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Obituary

Kenneth John Carpenter (1923–2016)

Kenneth Carpenter was an eminent British nutrition scientist whose career, spanning approximately 60 years, was almost equally spent in the UK and the USA. In the UK, from 1946 to 1976, he focused on some of the key nutrition issues of the time, starting with B vitamins, including niacin, folic acid and riboflavin, and moving on to the influence of processing and storage on protein quality. He pioneered the notion of nutrient bioavailability, and the concept that a nutrient can be present in a foodstuff, as measured analytically, but is not absorbed and utilised because it is present in a non-digestible bound form. His research led to the identification of bound niacin in maize and explained why pellagra was common in most but not all maize-eating populations. He identified bound lysine in certain high-protein animal foods and explained why chickens and pigs fed rations based on 'high-lysine' fishmeals, meat meals or milk powder did not grow as well as would be expected. The Carpenter analytical method to measure available lysine in foods based on fluorodinitrobenzene (FDNB) is still a standard laboratory procedure. It has been used extensively in the milk industry to control lysine losses during heat processing so as to ensure the nutritional quality of infant formula and complementary foods.

In the USA from 1977 onwards, Kenneth gradually moved from nutrition research to the history of nutrition as he became more interested in the evolution of ideas in nutrition science. He is credited as making this complex history widely accessible to both serious scholars and the general public through a series of highly acclaimed monographs and papers. In his work, he saw himself as a nutrition scientist rather than historian as he did not, as does the classical historian, use archival records as a source of his information but reviewed early published literature and presented the problem as seen in the publications of the time[1].

Kenneth John Carpenter was born in London in 1923. His father, James, was managing director of a chain of hardware shops and his mother, Dorothy, a teacher. He attended the Merchant Taylor's School in London, leaving in 1941 with an open scholarship to study Natural Sciences at Sidney Sussex College, Cambridge. During those World War years in Cambridge, while completing his studies, Kenneth also took part in military-related work on nerve gases (including being an experimental subject) under the Nobel laureate Edgar Adrian. He also obtained a first in economics as an external student at the University of London, and in 1945 married his first wife Daphne Holmes. Their son, Roger Carpenter, who became Professor of Oculomotor Physiology at Cambridge, sadly passed away 1 year after his father.

Kenneth stayed in Cambridge to complete his PhD under Egon Kodicek at the Dunn Nutritional Laboratory (now the Medical Research Council (MRC) Human Nutrition Research). As was the practice of the day, he used rats to study aspects of B vitamin metabolism including issues related to folic acid, pyridoxine and riboflavin and niacin. The focus became ultimately fixed on niacin in maize and pellagra, a disease associated with populations consuming large quantities of maize and little animal protein. Pellagra was the cause of many deaths in Italy and France in the 19th century, and in the early 20th century reached epidemic proportions in the southern USA, being responsible for more than 100 000 deaths. Pellagra is caused by lack of niacin, obtained from food either directly as the vitamin itself or indirectly from tryptophan that is a precursor of niacin.

What was difficult to explain at the time was why maize, with its apparent adequate level of niacin, caused pellagra. Kenneth's first studies published in the Lancet in 1946[2] investigated the 'pellagragenic' effect of indole-3-acetic acid in rats, the hypothesis being that indole-3-acetic acid, also present in maize, had an antivitamin effect. Needless to say, the hypothesis was wrong and later studies focused on why the Mexicans, who also consumed large quantities of maize and little vegetable protein, did not develop pellagra. The answer was that, in Mexico, before the preparation of tortillas, the maize is first cooked in lime water. This alkaline treatment, unlike boiling in water, releases the bound niacin[3,4] into a form that is bioavailable. Later, rat studies identified bound niacin in other cereals, potatoes and some legumes. In most cereals and peanut flour, all niacin was reported to be bound, whereas in rice and potatoes it was found to be 80 % bound[5]. In a later human study, niacin bioavailability was estimated based on urinary metabolites, and bound niacin in wheat was reported to be 24 % bioavailable[6].

Kenneth's first appointment in 1948 after completing his PhD was as scientific officer at the Rowett Research Institute, Aberdeen, which at that time was mainly concerned with animal nutrition. The focus of his research turned to protein quality and to the relative nutritive value of animal and vegetable proteins in the rations of pigs and poultry[7]. It soon became clear that lysine was the limiting amino acid for animal growth, and that many supposedly high-lysine protein sources such as fishmeal and milk powder were not performing as well as they should. The reason was that the ε-amino group of lysine in these protein sources had combined with other feed components during processing or storage and formed a complex that was resistant to enzymatic digestion[8]. This led to the development of the Carpenter method that measured available lysine by quantifying the free unreacted ε-amino groups in food proteins using the reagent FDNB[9].

After spending a year in Harvard in 1955 as a Kellogg Foundation fellow, Kenneth returned to Cambridge in 1956 as a lecturer at the School of Agriculture. He continued his work with rat and chick assays on protein quality, investigating protein components of animal rations including fishmeals[10], meat meals[11] and groundnut products[12] and then focused more on heat damage to proteins, particularly the decrease in digestibility[13], the loss of available methionine and cysteine[14] and the loss of available lysine[15]. A major achievement was the publication between 1969 and 1977 of a series of eight papers in the *British Journal of Nutrition* investigating the mechanisms of heat damage to proteins. These included papers on the chemical changes in pure proteins[16], the formation of protein cross-linkages that decrease protein digestibility[17] and the reaction of lysine with reducing sugars in Maillard reactions[18].

Kenneth was elected a Fellow of Sidney Sussex College in 1962 and was appointed graduate tutor in 1971. In 1969, together with Egon Kodicek, Kenneth set up a 1-year postgraduate course at Cambridge that was designed to provide a general nutrition education coupled with experience in research[19]. The research project, made in a variety of Cambridge Institutes, could be used as part of a PhD degree. The course lecturers included other well-known nutrition scientists such as Elsie Widdowson, David Southgate, Roger Whitehead and even RA McCance. I joined the course in 1970, and in 1971 Kenneth became my PhD supervisor. His guidance and mentoring during my doctoral and subsequent postdoctoral studies were a strong foundation for my later career. Kenneth was above all a scholar, and a rigorous scientist with intelligence, integrity and a vast nutritional knowledge. He was an excellent teacher, believing that a university education should not only pass on accumulated knowledge but should also teach new generations to think for themselves. He was a caring person who encouraged and enthused others, and worked tirelessly to further nutrition science. Alumni from the Cambridge nutrition course who continued in nutrition research include John Mathers (Newcastle), Jo Hautvast (Wageningen) and Yves Schutz (Lausanne).

Kenneth's life changed radically in 1974, when his wife Daphne died after a long and debilitating illness, during which he had cared for and supported her. In her memory, he commissioned a sculpture of a mother and child that is permanently on display in Sidney Sussex College gardens. The loss of his wife was a major turning point and it precipitated the end to his Cambridge career. In 1976, Kenneth, now a Reader in Nutrition, left Cambridge for a sabbatical year at the University of California, Davis, and in 1977 he was appointed Professor of Experimental Nutrition at the University of California, Berkeley. During his time in California, he met his second wife, Antonina (Nina) Borgman. They married in 1977 and settled in Oakland close to the Berkeley Campus.

In the early years in Berkeley, Kenneth continued with his long-term research interests, especially bioavailable niacin and pellagra, but progressively turned his attention to the history of nutrition, or more specifically to the history of ideas in nutrition, and he also took a large interest in teaching. His most accessible and widely used publications of this period are a four-part series of papers entitled *A Short History of Nutrition Research*[20–23], which provide a valuable summary of 200 years of nutrition research. His major works, however, are three historical monographs. These are as follows: *The History of Scurvy and Vitamin C*[24], *Protein and Energy: A Study of Changing Ideas in Nutrition*[25] and *Beriberi, White Rice, and Vitamin B: A Cause and A Cure*[26]. In these monographs, Kenneth points out how lack of specific nutrients over the centuries caused major social, military and economic consequences, and how uncertainty, competition and contradiction in nutrition research made obtaining scientific 'truth' elusive. It often took a long period of time before consensus was achieved. For example, after the demonstration by James Lind that lemons cured scurvy, it took another 40 years to resolve the inconsistencies in the results so that the Lords of the Admiralty could authorise a daily allowance of lemon juice to the British Navy. Similarly, controversies over the aetiologies of kwashiorkor and marasmus led first to alarm, and to the perception that there was a global protein crisis that could only be solved by providing more high-quality protein sources for complementary foods. This view, however, later became known as 'the great protein fiasco' and protein malnutrition and the search for high-quality proteins largely disappeared from the global research agenda. Finally, I noted that at the beginning of Christian Eijkman's studies on thiamine his first theory was that rice bran contained a toxic substance that prevented the infection thought to cause beriberi. This theory, from a Nobel laureate, was thus similar to Kenneth's first hypothesis that maize contained a toxic substance that prevented niacin from being used. Kenneth received the Atwater medal from the US Department of Agriculture in 1993 for his work on bound niacin, indicating that starting with the wrong idea may have some advantages.

I, and my family, maintained a strong friendship with Kenneth and Nina over the years and visited them several times in Oakland. Kenneth remained a very English gentleman who over time took up some of the more relaxed Californian habits and dress. He had wide-ranging interests other than science. A major hobby was collecting antiques, which he did from a very young age. He had a particular passion for English Delftware, later presenting some of his specimens to the Fitzwilliam Museum in Cambridge. He also enjoyed gardening, tending carefully to his orange and lemon trees, but in later years needing help from students or friends to climb and fertilise the female Kiwi flowers with their male counterparts. He also found time to tutor disadvantaged children from the Oakland area so they could go on to a college education.

Kenneth lost mobility and coordination following an earlier stroke, but he was good company as usual, only complaining that his damaged brain slowed down his thought processes. Kenneth died in Oakland on 13 October 2016 at

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the age of 93. He is survived by his wife Nina, his grandchildren and great grandchildren, and Nina's children and grandchildren.

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