and PhD in Geology at Exeter University. His research has concentrated on ancient rocks of West Greenland (for example the Isua supracrustal belt), Labrador and Western Australia. He has held posts in Denmark, Canada, Japan and Brazil and is currently located in the School of Earth Sciences at the Australian National University, Canberra.

INTERNATIONAL ACTIVITIES

In 1949 Nutman attended a Commonwealth Specialist Conference on Plant and Animal Nutrition in Adelaide, South Australia. The quite numerous UK delegation travelled by sea to Perth and then overland to Adelaide. En route they were able to study at leisure the texts of the papers to be given at the conference, an advantage never to be repeated at later conferences. His contribution about his early nodulation studies aroused considerable interest but was not published. Dr O. H. (later Sir Otto) Frankel (FRS 1953), a cereal geneticist from Christchurch, New Zealand, was greatly interested in Nutman's genetical approach to legume nodulation. Nutman returned to the UK via Christchurch, for further conversations with

Frankel. This led to an initial invitation to join Frankel in New Zealand; however, after Frankel's move to Canberra this was amended to the CSIRO Division of Plant Industry and the period of successful research there.

Throughout his career, Nutman contributed to various international conferences and congresses, reporting on the progress of his studies of the physiology and genetics of nodulation of legumes. These contributions make an interesting overview of the progress of his research. The first, in 1948, at the 4th International Microbiology Congress in Stockholm, was brief, outlining the nature of the research that was to follow. The second, at the 9th International Congress for Microbiology in Moscow, outlined findings from 13 of his major publications, each related carefully to contemporaneous research by others. This congress also saw the beginning of the International Biological Programme (IBP), in which Nutman played a leading role in Section PP (Nitrogen Fixation). He led research at Rothamsted until its conclusion in 1973. In 1970 he contributed to an important conference in Brazil from which proceeded significant developments in nitrogen fixation research in that country. He also made important contributions to International Nitrogen Fixation Conferences.

Nutman had many valuable interactions with scientists from developing countries. Some of them were graduate students and some were participants in international conferences in which Nutman was also a participant. To my knowledge, he made visits to Egypt, India and China, in all of which he passed on to others some of his extensive personal scientific knowledge and skill. In his Personal Record he referred to his consultancy at the International Atomic Energy Agency in Vienna in 1971, to his roles as an External Examiner at the University of the West Indies, Trinidad, in 1975 and at the University of Ife, Nigeria, in 1976; at various times he was a visiting lecturer at universities in South Africa, Egypt, India, the People's Republic of China and the USSR. In 1975 he was a Royal Society visiting scientist to Moscow, Kiev and Leningrad,

When writing in his personal records of his many international visitors and collaborators, Nutman acknowledged that most of them came from countries of the British Commonwealth, often being rigorously selected from many applicants, but there were others, particularly from Europe, China and Latin America. Many of them were co-authors of his publications listed in the bibliography.

RESEARCH, 1939–87

After publication of his Ph.D. research (1)* and apart from a few excursions into incidental topics in plant physiology, some of which were very significant (for example (2)) Nutman's research at Rothamsted was confined to studies of the root nodule symbiosis. His research has been meticulously documented in more than 80 papers, each of which presented experimental detail at a level not seen in papers in current journals. One early paper (3) suggested that the experimental methods used influenced the physiology of the nodulation process. So, experimental methods were devised in which clover seedlings were grown under bacteriologically controlled conditions, in naturally illuminated glasshouses within glass test tubes plugged with cotton wool. Plants were germinated from sterilized seeds in sterile agar media containing

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

standardized mineral nutrients and nodule bacteria. Subsequently there was a period of research into new features of this physiology. Significant among these papers were (4), (6), (9) and (12). Initially this work used late-flowering Montgomeryshire red clover (*Trifolium pratense*) but subsequently other species were included with various strains of *Rhizobium* spp. One interesting feature of the work was the discovery of the pre-planting effect (in which a clover plant, grown in the medium and then removed, stimulated nodulation of a second clover plant, grown subsequently in the same medium). This effect was due not to secretion of unknown stimulating factors by the first plant, as proposed (9), but to removal by the initial plant of inhibitory nitrate, present in the tap water used in the medium (12). Interspersed between 10 papers about the physiology of the nodulation process were 13 papers about the genetics of the host plant, which governed nodule development. Both nuclear and cytoplasmic genetic factors were involved (5). In addition, bacterial factors were identified (7). A major host gene for ineffectiveness was identified (8) and the sites of action of two such genes were defined in structural terms (10). Later, two further host genes for ineffectiveness were characterized (14).

From this work it was clear that initial phases of infection of legume roots by the nodule bacteria were fundamental to nodule development. In his personal recollections of this phase of his research, Nutman acknowledged his indebtedness to the work of Professor G. Fahreus, whose methods he used extensively. There were nine papers about various aspects of this topic. An early paper described the initial phases of infection of root hairs (11). Later papers extended these initial observations to effects of temperature (15, 19) and to time-lapse cinematography (20).

A few papers concerned the description of root nodule bacteria in the soils of Rothamsted (for example (13)), reflecting a continuing concern for the integration of his laboratory work with practical farming (22), and he wrote of these matters in several papers (for example (21)).

Five papers (such as (23)) described improvements to nitrogen fixation achieved by plant breeding. Ten papers were given at conferences or as chapters in edited books with the purposes of integrating different aspects of root nodule biology. Notable among these were (16) and (17). Some papers, such as (18), attempted to chart a course for future research,

Nutman was intensely interested in the history of science, particularly in the important part that Rothamsted Experimental Station and its scientists had played in research in nitrogen fixation. He drew heavily on his knowledge of this topic when preparing his important paper (24), presented at the Royal Society Discussion Meeting held in 1986 to mark the centenary of the meeting in Germany at which Hellriegel (1886) communicated his important results, soon confirmed at Rothamsted, demonstrating nitrogen fixation by nodulated peas.

RETIREMENT

Having spent all their married life in Harpenden and knowing Mary's nostalgia for Devon, and in particular her desire for a thatched cottage there, Phillip promised her fulfilment of that dream. Therefore, soon after retirement from Rothamsted, the Nutmans moved to Great Hackworthy Cottage, converted from a farmhouse near Tedburn Saint Mary, a few miles from Exeter. There they re-thatched the roof, established a productive kitchen garden, grew stone fruit and cider apples and built an attractive summer house. Phillip pursued his interests in woodwork and music; the living rooms housed an electronic organ and a small grand piano.

They joined in the activities of the Devon Dialect Society, recording speech by elderly inhabitants who had seldom moved from villages where they had been born. Phillip was able to maintain his scientific interests with service in Royal Society activities in London and by frequent visits to the university library in Exeter. He engaged in several editorial activities, in particular with Research Studies Press. There were visits abroad to their children in the USA and Australia.

Eventually, after about 20 years at Great Hackworthy Cottage, these activities were curtailed by physical limitations and the Nutmans moved to a less demanding home in Exeter. Phillip died after a brief illness, in his ninetieth year. His wife, Mary, and their three children survive him.

HIS AUSTRALIAN COLLEAGUES REMEMBER HIM

On Friday, 21 June 2004, at the annual symposium of the Sydney University Nitrogen Fixation Centre (SUNFIX), after tributes given by Dr R. J. Roughley and myself, delegates, including several who had worked with him during his Australian secondment in 1953–56 and at Rothamsted during doctoral and postdoctoral studies, stood in silent tribute to their friend and mentor, Dr Phillip Sadler Nutman FRS.

HONOURS AND AWARDS

- 1959 Awarded the Huxley Research Medal
- 1968 Elected Fellow of the Royal Society
- 1981 Awarded the Hannaford Research Fellowship, Waite Research Institute, University of Adelaide

ACKNOWLEDGEMENTS

The author acknowledges the help of Mrs Mary Nutman and Robert Nutman for assistance in compiling the complete list of references. Dr Allen Nutman kindly added corrections to my initial text. Various colleagues have shared memories of their friend and colleague, Phillip Nutman.

The frontispiece photograph was taken by Godfrey Argent, and is reproduced with permission.

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