RUDOLPH ALBERT PETERS
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BY R. H. S. THOMPSON, F.R.S., AND A. G. OGSTON, F.R.S.

FAMILY BACKGROUND

Rudolph Albert Peters was born in Kensington on 13 April 1889. His grandfather, Ralph Benjamin, had been born in Denmark, the son of Rudolph Daniel Benjamin Peters (1781–1861) who was a Captain in the Danish Army (2nd Battalion, the Altona Infantry) under King Christian VIII, and who had been appointed by him a Knight of the Order of the Dannebrog for his services in defending the neutrality of Altona in the face of Napoleon’s army.

His father, Albert Edward Duncan Ralph Peters, M.R.C.S., L.R.C.P. (1863–1945), was a younger son of Ralph Benjamin Peters, who had come to England as a young man and had married Elizabeth Sewell Pape, who belonged to a Lincolnshire family said to have been friends of the Wesleys.

His mother was Agnes Malvina Watts (1867–1950), the granddaughter of Commander C. N. Watts, R.N., whose father, Admiral George Edward Watts, C.B., had been engaged in many naval actions in the time of Napoleon. Admiral Watts was himself the only son of John Watts, an officer in the army who fell while serving under the Duke of Kent at the storming of Fort Bourbon, Martinique, in 1794. The Watts ancestors also include a Captain of Infantry who had fought under the Duke of Cumberland at the Battle of Culloden, and who was a first cousin of Dr Isaac Watts, the writer of a number of well known hymns including ‘O God, our help in ages past’.


Rudolph’s maternal grandmother, Julia Septima Watts, had been born Julia Septima Herring in Brazil, where her father was manager of the St John del Ré mines.

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His mother and father were married in 1888, while his father was still a medical student at St Bartholomew's Hospital. Up to the age of 3 most of his time was spent at the home of his maternal grandmother in Cheltenham, but in 1892 his father became a partner in a general practice in Sussex, and the family moved into a house in High Street, Midhurst, where his sister Gwendoline was born in 1904.

He remained at Midhurst until the age of 15, enjoying the relaxed country life of those days; his father did his medical rounds in a dog-cart and had his own shooting.

From 9 to 13 years of age he was at a preparatory school, Warden House, at Deal, where he was eventually Head Boy. On most Sundays during term the boys walked to Walmer Church in Eton jackets and top hats, and Peters has recorded that occasionally he fainted in church, and had to be brought out to be revived. He tells us that he was not much interested in games, though better at football and hockey than at cricket, which he found 'definitely boring'. He applied himself, however, with evident keenness to his violin lessons, which he learnt 'from an excellent teacher, Miss Bruce Payne', but he goes on to observe that without his mother's earlier encouragement and patience he 'never could have played'. He also tells us that he 'was supposed by some of the other boys to be quite good at acting in the school plays'.

When he was 13 he moved on to Wellington, and as he had entered as a Classical Scholar he was put onto the classical side, which the Headmaster thought was a very suitable background for medicine.

Although he had no formal teaching in science until his last year at Wellington he had, by the age of 17 or 18, become interested in it as a hobby. He read extensively in books on electricity and magnetism and the more chemical aspects of photography (he had acquired an early interest in photography through the encouragement of his grandmother Watts). He even prepared some hydrogen sulphide in an upper room at home, and has told us that it was 'much to the discomfort of my father's consulting room and of the neighbours next door, who sent for the sanitary inspector'.

While he was at Wellington the family left Midhurst because of the break-up of the partnership, and his father set up in practice in Petersfield, though retaining some of his old patients in the Midhurst area whom he would visit on a motor cycle.

In due course Peters became a Dormitory Prefect at Wellington, but was never a School Prefect, which, he observed, was not surprising as he was never much of an athlete. Towards the end of his time at Wellington he had the good fortune to become friendly with Mr S. A. Saunders, one of the mathematics masters, who was a distinguished astronomer and possessed his own telescope. He was at that time engaged in making an accurate map of the craters on the Moon for the British Astronomical
Society, and Peters spent many hours with him in his observatory looking at the stars and discussing with him his work on the Moon. He has said that at one time indeed he was much attracted by the thought of a career in astronomy and throughout his life he displayed a keen interest in this subject.

Another of the masters, Mr A. H. Fox Strangeways, was a good pianist and an excellent musician, and with his encouragement he was able to improve his playing of the violin. He has recorded, however, that at that time Wellington was very unmusical, and he was the only violinist among the boys capable of playing in a concert. He also took a keen interest in the ‘Corps’ at Wellington, going to camp regularly each summer, and finally reaching the rank of Sergeant.

On leaving Wellington at the age of 18, and while waiting for a vacancy for admission to Cambridge, Peters spent a year in London as an external student at King’s College in the Strand. Here he worked for ‘Little-go’ and for the 1st M.B. (Cantab.). He has written warmly of the excellent teaching he received there in chemistry, physics, zoology and botany.

Cambridge 1908–14

In 1908 Peters entered Gonville and Caius College, Cambridge, and here, under the stimulating influence of Joseph Barcroft, J. N. Langley, A. V. Hill, H. K. Anderson and W. B. Hardy, his scientific life began in earnest. He obtained a ‘first’ in part I of the Natural Sciences Tripos in 1910, and then went on to work for his part II in physiology, which included physiological chemistry, taught at that time by F. Gowland Hopkins and S. W. Cole.

While engaged on this he was invited by Barcroft to embark on his first research problem, the determination of the relation between iron and oxygen in haemoglobin. This work, which was published in the Journal of Physiology in 1912, proved for the first time that the O2/Fe ratio in haemoglobin, the so-called specific oxygen capacity, was in stoichiometric proportions, and that although the oxygen was dissociable it was none the less present in a chemical combination with the iron.

Although he spent nearly two years working for part II of the Tripos he was unable to sit for the examination because in the early summer of 1912 he developed an attack of typhoid fever and was forced to spend five weeks in a nursing home in London.

When he returned to Cambridge in the autumn of 1912 he joined A. V. Hill in a study of the relation of heat production and lactic acid formation in frog muscle after stimulation through the nerve. A detailed account of these experiments was given in a paper in the Journal of Physiology (Peters 1913). Looking back to those days Peters (1981) has said that

‘The paper has never been much noticed because it didn’t fit in with the Meyerhof lactic acid view of muscle. I found more lactic acid than
Meyerhof’s people liked, and consequently of course they all said it was wrong. Actually my results were right, and of course they really showed very clearly the process of heat production on stimulation of muscle. At any rate this was a stone thrown at the lactic acid theory, which now has no shape of any kind.’

However, it is clear that he much enjoyed his association with A. V. Hill, and he has commented that ‘during that time he taught me, in addition to his approach, some thermodynamics, a slight amount of mathematics, and at any rate something about galvanometers, for which I have always been grateful’.

In the following year (1914) he was awarded a Fellowship at Caius, but on the outbreak of World War I he decided to complete his medical education, and so left Cambridge to go to London, to his father’s old hospital, St Bartholomew’s Hospital. He qualified in 1915, and has told us that he ‘was very happy in the Bart’s surgery. It was a very warm, cosy place. The old ladies used to call you “dearie”, and you really got some sense of what clinical medicine meant in the Bart’s surgery. It was a very splendid place.’

THE WAR YEARS, 1914–19

After qualifying in medicine in the summer of 1915 Peters joined the R.A.M.C. and was immediately sent to Salisbury Plain to train a Field Ambulance before leaving for France in November of that year. After six months with a Field Ambulance and Advanced Dressing Stations in the area of the front around Béthune he was transferred to the 1st Battalion of the 60th Rifles as their medical officer. He was with the regiment throughout the Delville Wood, Vimy Ridge and Beaumont Hamel engagements. For his work in France as M.O. to the 60th Rifles, a regiment not usually regarded as profuse with their awards, he was awarded the Military Cross and later a bar to it, and was also mentioned in despatches.

Peters never spoke much about his time in France, but in an interview that he gave at the request of the Biochemical Society in 1981 he described how, when they were in billets behind the lines, the French used to expect the M.O.s to attend to their medical needs:

‘One farmer where we were billeted came along and said that his daughter had a bad pain. Well, I remember I gave her a dose of castor oil because that was one of the things which we had in our medical kit. I was a bit worried that I might have overdone it, but next morning they rushed out at me, held up something and said “Un ver!” I didn’t understand what that meant, but she had produced an enormous worm. This was quite a relief to me because I had wondered whether I had given her too heavy a dose of castor oil. But
that was the kind of thing you might be landed with when you were in France!'

In the early part of 1917, with the advent of gas warfare, Peters was recalled from the 60th Rifles to carry out research on problems of chemical warfare in the R.E. Experimental Station, which had been set up at Porton on Salisbury Plain in 1916, and which has now become the Chemical Defence Establishment of the Ministry of Defence. Before returning to England he spent a brief period with some of the units that had been set up to deal with chemical warfare problems on the British First Army Front. Here he had unique opportunities, through the examination of casualties, for studying the effects of gas.

The Physiological Laboratory at Porton began work in 1917, with Professor J. Barcroft, F.R.S., as its Head. The accommodation for the physiologists consisted originally of one hut (30 ft × 15 ft (ca. 9 m × 4.5 m)), which was used as office and laboratory, the animals being kept in a one-time barn. For some time Peters not only worked but lived in the hut, and had his bath, the round tin type, on the floor of the post-mortem room. He spent the rest of the war working at Porton, and he has said that the experience he gained there, working with Barcroft, Boycott, Shaw Dunn and others on phosgene, arsenical smokes and mustard gas, orientated a good deal of his subsequent outlook.

For some of his work on toxic compounds while he was at Porton, Peters used ciliate protozoa such as Paramecium. He found, among other things, that if small amounts of thallium salts were added to the medium the ciliary action was reversed. This finding was soon put to good use, for Peters (1981) has recorded that

'On one occasion we were in despair because some generals were coming down to inspect us. We knew that the generals wouldn’t understand anything at all about biochemistry, let alone pathology, though they might have understood a bit about what Shaw Dunn was doing. So I didn’t know what to do, but I had recently discovered that if you treated these Paramecia with thallium salts it reversed the ciliary action. It was a very remarkable thing really because it got to the root of the thing and changed something on the surface membrane. So, in despair, when the generals came round I was able to show them this phenomenon. And the first General who looked at it said “What! a gas that makes the enemy go backwards!” I’ve never forgotten that. I didn’t know how to answer this, for it really was rather an obvious application I suppose for the General.'

In the summer of 1917 he was given some leave, and went to Scotland to propose to Frances Vérel, his future wife, appropriately enough on the banks of Loch Lomond. They were married on 7 November 1917, and Peters has recorded that ‘this was not without incident’: Major Rendel, a
gunner, was the Adjutant at Porton, and when Peters was due to start for Glasgow to be married Rendel called him into his office and showed him an order that said that there would be no further leaves because things were beginning to get very bad again at the Front. He then said he would be issuing this order at 5 p.m. and if Peters was not out of the Station by then it would be his own fault!

CAMBRIDGE, 1919–23

When the Armistice came in 1918, Peters was approached with a view to continuing work at Porton, but decided that he wanted to return to his Fellowship at Caius, which had been suspended during his military service. He was offered a temporary post by Professor Langley in histology, but Peters has said that ‘nothing would have made me a histologist’. After his time at Porton he now wanted a career in biochemistry, and fortunately Gowland Hopkins offered him a post, ‘so that I moved over as a kind of adjutant to Hopkins’ laboratory’. With his work in College, supervising in physiology, and his various research activities, his life at Cambridge was a busy one.

His research interests at this time were threefold: first, a pharmacological interest in the mechanisms of action of the toxic gases he had been concerned with in his work at Porton. This led him to a study of the nutrition of certain protozoans (Colpidium colpodla, now Tetrahymena pyriformis), which in turn, arising from his attempt to grow Paramecium in media containing yeast extracts, initiated his interest in the vitamin B complex. And thirdly, his observations on changes in the lung alveolar epithelium induced by phosgene and other respiratory irritant gases stimulated his interest in surfaces (a topic that W. B. Hardy was then actively studying) and together with H. Hartridge he embarked on a research into the effect of pH on interfaces between oil and water (1922).

Concerning those years Dr Robin Hill, F.R.S., has written: ‘I was especially fortunate as a graduate student in 1922 to be allowed to join the members of the keen and enthusiastic group of people that F. G. Hopkins had recently gathered around him. At this time R. A. Peters was a senior member, being a university lecturer in the Cambridge school of biochemistry. He had been thrilled as an undergraduate in 1909 with the lectures on biochemistry given by Hopkins.’ Among the group also was N. K. Adam. In his contribution to Perspectives in biochemistry Adam wrote: ‘It was in the spring of 1920 that R. A. Peters drew my attention to the two classical papers by Langmuir on the constitution and fundamental properties of solids and liquids.’

This interest in monolayers and cell surfaces led him to put forward some original and imaginative ideas concerning the internal organization of cells, which, as we can now see, clearly anticipated the modern concept
of the anatomy of the cell; thus in the Harben Lectures, given in 1929, he stated:

'The fact that the cell contents are often quite fluid can be reconciled with the fact that the living cell shows a continuous directive power by the view that protein surfaces in the cell constitute a mosaic form which radiate chains of molecules, controlled by their attachment to the central mosaic. These constitute a fluid anatomy in the cell, and the central mosaic behaves as a kind of central nervous system.'

Oxford, 1923–39

The Whitley Chair of Biochemistry had been established in Oxford in 1920. After the premature death of its first holder, Professor Benjamin Moore, in 1922 Peters was invited to accept the Chair at the age of 34. Although it was with some reluctance that he left his Fellowship at Caius, the spring of 1923 saw him installed in Oxford as a very young Professor in a small biochemistry department situated in part of the old Physiology Laboratory. In 1925 he was appointed to a Professorial Fellowship at Trinity College.

Even before his arrival in Oxford moves were in progress for a new building for biochemistry, and as a result of a grant from the Rockefeller Foundation, and with the encouragement and help of Sir Charles Sherrington and Sir Archibald Garrod, a new laboratory was built adjacent to the Physiology Department. In 1926 Peters and his small staff moved into this new building, which was officially opened by Viscount Cave, the Chancellor of the University, on 21 October 1927.

With the administrative and financial problems connected with the building of a new laboratory behind him, Peters was now able to settle down to his research on what was then known as vitamin B. His interest in this nutritional problem derived from his earlier work at Porton and in Cambridge on the culture requirements of protozoans, and in turning to the vitamins he must also of course have been greatly influenced by his contacts with Gowlind Hopkins.

At the time when Peters started this work it was not generally recognized that 'vitamin B' was a complex of a number of essential nutritional factors. Peters chose to work on the factor that cured pigeon or fowl beri-beri, partly because he thought that the opisthotonus brought about by dietary deficiency of this factor provided a more definite indication of deficiency than mere changes in the weight of growing rats. He set out to answer two questions: first, what is the chemical nature of this 'anti-neuritic' factor, and secondly how does this vitamin bring about its anti-neuritic effects inside the body?

He began by attempting to isolate the antineuritic factor from yeast, having satisfied himself that a test based on the ability of yeast concentrates to cure the symptoms of head retraction in pigeons fed on polished
rice provided him with a satisfactory guide as to the concentrations of the active factor (Peters 1924; Kinnersley & Peters 1925). Although Jansen & Donath succeeded in 1926 in obtaining crystalline preparations of vitamin B$_1$ from rice polishings, Peters continued his work with yeast, and a series of papers appeared describing the preparation and properties of vitamin B$_1$ concentrates obtained from this source (Kinnersley & Peters 1927; Kinnersley, Peters & Reader 1928; Kinnersley & Peters 1928). He next undertook the large-scale preparation of fractions from baker’s yeast (Kinnersley, O’Brien, Peters & Reader 1933), and by 1932 he and his colleagues had obtained crystalline preparations of high vitamin B$_1$ activity (Kinnersley, O’Brien & Peters 1932, 1933, 1935).

The head retraction of the rice-fed B$_1$-deficient pigeon, and its rapid cure by administration of the vitamin (thiamine), presented a most striking and intriguing problem, and one that was rapidly seized on by Peters with his training as a physiologist. It was indeed his investigation of the nature of the underlying damage in the nervous system of the vitamin-deficient bird that resulted in the work for which he will be best remembered: in the ten years or so before the outbreak of World War II, assisted by a succession of colleagues, some of them only starting out in research, he succeeded in describing for the first time the mode of action of a vitamin, which until that time had been a mystery.

Although the neurological damage in human beri-beri is predominantly a peripheral polyneuropathy, Peters was of the view that the head retraction in the acute B$_1$-deficient pigeon must be central in origin, and he therefore began with work on the brain.

He had observed (Kinnersley, Peters & Reader 1928) that some cases of opisthotonus in rice-fed birds could be temporarily cured by giving glucose alone, which led him to the view that ‘... investigation of the relation between these symptoms and carbohydrate metabolism might shed light upon the metabolic lesion in avitaminosis proper’ (Kinnersley & Peters 1929).

Adopting this approach he was able to show that there is an increase of lactic acid in the brain of pigeons in the terminal stages of avitaminosis B$_1$, and that the excess of lactic acid disappeared within a short period after dosing with thiamine (Kinnersley & Peters 1929, 1930). In support of this finding, R. B. Fisher (1931) showed that liver, skeletal and cardiac muscle from avitaminous birds each exhibited abnormally high levels of lactic acid after exercise.

Gavrilov & Peters (1931) next showed that minced brain from polyneuritic pigeons has a diminished oxygen uptake in the presence of glucose as substrate, and also that a partial restoration of uptake can be produced in vitro upon addition of vitamin B$_1$ concentrates to the minced brain; they concluded that vitamin B$_1$ is directly concerned with the oxidative metabolism of the pigeon brain.

In a series of further papers from the Oxford Laboratory (Gavrilov,
Meiklejohn, Passmore & Peters 1932; Meiklejohn, Passmore & Peters 1932; Peters & Sinclair 1933; Peters & Thompson 1934; O’Brien & Peters 1935) evidence accumulated indicating that thiamine is concerned specifically with the metabolism of pyruvate (and other α-oxo-acids), and that in the absence of the vitamin pyruvate accumulates in the tissues and in the blood. By 1936, therefore, in a lecture that Peters gave at the National Hospital for Nervous Diseases in London, he was able to conclude that vitamin $B_1$ ‘is a catalyst needed for the oxidative removal of one of the degradation products of carbohydrate metabolism’ (pyruvic acid), and for the first time the way in which a vitamin acts inside the body had been described.

Following the discovery by Lohmann & Schuster (1937) that yeast co-carboxylase is the pyrophosphate ester of vitamin $B_1$, Peters, together with Banga and Ochoa, finally showed that in the brain also it is the pyrophosphate ester of the vitamin that is the active form necessary for the oxidation of pyruvate (Banga, Ochoa & Peters 1939).

Although Peters also devoted attention to the question of the structure of thiamine, with some collaboration by Sir Robert Robinson, F.R.S., it was left to R. R. Williams and his colleagues to solve this problem (see Williams & Spies 1939).

His broader interests in nutrition, even in these early years, were shown by his work (Carter, Kinnersley & Peters 1930) on factors present in yeast that were at that time known as vitamins $B_3$, $B_4$ and $B_5$, but although some order emerged there was little hope of any real advance when nutritional deficiencies were traced merely by observing changes in body weight.

A further development in the Oxford Laboratory in the 1930s was the installation of a Svedberg ultracentrifuge. Philpot had joined the Department in 1934 to continue his work on pepsin, which he had begun in Prague and in Uppsala, and wished to install one of these centrifuges for this work. Peters actively backed the idea, obtaining funds from Lord Nuffield and the Royal Society to cover its cost and maintenance. At the same time A. S. Macfarlane was ordering one for the Lister Institute. Both instruments came into operation in 1937. Until the advent of the Spinco these two were the only effective ultracentrifuges in the United Kingdom, and the Oxford instrument the only one regularly available for work on material from other laboratories. Ogston inherited responsibility for the ultracentrifuge after Philpot’s departure from Oxford in 1941, and was joined by R. Cecil in 1945.

Oxford, 1939–54: the war years and after

Peters had for long expected the outbreak of war with Germany. Even at the time of the invasion of Czechoslovakia he had the staff filling sandbags to protect the entrances to the Department. Since his involve-
ment with chemical warfare in World War I he had maintained an
interest in these problems, and shortly before the outbreak of World War
II he was asked by Sir Joseph Barcroft, F.R.S., to hold himself in
readiness to recommence work on defence against chemical warfare
agents. By September 1939 an extra-mural team had been recruited for
the Ministry of Supply and had begun work under Peters’s direction into
the mode of action of vesicant gases (in particular mustard gas and
Lewisite) with a view to devising specific antidotes to them capable of
being used therapeutically. Peters, together with J. St L. Philpot, A. G.
Ogston and E. R. Holiday, took on the mustard gas problem (with the
collaboration of L. A. Stocken in the early stages, who was actively
involved in carrying out and advising on methods of synthesizing
‘competitors’, especially thiophosphates and thiophosphonates), while
H. M. Sinclair, R. H. S. Thompson and later L. A. Stocken worked
on Lewisite.

Starting from Peters & Walker’s early observation (1923) of the
apparent retarding effect of chloride on the hydrolysis of mustard gas,
and with the benefit of the Hughes–Ingold theory of the mechanisms of
replacement reactions, the ‘mustard team’ set about seeking a reagent
that would react with and neutralize ‘mustard’. In spite of the develop-
ment of a number of very active replacement reagents they found none
that was effective in vivo (nor did anyone else). They also investigated
methods (solvent soaps and pastes) for extracting unreacted mustard
from the skin. At first human testing had to be done on soldier volunteers
at Porton, but as this proved something of a bottleneck permission was
given to use student volunteers (although the Ministry of Supply would
on no account accept responsibility). Each volunteer received not more
than four applications of very small amounts of vesicant on the forearm
and, with the exception of one volunteer who developed some rather large
blisters not from the vesicant but from the treatment, no one was much
the worse for it.

The pursuit of an antidote to Lewisite was more fruitful. It had been
known for some time that sodium arsenite inhibited the oxidation of α-
oxo-acids, and early in the war Peters, Sinclair & Thompson (1940, 1946)
showed that both sodium arsenite and Lewisite had a selective action on
the pyruvate oxidase system. It seemed therefore that tervalent arsenicals
showed some similarity to iodoacetate, which is also a powerful inhibitor
of that enzyme system (Peters, Rydin & Thompson 1935). Earlier work,
mainly by Voegtlin and his colleagues (1923, 1931) and by Walker (1925),
had suggested that the toxic action of arsenic on living cells was due to its
reaction with essential thiol compounds, and it was known that iodo-
acetate also reacts with thiol groups in proteins (Rapkine 1933). But when
Sinclair tested a series of monothiol compounds he was unable to show
any protective action against the toxic effects of Lewisite on the pyruvate
system. However, on preparing derivatives of kerateine with Lewisite
Stocken & Thompson (1940) found that most of the arsenic in these derivatives was in combination with two thiol groups, which suggested that dithiols might prove more effective antidotes than the monothiols used in the past. This ‘dithiol theory’ led to the development (Stocken & Thompson 1941, 1946) of an effective antidote, 2:3-dimercaptopropanol (British Anti-Lewisite or BAL). It must be recorded that Peters was at first sceptical of Thompson & Stocken’s approach, but later he adopted it with enthusiasm and took an active part in studying the clinical use of BAL in the treatment of dermatitis arising as a complication of arsenotherapy (Carleton, Peters, Stocken, Thompson & Williams 1946; Carleton, Peters & Thompson 1948). He remained throughout the war, and indeed for many years after the war, a member of the Chemical Warfare Committees of the Ministry of Supply and, later, of the Ministry of Defence.

At the request of the Burns Subcommittee of the War Wounds Committee of the Medical Research Council, Peters also undertook work on the biochemical changes occurring in thermal burns. In the main he was interested in the local changes taking place in and around the burnt area, his objective being to discover whether toxic substances are released from the burnt tissue. He demonstrated the presence of a protease in skin with a pH optimum around 7.5 that retained about 70% of its activity after heating at 70°C for 5 min (Beloff & Peters 1945); further study of the activity of this enzyme in skin after burning led him to the view that some of it escapes from the burnt skin, and may contribute to the formation of the blister. He also studied the nitrogen metabolism after burning (Clark, Peters & Rossiter 1945) and the effect of adding protein and methionine to the diet of rats on the nitrogen loss after thermal burns (Croft & Peters 1945). The latter work showed that an increase in the dietary protein substantially reduces the tissue wasting and loss of nitrogen in the urine; the inclusion of methionine supplements in the diet had a similar effect in reducing urinary loss of nitrogen.

From 1930 on Peters was much involved in the work of the Accessory Food Factors Committee of the Medical Research Council, and was Chairman of this Committee from 1943 to 1954.* This resulted in his being actively concerned with a number of nutritional researches and surveys that were carried out at that time. One of the problems that engaged his attention was the question of the degree of extraction of flour for the wartime loaf of bread, and also the addition of calcium and thiamine to the wartime flour. He also took part in a study of a group of volunteers at Sheffield designed to describe the effects of vitamin C deficiency in human adults and to assess their vitamin C requirement.

*He was also Chairman of the following Subcommittees of the Accessory Food Factors Committee: Vitamin B Subcommittee, Vitamin C Subcommittee, Vitamin Claims Subcommittee, and the Subcommittee on Postwar Opportunities for Nutritional Research in Occupied Countries in Europe.
With H. M. Sinclair he undertook another survey on a group of Jesuit students at Heythrop College who, as a piece of warwork, had volunteered to submit to a diet calculated to be deficient in thiamine; although clinical examination of the students revealed nothing, the study did indicate the diagnostic value of estimation of blood thiamine levels.

Shortly after the end of the war Peters embarked on an extended research into the toxic action of fluoroacetate. He had been introduced to this compound in 1942, since it was known to be highly toxic, particularly to the nervous system and the heart, and to be a vesicant and therefore possibly of interest in warfare. In 1944 it had been shown to be the toxic principle of a poisonous S. African plant known as Gifblaar (Dichapetalum cymosum). Fluoroacetate differs from the other halogen acids such as iodoacetic acid in the much greater stability of the C–F bond. It does not therefore act like iodoacetate or bromoacetate by combining with SH groups, nor does it act by the liberation of fluoride. Peters showed that the mechanism of its toxic action depends upon its metabolic conversion inside the body into another compound, fluorocitrate, an example of what he called a 'lethal synthesis', in contrast to the protective syntheses used in many detoxication processes. He has described this work both in his Croonian Lecture (Peters 1952) and, more fully, in his monograph entitled 'Biochemical lesions and lethal synthesis' (Peters 1963). It had been found by Bartlett & Barron (1947) that fluoroacetate competitively blocks the oxidation of acetate. Liébecq & Peters (1949) discovered that there is also a marked accumulation of citrate. This latter observation was energetically followed up by Peters and his colleagues, and provided the clue to the mode of action of fluoroacetate. With Liébecq, he had concluded that fluoroacetate must enter the tricarboxylic acid cycle and in some way block the metabolism of citrate. Eventually he was able to prove that on entering the tricarboxylic acid cycle it is enzymically converted into fluorocitrate, which then competitively inhibits aconitase, and in this way blocks the further metabolism of endogenously formed citrate (Lotspeich, Peters & Wilson 1952; Peters, Wakelin, Buffa & Thomas 1953; Morrison & Peters 1954).

Babraham, 1954–59

Shortly after the 1939–45 war the Agricultural Research Council decided to establish an Institute of Animal Physiology. The Babraham Hall Estate, six miles south of Cambridge, was purchased to house the new Institute, and Dr I. de Burgh Daly, F.R.S., was appointed Director. As part of the development plans for the new Institute, Daly considered it essential to obtain scientists of distinction to start research off along the right lines, and Peters was invited to take over this responsible function for the Biochemistry Department. So it was that at the age of 65 he retired
from the Whitley Chair at Oxford to become a member of the Scientific Staff of the Agricultural Research Council, and Head of the Biochemistry Department at Babraham. A number of research workers who had been members of his laboratory in Oxford also went with him to Babraham (R. M. C. Dawson, D. B. Lindsay, P. F. V. Ward and, later, V. P. Whittaker).

He entered into his new life with characteristic enthusiasm, even living on the estate at Babraham until a suitable house became available in Cambridge. Although officially his appointment was supposed to be a part-time commitment because of his age, he nevertheless throughout his term of office worked as long hours at the Institute as did his junior colleagues.

Through his leadership the Biochemistry Department was quickly moulded into a strong research group. Owing to the lack of other suitable accommodation, research discussion meetings were at first held in his own office, with his own personal furnishings, and Dawson has recorded that these included a Victorian painting of a shipwreck which Sir Rudolph would say reminded him of his own research on its bad days!

His own research at Babraham was an extension of the work he had carried out in his later years at Oxford on the toxic action of compounds found in Nature that contain the C–F bond, and he became especially interested in those plants that posed a threat to livestock. Together with members of his staff he isolated a number of fluoro fatty acids from the seeds of Dichapetalum toxicarium, which were much used by the witch doctors of Sierra Leone for trials by ordeal. The main component was shown to be ω-fluorooleic acid, but smaller amounts of ω-fluoropalmitate and ω-fluorocaproate were also present, suggesting that the biosynthetic pathway for their production involved fluoroacetate and malonyl CoA. Fluorooleic acid was found to be extremely toxic, and to form fluoroacitrate by way of the tricarboxylic acid cycle. His group investigated the toxicology and biochemistry of various fluorine-substituted metabolites, including fluoroglyceraldehyde, fluoroglycerol, fluoroethanol and fluoropyruvate. He was also much interested in the stereochemistry of the inhibition by fluoroacetate of aconitase, and he was able to reconcile many of the earlier discrepancies and problems brought to light in the course of the original work on lethal synthesis at Oxford.

Retirement

When Peters retired from his A.R.C. post at Babraham Sir Frank Young welcomed him into the University Department of Biochemistry at Cambridge. He says that

'for many years Peters arrived daily at the Department on his bicycle, though in time he often came by taxi. He continued to impart to those
around him his enthusiasm for research, and his delight in the discoveries that he continued to make. He certainly embodied in himself an outstanding example of an effective biological catalyst.’

Dr R. M. C. Dawson, F.R.S., has written as follows about the years of retirement in Cambridge:

‘After his retirement from the Institute of Animal Physiology in 1959, he continued an active scientific life at the Department of Biochemistry in Cambridge, occupying a small laboratory at the front of the building. He cycled in nearly every morning although in latter years he walked to the Department via the grounds of Pembroke College.

‘His work was supported by grants from a number of sources, particularly the Wellcome Trust, and for a number of years he had the excellent and loyal assistance of Mrs M. Shorthouse. In the main he continued to extend his studies on the pharmacology and biochemistry of the aliphatic fluorine-containing compounds occurring in plants. It was shown that *Acacia georginae* was able to absorb fluoride ions especially at pH 4 and that the plant could convert this into a variety of fluorocompounds including volatile substances such as fluoroacetone.

‘Many aspects of the toxicity of such fluorine-containing substances were investigated, such as the problem of the relative insensitivity of rats to poisoning by oral fluorocitrate and the elimination of the organically combined fluorine from the body as fluoride ion. The limited ability of brain tissue to convert fluoroacetate to fluorocitrate was ascribed to the low level of acetyl CoA synthetase in the tissue and fluorocitrate was detected in the bones of cattle suffering fluoride poisoning. Associated with this work were further studies on aconitase; results were obtained which suggested that the enzyme complex contained two active centres, different preparations having wide variation in isocitrate hydro-lyase and citrate hydro-lyase levels.

‘Studies on fluorocompounds were by no means exclusive and there were a number of collaborative studies on a variety of problems. The toxicity of copper to brain tissue both *in vivo* and *in vitro* was investigated (with Dr J. M. Walshe) in view of its relevance to patients with Wilson’s disease (hepatolenticular degeneration) in which copper accumulates in the tissues. It was concluded that part of the toxic action was due to reaction of the Cu ions with membrane-bound ATPase.

‘As well as carrying out experimental work, he continued to play an active part in scientific meetings and conferences, often participating as the plenary speaker. He retained his ability as a public speaker and gave a particularly fine speech at a dinner in Christ’s College in
honour of his 90th birthday. He published a number of thought-provoking reviews including one on problems of cellular integration which appeared in the Proceedings of the Royal Society B. All knowing him at this time speak of his absolute enthusiasm, both for his own research work and for scientific advances in general. He was keenly sought out by students and others for his much valued advice. It is fitting that his last written scientific publication was in the journal which he had founded—Biochemical Pharmacology. It was described as a preliminary communication announcing the discovery of an enzyme, ether-O-oxidase, which enabled rat liver endoplasmic reticulum to deal with diethyl ether.'

**Personal characteristics**

Rudolph Peters was a man who inspired affection and respect. His friendly and outward-going manner was appreciated by all his colleagues, but at the same time our form of address to him was 'Professor', never 'Prof'; somehow that would have seemed to be taking an undue liberty. His nickname 'Bunny' was used only by some of his contemporaries and older friends, and did express certain aspects of his character: his air of nervous alertness and all-round awareness; his moustache could, like a rabbit's whiskers, seem to tremble with expectancy. His speech was rapid, tending to come in short bursts, and delight or perception of some absurdity would produce a ready smile or quick short laughter.

His mind was quick, but tended to move elliptically in a way that could confuse. Particularly when one required an answer or decision from him there were always one or more other subjects in his mind which would suddenly and disconcertingly break into the discussion. This gave some the impression that he thought vaguely and indecisively, but this was far from the truth. A clear opinion or decision would be obtained from him an hour or a day later. He was certainly shrewd, as he demonstrated to the advantage of his department more than once when dealing with the General Board over departmental economies demanded by the University.

His style of writing was apt to be loose and sometimes unclear, but at the same time he was an artist in choosing the right and striking phrase, examples of which are shown in the titles of two of his Harben Lectures: 'The ministers of metabolic change' and 'Tissue anarchy', and in his use of terms such as 'cytoskeleton', 'biochemical lesion' and 'lethal synthesis'.

In this connection Sir Frank Young, F.R.S., has written to say that

'in 1929 or 1930 there appeared on the Notice Board in the Department of Biochemistry at University College London, an announcement that four lectures on vitamins were to be given by Professor R. A. Peters of Oxford. The third of these lectures was
concerned with the effects of vitamin B₁ deficiency on the metabolism of tissue removed from a pigeon. The title of this lecture was given as "Vitamin B₁ deficiency—tissue anarchy."

He goes on to say,

'I enquired from Professor Drummond (later Sir Jack Drummond, F.R.S.), who was Head of the Department, what this title meant, but he also was puzzled by it; nevertheless, as he explained, Professor Peters was not only a scientist but also a musician and a poet. In time I learnt for myself some of the special qualities of Professor Peters which were implied by that statement.'

He was first and foremost an enthusiast for biochemistry. He insisted that his department should be represented on the Faculty Boards of Physical and Biological Sciences and of Medicine, believing that biochemistry had important contributions to make to all three. Under him the Biochemistry Department at Oxford was a very happy place, and he attached great importance to this. By today's standards it was a small department, in which we all, including the research students, seemed to know each other well, who we were, and what we were doing. No system of seminars was needed for this. We met and discussed casually in chance meetings in corridors, during lulls in the practical classes for students, and at tea, taken jointly with the physiologists. From his earliest days in Oxford, Peters had the strong support of Sir Charles Sherrington and his colleagues, and he needed it, as many of the Oxford chemists in those days had little time for what they regarded as a new-fangled subject. He therefore, quite rightly, fostered a close relationship with the Physiology Laboratory, which resulted in an extraordinarily friendly association between the members of both departments, and nowhere was this more obvious than at tea-times in the old communal library. He believed that physiology—or more generally biology—and biochemistry were so closely linked that to be a good biochemist a background of physiology was essential.

The purely physical and chemical analysis of living matter was not completely satisfying to him. It must be remembered of course that his training had been in physiology and medicine, and he had therefore little direct experience of straight chemistry or of the methods of degradation and synthesis of organic compounds. He was, however, very aware of the need to employ both chemical and physical methods whenever possible. Quite early on he established a room in his department for quantitative microchemical analysis, and arranged for J. R. P. O'Brien to receive instruction in the use of Pregl's methods. The installation of the Svedberg ultracentrifuge was another example of his awareness of the growing usefulness of physical methods in biochemistry, and of the fact that, despite his strong leanings towards and advocacy of the biological
approach, he did not deny opportunities to those members of his staff more physically minded.

Although the practical day-to-day problems of clinical biochemistry held little attraction for him, he persuaded O’Brien to take on the task of establishing biochemistry in the Radcliffe Infirmary, and of acting as a liaison between the Nuffield Departments and the Science Area. But although he was in the habit of visiting O’Brien’s laboratory in the Radcliffe Infirmary on Saturday mornings he never involved himself with the hospital work.

He had also for long been aware of the importance and the potential of microbiology, and he and his colleagues, E. Walker, V. Reader, J. R. P. O’Brien and H. M. Sinclair, studied a variety of problems relating to growth factors for microorganisms. After World War II he arranged for D. D. Woods to join him in Oxford to develop his promising work on the mechanisms of action of anti-bacterial compounds, and he eventually obtained funds to support a Professorial appointment and a laboratory for him and his colleagues—a major achievement in the immediately post-war period with all its shortage of money, materials and labour.

He used regularly to lecture on cell metabolism to second-year and third-year students. His lectures were exciting, delivered with enthusiasm, but not particularly well organized in content. Less good students found them a bit wandering, but better students appreciated them for the ideas that he threw out, and for the historical perspective that they gave of earlier days of the subject, based on his own experience. He liked to present biochemical advances ‘hot from the press’, and would bring into the lecture theatre a stack of journals which a member of his audience would then be asked to put into the epidiascope in order that he might present some figure or table of results. Occasionally he would put on a demonstration for the undergraduates; this would often be a vitamin B₁-deficient pigeon.

The second-year and third-year practical courses were always described in the lecture lists as being supervised by the ‘Professor and Staff’, though he did not take an active part in them himself. But he would usually appear from the door of his private lift and sweep rapidly through the classroom with a word here and there. He was always concerned about ‘the men’ (‘How are the men getting on?’) and took care that all of us on the teaching staff looked after them and gave them proper instruction. He was also largely responsible for the development after World War II of the Honours School of Biochemistry.

It was in 1931 that an unexpected diversion occurred one day in the course of a practical class, when a goat fell through the glass roof of the main teaching laboratory. The surprise caused by the sight of a large and shaggy animal jumping onto the glass roof followed quickly by a shower of broken glass and the spectacle of a fully grown goat falling onto one of the benches below can be imagined. Fortunately no one was hurt, and
least of all the goat which, after a moment's dazed contemplation of the episode, quickly got to its feet none the worse for its experience. The animal had somehow escaped from its house on the roof, and, vaulting over a low wall, had landed on the glass. Peters (1981) described the incident (which was witnessed by one of the present writers) in an article aptly entitled 'The year of the goat'. He tells us that he had been hoping to produce signs of cardiac dysfunction in it by feeding it on a thiamine-deficient diet of 'polished rice and some salt and paper as roughage (it would not eat "The Times", but enjoyed the Oxford paper').

Not only academic staff and students felt and appreciated his fatherly interest, but also the technical staff, many of whom, coming young to the department, remained in it until their retirement. In his research he was particularly fortunate in having had with him for many years a first-class laboratory assistant, R. W. Wakelin. They worked closely together, and Wakelin's technical skills contributed greatly to Peters's achievements in research throughout his years at Oxford.

In those days the Professor was still solely responsible to the university for the running of the department, but he freely consulted his staff and freely delegated responsibility both for teaching and administration, leaving staff members wide discretion with regard to their lectures and to the conduct of experimental classes. Likewise he left his staff entirely free as to their choice of areas of research, though being interested in all of it. Although he could apply a firm hand within the department as well as in its external relations when he felt that vital interests were at stake, he rarely passed a rough word, and his reprimands were mild. He was a kindly and courteous man who ran his department smoothly and competently.

He maintained his interest in music and in his violin throughout his life. He found much enjoyment in playing chamber music with his friends both in Cambridge and in Oxford, including two of his scientific colleagues, Professor Malcolm Dixon, F.R.S., and Sir Ernst Chain, F.R.S. He served for a time on the Faculty Board of Music at Oxford, and was for many years the Chairman of the Caius Musical Society at Cambridge.

He remained active and productive in research until late in 1976 when his eyesight began to fail him. And, as evidence of his physical fitness and mental agility even when over 90 years of age, it should be recorded that he gave an interview at the request of the Biochemical Society, and with the help of the Open University and the B.B.C., in March 1981, lasting more than an hour, during which his recollections over his working life were recorded on tape. We are fortunate to have this record because in it he tells a fascinating story clearly and with humour and understanding.

Peters will be remembered as a wise and distinguished figure in biochemistry and medicine, not only in this country but throughout the world. Elected a Fellow of the Royal Society in 1935 he was a Vice-
President in 1945–46 and again in 1955–56, and received a Royal Medal of the Society in 1949. A knighthood was conferred on him in 1952 in recognition of his many services to science. The many other honours and honorary degrees bestowed on him are listed below. Special reference, however, must be made to the deep interest which he took in the international aspects of science. He played an important part in bringing into existence the International Union of Biochemistry, and was a founder member of the International Brain Research Organization. From 1958 to 1961 he served as President of the International Council of Scientific Unions, a post that gave him much pleasure and that he filled with great distinction and courtesy.

Honours

1917  Military Cross (and Bar)
1935  Fellow of the Royal Society
1951  Hon. Fellow, Gonville and Caius College, Cambridge
1952  Knight Bachelor
1952  Fellow of the Royal College of Physicians
1957  Hon. Fellow, Royal Society of Edinburgh
1958  Hon. Fellow, Trinity College, Oxford
1959  Hon. Fellow, Royal Society of Medicine
1967  Hon. Fellow, Royal College of Pathologists
1946–50  Member, Medical Research Council
1947–50  Member, Military College of Science Advisory Council
1950–53  Member, Science Advisory Council, Ministry of Supply
1952–82  Member of the Governing Body of St Bartholomew’s Hospital Medical College
1965–67  President, Cambridge Philosophical Society

Honorary degrees

M.D., 1950  University of Liège
Hon. Doctorate, 1952  University of Paris
D.Sc., 1953  University of Cincinnati
M.D., 1954  University of Amsterdam
D.Sc., 1954  University of London
D.Sc., 1959  University of Leeds
D.Sc., 1961  Australian National University
LL.D., 1963  University of Glasgow

Medals, prizes and special lectures

1918  Thruston Medal
1947  Medal of Freedom with Silver Palm (U.S.A.)
1949  Royal Medal of Royal Society
1949  Cameron Prize, Edinburgh
1958  Hopkins Memorial Medal, Biochemical Society
1972  British Nutrition Foundation Prize
1929  Harben Lectures, Royal Institute of Public Health and Hygiene
1952  Croonian Lecture, Royal Society
1948  Dixon Memorial Lecture, Royal Society of Medicine
1952  Louis Abrahams Lecture, Royal College of Physicians
Biographical Memoirs

1946–47 Dunham Lectures, Harvard
1947 Herman Leo Loeb Lecture, St Louis University
1947 Christian Herter Lecture, New York University
1951 Harben Lectures, Royal Institute of Public Health and Hygiene
1954 Dohme Lecture, Johns Hopkins University
1958 Hopkins Memorial Lecture, Biochemical Society
1962 Linacre Lecture, Cambridge
1963 Visiting Professor, Dalhousie University, Halifax

Honorary and foreign memberships

Royal Netherlands Academy of Arts and Sciences
Accademia Nazionale dei Lincei, Rome
American Academy of Arts and Sciences
Royal Academy of Medicine, Belgium
Finnish Biochemical Society
Biochemical Society
American Society of Biological Chemists
Physiological Society
Nutrition Society
Association of Physicians
Association of Clinical Biochemists
American Institute of Nutrition
Institute of Medical and Laboratory Technology

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The photograph reproduced was taken by Ramsey & Muspratt.

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An interview for the Biochemical Society, recorded on tape by the Open University BBC Production Centre.

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