BIOGRAPHICAL MEMOIRS OF FELLOWS OF THE ROYAL SOCIETY

Elsie May Widdowson, C.H. 21 October 1906 – 14 June 2000

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Elected F.R.S. 1976

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INTRODUCTION

I first met Elsie Widdowson in the early 1970s, but it was not until the mid-1980s that I began to take a particular interest in the story behind her remarkable scientific achievements.

I was working at the MRC Dunn Nutrition Unit in Cambridge studying the cold acclimation of newborn animals and trying to relate it to the content and function of brown adipose tissue. Guinea-pigs were my experimental model because I had heard Elsie emphasize, on many occasions, that they were the ideal model for the human baby because their fat contents at birth were roughly similar. What I had not realized was that the friendly animal technician who was looking after my guinea-pigs, Terry Cowen, had been one of the animal technicians trained and cherished in the Department of Experimental Medicine in Cambridge by Elsie Widdowson and her scientific partner of 60 years, Robert McCance, F.R.S. It was Terry who first told me some wonderful stories about Elsie and showed me his own collection of photographs of her.

I was fascinated by the stories but did not take things any further. However, on joining the British Nutrition Foundation in 1988, my meetings with Elsie became more frequent. We lived a mere 12 miles from each other and it was often my pleasure to accompany her home on train journeys from London and to transport her to meetings in Cambridge. Travelling with Elsie was never boring; there was so much to talk about and she had so many stories to tell and views to express. Gradually the idea began to form in my mind—everyone knows the books on the Composition of Foods *by* McCance and Widdowson; why not write a book *about* McCance and Widdowson? I approached Elsie with a certain amount of trepidation; I felt that I might be yet another in a long line of people who had asked the same question. 'Has anyone ever approached you and the Professor to write a book about your work together?' 'Good

Lord, no', she said; 'whoever would want to read a book about us?' 'A lot of people', I thought, but decided not to pursue the subject any more on that occasion.

A few weeks later, I reminded Elsie of our conversation and confessed that I had a very good reason for asking the question. Naturally, she wanted to discuss the idea with Professor McCance, but they were happy to say yes. Their joint biography was published (Ashwell 1993), with unintended stage management on my part, only two days after Elsie's highest accolade—her appointment as a Companion of Honour—was announced.

I have drawn heavily on this story of the joint partnership for this biographical memoir about Elsie, not only because it has enabled me to produce it in (apparently) record time, but because, writing about a perfectionist like Elsie Widdowson, I was keen to make no mistakes in the record of her life and I knew she had checked every word of the joint biography and had (eventually!) been happy with it.

Early years in London, 1906–33

Student life

Elsie's schooldays were spent in southeast London. Zoology was her favourite subject, and she had the idea of taking it for a degree. However, she had a very good chemistry mistress who persuaded her to take chemistry instead. The tradition at the school was for the girls to go to one of the London colleges for women. Encouraged by three girls who were a year ahead of her, and who had gone to Imperial College, London, she decided to do the same. This was a man's world, with three women in her year of about a hundred. She took the BSc examination after two years but had to spend another year at the college before her degree was awarded. She spent this time in the small biochemistry laboratory presided over by Professor S.B. Schryver (F.R.S. 1928)—Sammy Schryver, as he was generally known.

Early research on apples

Everybody in the laboratory was separating amino acids extracted from various plant and animal materials. This was long before the days of chromatography, and they all worked on a vast scale, starting with bucketfuls, rather than beakers, of material.

Towards the end of the year an emissary from the Department of Plant Physiology came over to find Elsie. Rumour had reached them that she might be looking for a job. A grant was available in the department, and if she was interested, would she go for an interview? Elsie was interested, she went, and the result was that she worked there for over three years with Helen Archbold (later Helen Porter; F.R.S. 1956), who was in charge of a long series of experiments for the government on the chemistry and physiology of apples.

Elsie's part in the investigations was to separate and measure the changes in the individual carbohydrates in the fruit from the time it first set on the tree until it ripened, and then during storage. It was her responsibility to go by train every two weeks to Kent, then walk to an orchard to pick fruit from specified apple trees and bring them back to the laboratory for the various studies that were being made. She developed a method for separating and measuring the starch, hemicelluloses, sucrose, fructose and glucose in the fruit, and the first paper she ever published on the determination of reducing sugars in the apple appeared in the *Biochemical Journal* in 1931. She little realized how momentous this was going to be for the whole of her scientific life.

All this time Elsie worked under the guidance of Helen Archbold, who was always available to help and advise her, and Helen initiated her into the art of writing up the results for publication. She undoubtedly gave Elsie her lifelong love of research and she was able to use her work for a PhD.

At the end of the three and a half years the grant ran out and in any case, much as she enjoyed her time with apples, Elsie did not want to devote her life to plants. She was really more interested in animals and humans. So in 1932 she went to the Courtauld Institute at the Middlesex Hospital for a year or so, under Professor E.C. (later Sir Edward) Dodds, F.R.S., to get some experience in human biochemistry. One paper came out of that period, a comparative investigation of urine and serum proteins in nephritis. She was quite startled, but gratified, to later see this little effort of hers referred to as 'the pioneer work on the subject'.

King's College Hospital, London, 1933–38

First meeting with McCance

In 1933 Elsie was faced with finding a job, and research jobs were at that time difficult to come by. She went for several interviews but nobody wanted her. Professor Dodds told her that dietetics was an up-and-coming profession, and, on his advice, she enrolled for the first one-year postgraduate diploma course in dietetics at King's College of Household and Social Science under Professor V.H. Mottram.

As a preliminary to this course she was sent to work in the main kitchen at King's College Hospital to learn something about large-scale cooking. While she was there she often saw Dr McCance come into the kitchen and bring joints of meat to be cooked. She was told that he was doing research on cooking. Naturally she was interested, and one day she plucked up courage and spoke to him. He invited her to visit his tiny laboratory, where he told her about the work he was doing on the composition of meat and fish and their losses on cooking, and about his previous study on the available carbohydrate of foods. This had been published in 1929 as an MRC *Special Report*. It contained information about the reducing sugars present after acid hydrolysis in fruits, vegetables and nuts. Elsie at once realized, from her experience with apples, that the figures for carbohydrate in fruit were too low, because some of the fructose must have been destroyed during the acid hydrolysis. She told Dr McCance this, and the outcome was that he invited her to join him. He obtained a grant for her from the Medical Research Council—it was much easier to do this then than it is now—and they started another study on the composition of fruits, vegetables and nuts which included water, nitrogen, fat and inorganic constituents as well as carbohydrate. Where appropriate the foods were analysed both cooked and raw.

Elsie finished the Dietetics Diploma course, and that served her well in two ways. In the first place, it aroused her interest in nutrition. Second, as part of the course, she spent six weeks in the diet kitchen at St Bartholomew's Hospital (Bart's) with Margery Abrahams. She should really have spent six months there, but those six weeks were long enough to convince her that they badly needed comprehensive tables showing the composition of British foods. The composition of patients' diets was being calculated from American tables, which gave values only for raw foods. What was more, the carbohydrate fraction had not been determined directly but calculated 'by difference', that is what was left after deducting water, protein and fat from the total weight. It thus included everything that we now know as 'dietary fibre'.

British food tables

Elsie thought a lot about the need for British food tables, and one Saturday afternoon in 1934, while she was on a family outing to Box Hill, a beauty spot in Surrey, the idea came to her that meat, fish, fruit and vegetables would soon be completely analysed, so there only remained cereal foods, dairy products and some miscellaneous items such as beverages and sweets. If these were also analysed, she and McCance would have all the material available for making a practical set of tables showing the composition of British foods. She put the idea to Dr McCance the following Monday morning. He was willing, and this is how *The chemical composition of foods* came be to conceived and born. The first edition was published in 1940. All the values were checked and rechecked many times over. There were about 15 000 separate values in the tables and it was almost impossible not to let a mistake slip in here and there. For example, the decimal point slipped in the figure for nitrogen in blackcurrants, so that it was ten times too high. They never heard the end of that. Elsie sometimes thought that, of all the various aspects of nutrition she had dabbled in over the past 60 years, her first venture, on the composition of foods, would be the longest lasting.

Salt deficiency in humans

A highly productive period followed. Diabetics, particularly those in coma, provided McCance with many problems, one being that their urine contained no chloride. This observation led to his experimental and quantitative study on salt deficiency in humans, which involved making a number of subjects salt deficient. This was really rather a Herculean task, for it involved persuading healthy young men and women to eat a salt-free diet and to lie and sweat in a hot air bath for two hours a day for 14 days.

The subjects lay on a red plastic sheet inside the warmed-up apparatus for two hours every afternoon, keeping their temperatures between 100 and 101 °F. The amount of salt that they lost was measured by washing both them and the sheet down with a jet of distilled water after each session (figure 1), and analysing the washings; their water loss was measured by their loss of weight. Then, when they were salt deficient, they had to submit to a variety of tests, in particular of their renal function.

Elsie was roped in to help with these experiments and she admitted that they added considerable light relief to the food analysis and dietary calculations. These experiments have helped doctors to understand the important role of fluids and sodium. Today, maintaining fluid and chemical balance is a standard part of the treatment of patients with diabetic coma, kidney disorder and heart attacks, and of those who experience episodes of severe vomiting and fever, as well as the treatment of patients after surgery.

Absorption and excretion of iron

In about 1934, McCance was allowed some beds for patients in King's College Hospital and began admitting those who presented problems. One in particular had polycythaemia rubra vera. This lady, although she never know it, played a large part in the future of McCance and Widdowson. They treated her with acetyl phenylhydrazine and by so doing broke down enough red blood cells to liberate 5 grams of iron in her body. To their intense surprise none of it was excreted. McCance and Widdowson then injected iron intravenously into themselves and colleagues (figure 2), and they did not excrete the iron either. This led them to suggest that the amount of iron in the body must be regulated, not by excretion, but by controlled intestinal absorption. More sophisticated studies have since shown this to be true.

Figure 1. Elsie washing down a subject to collect sweated salt in the experiments on salt depletion in 1934. These experiments have helped us to understand the importance of maintaining fluid and chemical balance with practical applications in many fields, including heat exhaustion, diabetic coma and infantile gastro-enteritis. (Reproduced with kind permission from the British Nutrition Foundation.)

Renal function

For many years McCance and Widdowson were busy measuring various aspects of renal function in newborn humans and animals, and comparing them with those of adults of the same species. Whatever test and method of comparison was used, for example body weight or surface area, the newborn always seemed to have very inefficient kidneys. Its ability to excrete nitrogen, electrolytes and phosphorus was low in all the species they studied.

This in itself was a discovery at the time, but they were always worried that this did not make physiological sense, because the animals and infants were healthy. They grew well, and the composition of their body fluids remained normal. It took McCance and Widdowson a long time to realize what by hindsight is obvious: that the newborn does not need to have kidneys as efficient at excreting nitrogen and mineral salts as an adult, because so much of the intake of those substances is used for growth that they do not reach the kidney for excretion. As soon as they realized the importance of growth, rather than the kidneys, in maintaining a stable volume and composition of the body fluids, everything fell into place.

Figure 2. Elsie injecting herself with solutions of calcium, magnesium and iron in 1934. This led to an understanding of mineral metabolism and also to the proof that iron in the body must be regulated, not by excretion, but by controlled absorption. (Reproduced with kind permission from the British Nutrition Foundation.)

A visit to the USA

Elsie kept in touch with Margery Abrahams after she left Bart's, and in fact they wrote a book together, *Modern dietary treatment*, first published in 1937. In 1936 Abrahams persuaded Elsie to go to America, where the profession of dietetics had started and where she herself had been trained. So Elsie crossed the Atlantic on the *Aquitania*, which was quite an adventure for her, and she travelled to Washington to visit Charlotte Chatfield and Georgian Adams at the United States Department of Agriculture in Washington. They were responsible for the tables of food composition then in use in both the USA and Britain until the British tables were published in 1940. Elsie remembered discussing with Miss Chatfield whether it was better for compilers such as Chatfield to prepare tables from the published work of others, in this case that of Atwater, dating from 1900, or for people such as Elsie herself, who had analysed the foods, to make the tables. Elsie was in her twenties at the time and very much Miss Chatfield's junior. Chatfield was a rather forceful person and thought she had won the argument, but she did not convince Elsie Widdowson!

Diets of individuals

Because McCance and Widdowson had so much information about food composition, they were in a strong position to calculate the intakes of energy and nutrients by men, women and children. Up to the 1930s almost all dietary surveys had been made on families. The family was assigned a 'man-value', based on the sum of the supposed energy needs of each individual within it. The intake of the family was divided by the 'man-value', and this was then compared with the existing tables of requirements. This was obviously unsatisfactory. They clearly needed information about the intakes of individuals, and so Elsie started her individual dietary surveys, first on 63 men and 63 women, and she followed this up with the measurement of individual dietary intakes over a period of a week, of more than 1000 children aged between 1 and 18 years. These surveys brought out very clearly the large variation in the intake of energy and nutrients between one individual and another of the same sex and age.

Department of Medicine, Cambridge, 1938–46

Self-experimentation

The publication of the paper on iron absorption led to an invitation to McCance to become a Reader of Medicine in Cambridge. He asked the Medical Research Council to agree to his taking Elsie with him so that their joint work was not interrupted. So in 1938, during the Munich crisis, McCance and Widdowson moved to Cambridge.

They had what they later referred to as a ‘a slight accident’ during their first year in Cambridge, when they were studying the absorption and excretion of strontium, one of the so-called ‘trace elements’, chemicals that exist in minute amounts in the body. The element had been used medicinally for a long time for a variety of disorders, but although an understanding of how it is excreted is fundamental to its proper use in medicine, few studies had been made. Elsie designed an experiment to determine how the element was excreted from the body. They would inject strontium into each other’s veins each day for a week and then measure the amount in their stools and urine. They started on a Monday with McCance injecting strontium lactate into a vein in Elsie’s arm. Nothing happened after 24 hours, so they decided to double the dose. On Tuesday, McCance took his first dose. For the next five days they carried out their scheme without problems. But by Friday, they had used up the entire original batch and had to sterilize some more strontium lactate from the original solution.

At eleven on Saturday morning, the sixth day of the experiment, they injected the prescribed dose into each other’s arms. They had become overconfident, one of the biggest hazards of self-experimentation. During the week, someone had always stood by, but because nothing had happened they performed this extension of the experiment alone. Less than an hour later they began to feel ill. They suffered intense headaches and teeth-chattering rigors. Their backs and thighs hurt. They felt dreadful and did not know what had gone wrong, so they were apprehensive.

Fortunately, someone came by and called John Ryle, the Regius Professor, who rushed to the laboratory. After realizing that their lives were not in immediate danger, Ryle took Elsie and McCance home with him, where he and his wife could look after them. By this time about four hours had passed, and both of them had developed fevers of *ca.* 102 °F. Despite feeling ill, they still managed to collect the samples they needed. Later analysis showed that substances known as pyrogens, also called endotoxins, due to bacterial contamination, were present in the second batch of strontium. McCance and Widdowson had suffered a pyrogen reaction, which occurred much more commonly then than now because purification techniques were then cruder.

They recovered quickly but gave themselves no further injections of strontium. The results of this experiment showed that the body rids itself of strontium slowly and that 90% of the excretion is through the kidney, not the bowel.

An experimental study of rationing

As soon as World War II began, Elsie and McCance felt they must do something to further the war effort, so they started an experimental study of rationing. They used themselves and their colleagues as subjects to see how far food produced in Britain could meet the needs of the population and enable them to fare well, and hence how much shipping could be saved. Their allowances of milk, meat, eggs and other good things were so small that they were considered intolerable by their critics. Their total allowances per person per week were 4 ounces of fat, 5 ounces of sugar, including sugar in jam and marmalade, one egg, 4 ounces of cheese and 16 ounces of meat and fish combined. Six ounces of home-grown fruit a week was allowed, but wholemeal bread and vegetables including potatoes, were unrationed. The milk ration, their main source of calcium, was 35 fluid ounces a week, or a quarter of a pint a day. They realized that even with four ounces of cheese a week, their calcium intakes were likely to be very low, so they took the precaution of adding chalk to the flour used for the bread in these and subsequent experiments.

After three months they felt so strong that they decided to go the Lake District to test their physical fitness. Just after Christmas, McCance and a colleague started by cycling to Langdale against a northerly wind. They got there in two and a half days, the latter half of the distance over snowy roads. The rest of the party came up in Elsie's car, bringing a lot of food with them, including the flour, which they got baked into bread locally. They made many expeditions. McCance's longest day in that fortnight was the one he had with Andrew (later Sir Andrew) Huxley (F.R.S. 1955; P.R.S. 1980–85), who went on to become a Nobel Prize winner. They covered 36 miles, with 7000 feet of up and down in it, and they did it at an average speed of $3–3\frac{1}{2}$ miles per hour, including stops. These were not records, but they were enough to show that they were fit, and that their rations had served them well.

Absorption of calcium from breads made from flours of different extraction rates

After they had finished their experimental study of rationing, Elsie and McCance came to the conclusion that the population of Great Britain would not get as much calcium as it needed if milk and cheese were to be severely rationed and people had to give up their beloved white bread and take to bread of high extraction. They believed that the wholemeal breads interfered to some extent with the absorption of calcium.

They decided to put this to the test, and this led to a long series of balance experiments in which they set out to measure all the calcium and other minerals that went into and came out of the body. For this sort of work great accuracy was needed because they were measuring a small difference (absorption) between two large numbers (intake and faecal excretion). Everything that the volunteers ate (figure 3) had to be weighed and measured separately, and an exactly similar but smaller portion set aside for analysis; and all excreta had to be collected. This sounds easy but it was not, for if they wanted any lunch while at a meeting in London, this meant that sandwiches had to be prepared beforehand and duplicates taken for analysis; if they wanted anything to wash it down with, a bottle of distilled water or other liquid was required as well.

This was not the end, however, for the men needed to take a bottle for urine and the women needed a filter funnel as well. Staying a night away meant a bowl with a cover of some sort and there were no plastic wrappings in 1940!

Ten subjects took part in the experiment. Each experimental period lasted three or four weeks, and the whole study with the ancillary experiments lasted nine months. In each exper-

Figure 3. Elsie (centre) and McCance (on Elsie's right) with members of their staff in Cambridge enjoying a meal as part of the study to determine the mineral metabolism of healthy adults on white and brown bread diets (*ca.* 1940). One of the main outcomes was the mandatory fortification of bread with calcium. (Reproduced with kind permission from the British Nutrition Foundation.)

iment, 40–50% of the energy was provided by the flour under study at the time. The main conclusions were that there was something in brown, i.e. high extraction, flours that interfered with calcium absorption by the gut. This was not due to the laxative properties, although these were considerable, but to a phosphorus compound, phytic acid, which formed an insoluble salt with calcium in the small intestine. Vitamin D did not improve the absorption, but fortifying the flour with calcium carbonate or phosphate did.

Elsie and McCance recommended therefore that to every 100 g of 69% extraction white flour, 65 mg of calcium should be added; to every 100 g of National, 85% wheatmeal flour, 120 mg of calcium; and to every 100 g of wholemeal flour of 92% extraction, 200 mg of calcium.

On the basis of these experiments calcium was by law added to the 85% flour used for making bread at the time, but wholemeal, which most needed the calcium to ensure that enough calcium was absorbed for the body's needs, was not fortified. This was in deference to the pure-food enthusiasts. No sooner was the proposal made to add calcium than it was bitterly opposed. It was said to be causing stones in the kidneys and hardening of the arteries even before it had been added. A man called Isaac Harris, who wrote a booklet called 'The calcium bread scandal', was particularly vociferous. However, the fortification became statutory and the fuss over it died down. When eventually, in the early 1950s, the loaf made from white flour came into being again, it was decided to continue to fortify it with calcium carbonate.

Ever since, when the flour and bread regulations have come up for review, it has been decided to continue the fortification. In 1974, this was again the recommendation, but it was made in a rather less positive way, 'we therefore, do not recommend that chalk be no longer added flour'. So, in accordance with the double negative, we still have calcium carbonate added to our flour, although all the reasons for adding it in the first place have gone and supplies of milk and cheese are unlimited.

Elsie's work on the effect of high-extraction flour on the absorption of calcium brought her a minor adventure during the war in the shape of a trip to Dublin. Owing to a shortage of wheat, 100% wholemeal flour was being used for bread-making, and the incidence of rickets started to increase in the cities in Eire. McCance and Widdowson were invited to Dublin to describe their studies to a group of doctors and politicians, including the Taoiseach, Mr De Valera. As a result it was decided to lower the extraction rate of the flour used for bread-making in Eire, and later to add calcium phosphate to it; the incidence of rickets in children over one year old decreased.

Composition of the human body

Elsie next turned her attention to another use of the analytical experience that she had gained during her years of food analysis: the composition of the human body. This was a more difficult problem than food analysis. She managed to overcome the difficulties that she had in obtaining bodies or dealing with them once she had obtained them, and she started the work. Then the war ended and she changed course completely, for in the spring of 1946 McCance and Widdowson went to Germany to study the effects of undernutrition on men, women and children.

Studies in Wuppertal, Germany, 1946–49

Breads, white and brown

Elsie had intended to stay in Germany for six months, but in the end she stayed for nearly three years. This came about because in December 1946, while she was home on leave, Sir Edward Mellanby, F.R.S., called a meeting to discuss the postwar loaf. Up to that time there had been no question in the minds of nutritionists that high-extraction flour was more nutritious than white, but here was a question as to whether white flour could be made as nutritious as wholemeal by adding to it the B vitamins and iron. At the meeting Mellanby said to Elsie, 'There must be a lot of hungry children in Germany. You go and find out the truth about all this.'

Elsie returned to Germany at the beginning of January; she drove about in deep snow looking for a suitable orphanage where they could feed children on different kinds of bread. She found one in Duisburg, about 30 miles from Wuppertal, where they had their headquarters. The children, aged between 5 and 14, were below normal height and underweight at the outset. They gained height and weight equally rapidly on bread made from all five types of flour, 100% (wholemeal), 85% and 72% extraction (white), and white enriched with B vitamins and iron to the amounts in 100% and 85% extraction flours. All the flours contained added calcium carbonate. Bread provided 75% of the energy and the diets contained only 8 g of protein from animal sources a day. The experiment lasted for 18 months; the children improved physically and it was impossible for the outsider to tell which kind of bread the child was eating. During the latter part of the experiment the British Medical Association held its annual conference in Cambridge, and Elsie brought five of the girls, one from each group, from Wuppertal to Cambridge, so that the members of the audience could see for themselves the results she was describing. This was typical of Elsie, and the girls thought it was a tremendous adventure.

The importance of tender, loving care

While they were in Germany, Elsie made nutritional studies in several orphanages. Food was severely rationed and the children were somewhat undernourished but not exceptionally so. They weighed and measured the children regularly in two orphanages for six months while they lived on their German rations. They had planned at the end of this time to provide unlimited bread, with some margarine and jam to spread on it, to the children in one home (A), while nothing extra was to be given to the children in the other. At the end of six months, the second home (B) would get extra food.

Elsie found that during the first six months, when no extra food was supplied, the children in home A were growing faster in height and weight than those in home B. It so happened that they had chosen home A to receive the extra food, and they had to go on with their plan. To her astonishment the children in home A, who had originally grown faster and now received the extra food, immediately began to grow more slowly, whereas those in home B began to grow rapidly in weight and height, although they had nothing but their German rations.

What could the explanation be? Did extra food actually hinder growth? This seemed to be too absurd to consider. Did the children in home A eat the extra food? They did. A dietitian supervised their meals all the time. Did the children eat the same amounts of their German rations in the two homes? They did. Was there some noxious agent that somehow moved from one home to the other just when they began to give the extra food? There was.

It so happened that the housemother who presided over home B during the first six months was moved by the authorities to home A just when they began to give the extra food to home A. Thanks to the smartness of her research nurse, Elsie discovered that the housemother was a most unpleasant woman and very unkind to the children. Her unkindness towards, and the unhappiness of, the children were sufficient to delay their growth in spite of the extra food.

Later, Elsie wrote, ‘Tender loving care of children and careful handling of animals may make all the difference to the successful outcome of a carefully planned experiment’. Others have since commented that love must be the best diet.

Back to the Department of Medicine, Cambridge, 1949–68

Body composition

Elsie left Germany in January 1949, and returned to the work she had begun four years earlier on the composition of the body. She approached this in two ways. The first was to study the effect of growth and development on body composition, and she analysed the bodies of 19 human foetuses and still-born babies, of one four-year-old boy, and of three men and one woman. She measured the amounts of the same constituents as they had done in the foods.

Elsie always had a great interest in the similarities and differences between species, and her second approach to body composition, which was really an extension of the first, was to study changes in composition during the development of other species. She included pigs, cats, guinea-pigs, rabbits, rats and mice in the investigations. As a result of all this work, she was able to establish some general principles, and also some important species differences, which were linked with the state of maturity that the young of each species reaches when it is born. The human infant is exceptional in having 16% of fat in its body at birth, whereas most species have only 1–2%. The guinea-pig, however, has *ca*. 10%, and one newborn grey seal, which they found dead on a beach in Scotland, and which Elsie brought to Cambridge in the boot of her car, had 9%. Fat was the great variable in the newborn as well as the adult, and it was essential to express the amounts of the other constituents per unit weight of fat-free body tissue to get a true picture of chemical development before and after birth.

In the early 1950s John Dickerson and David Southgate joined the team and stayed with McCance and Widdowson for many happy years. David's first job was to help with the preparation of the third edition of *The composition of foods*. Elsie was very pleased, later, to entrust the fourth edition entirely to him and to Alison Paul. The fifth edition, published in 1991, involved a much larger team.

Energy intakes and expenditures

John Dickerson extended the earlier work on the composition of the body to the separate organs and tissues, but soon after he arrived he went with McCance and Widdowson on their adventure at Sandhurst. Dr Otto Edholm told them that the General who had recently inspected the cadets, aged $18^1/_2$ to 20, was convinced that they were not gaining weight as they should, and that this was because they were not getting enough 'good red meat'. They agreed to collaborate with Dr Edholm in an investigation of the food intakes and energy expenditures of the cadets.

In fact, they found that the cadets got a large ration of meat, which they ate. The total energy from the food supplied amounted to 3714 kCal d^{-1} (15 539 kJ d^{-1}) but the cadets ate only 68% of this, and most of the missing 32% was accounted for by uneaten bread. The cadets preferred to go to the canteen and buy cakes and pastries providing almost the same amount of energy as would have been supplied by the bread they did not eat. More interesting perhaps to Elsie were the discoveries about the energy expenditure of the cadets. She had been led to believe that the cadets lived lives of ceaseless strenuous activity. In fact she found that they spent $8^1/_2$ hours out of the 24 in bed, $9^1/_4$ hours sitting—some of it at lectures—and these two together accounted for 50% of their total energy expenditure. Dressing, cleaning uniforms and getting about the grounds accounted for another 28%, and drill, sport and parades, which were regarded as so important in their training, took up only 7% of the time and 12% of the energy.

Small and large litters and nutritional manipulation

It was in the 1950s that Gordon Kennedy introduced Elsie to the idea of rearing rats in large and small groups. If two litters of rats born on the same day are mixed and three are returned to one mother and the remainder (16–20) to the second, those suckled in the small group get more milk per rat and grow faster than those in the large group, so that by weaning at three weeks they are two to three times as heavy. Elsie confirmed Kennedy's observation that, even though all the rats had access to unlimited food from weaning onwards, those that were small at weaning remained small, and showed no sign of the catch-up growth so characteristic of rehabilitation after undernutrition at older ages. Elsie used these large- and small-litter rats for a variety of studies, and since that time they have been used by investigators all round the world.

Elsie's studies on severely undernourished pigs arose out of her work in Germany, and were possible because McCance had facilities at his home in Cambridgeshire for keeping pigs. These pigs became an important part of their lives for about 15 years. They found that they could undernourish them so severely from 10 days of age that by one year they weighed only 3% as much as their well-nourished littermates. This was, Elsie believed, the most severe growth retardation that has ever been produced and was only possible because the difference between the weight of a newborn pig and an adult is so large. Elsie and McCance made many studies on these animals: anatomical, physiological, chemical and psychological.

In 1966, McCance went to Uganda for two years and Elsie became more adventurous. She continued the undernutrition for two and three years before she rehabilitated the pigs. They had to be allowed to gain weight very slowly all the time, for if they lost weight they died. When the animals were rehabilitated after one, two or three years, they ate a great deal of food and gained weight rapidly for a time, but the longer they had been undernourished the sooner they stopped growing, and the final weight of those rehabilitated after three years, the age at which the normal pig stops growing, was only half that of pigs well-nourished throughout. In spite of this they matured sexually, and when rehabilitated males and females were mated, the females produced good litters with normal sized piglets which they suckled satisfactorily, and these piglets bore no mark of the nutritional adventures that their parents had undergone.

Head of the Infant Nutrition Research Division at the Dunn Nutrition Laboratory, 1968–73

Studies on adipose tissue

In 1968 Elsie moved to the Medical Research Council's Dunn Nutrition Laboratory, as head of the Infant Nutrition Research Division. She became involved in the planning of a session on infant feeding for a conference and it was this that inspired her to analyse infant milks on sale in different European countries. In the course of this she discovered that a Dutch formula, used for nearly all babies in Holland who were not breast fed, had all the cows' milk fat replaced with maize oil. This had 60% of its total fatty acids as linoleic acid, compared with 1% in cows' milk fat, or even 8% in the fat of breast milk. This made her wonder what was happening to the fatty acid composition of the fat of babies living on it.

Elsie investigated this and found that it was indeed having a remarkable effect. In three months the linoleic acid in the body fat of the Dutch infants had risen to 46% of the total, whereas in the artificially fed British infants who were having cows' milk fat it remained at *ca.* 1%. In breast-fed infants linoleic acid contributed 3–4% to the total. These results are expressed as a percentage of the total fatty acids, but to understand the magnitude of the difference between the composition of the bodies of Dutch and British babies brought about by the kind of fat in the milk they receive one has to remember that by three or four months 25% of the baby's weight can consist of fat. If this fat has 40% linoleic acid in it, then 10% of the weight of the baby fed on the Dutch infant food will consist of this one polyunsaturated fatty acid. The corresponding figure for breast-fed babies was less than 1%. So the body composition of babies had been altered on a national scale in a remarkable way. The question was, did this matter? Are the Dutch people any better or worse off for having had such a highly unsaturated body fat in infancy? The composition of the depot fat might not matter very much, but what about the other lipids of the body?

Elsie had to go to animal experiments to look into this further. She used guinea-pigs because the guinea-pig is one of the few small mammals that deposits fat in its adipose tissues before birth. She fed a group of pregnant guinea-pigs on a diet containing maize oil, and therefore much linoleic acid, and another group on the same basic diet with beef dripping, which had very little linoleic acid in it. At birth the body fat of the young of the maize oil mothers was similar in fatty acid composition to that of the Dutch infants, whereas the fat in the young of the mothers fed with beef dripping was like that of British infants. She then looked at the fatty acid composition of the phospholipid fractions of red blood cells, muscle and liver and found that they were also very different. Not only was this so, but the myelin in all parts of the brain was affected by the nature of the dietary fat consumed by the mother during pregnancy. The lipids of the brain are not immutable but can be altered quite readily at the time when myelination is proceeding rapidly. Although much of the myelination of the human brain has occurred before birth, it continues for some time afterwards, and Elsie always vowed that if she were able to have another adventure in nutrition, she would use this ready-made experiment to look further at the implications of feeding such very different fats in infancy.

Pigs

Elsie still had pigs available in the late 1960s and early 1970s and she turned her attention to two other aspects of nutrition and early development, for both of which the pig was a particularly suitable experimental animal. The first was the effect of slow growth before birth and a small size at full term on subsequent growth and development. When a sow has a large litter there is sometimes one, the runt, that weighs only one-third as much as its littermates because it was undernourished before birth. Elsie investigated the physiological and chemical development at birth compared with that of the larger littermates and followed growth to maturity. The pig born small never caught up in weight.

The second study concerned the effects on the digestive tract of the newborn pig of its first experience of food by mouth. Some members of a litter were removed from the sow before they had suckled and they received only water by stomach tube for 24 hours. Others in the litter were allowed to suckle. The digestive tract of those having colostrum grew very rapidly both in weight and length, far more rapidly than any other part of the body. Elsie suggested that this was related to the absorption of γ-globulins just after birth; this has since been shown to be true.

Department of Investigative Medicine at Addenbrooke's Hospital, 1973–88

In 1973 Elsie retired for the first time. She moved to the Department of Investigative Medicine at Addenbrooke's Hospital. This department was the successor to Professor McCance's Department of Experimental Medicine, because the hospital had always disliked the word 'experimental'. The authorities there had never heard of Claude Bernard! For a time she had laboratory accommodation and some PhD students, and even when laboratory space was no longer available she still had an office that Professor Ivor Mills allowed her to keep until he retired in 1988. Elsie then retired for the second time.

Bigger animals

In 1986 Elsie went to Washington, DC, for a few weeks to work in the Nutrition Laboratory at the Zoo. It came about in this way. In 1975 she was invited to Cornell University to lecture. Her plane to New York was delayed, she missed the connection to Ithaca, and she finally arrived there at midnight one snowy winter's night. She was afraid there would be no one to meet her, and she did not know where she was staying. But there stood a solitary figure, a young man, who greeted her by telling her she was the only person in the world who would understand what he was doing for his PhD. His name was Olav Oftedal. He was collecting information about the composition of the milk of all the species whose milk had been analysed, and he was filling in the gaps by analysis where possible. They remained lifelong friends.

In 1984, Olav and two colleagues mounted an expedition to the pack-ice off Labrador to measure the milk intake and milk composition of two species of seals born and suckled on the pack-ice. One of the species, the hooded seal, doubles its birth weight of 20 kg in four days on a milk containing 60% fat, of which it takes 10 kg a day. The mother then leaves it and goes back to the sea. Olav had brought to Washington 20 frozen bodies of newborn and suckled seals, killed in accordance with the Canadian Sealing Regulations. These bodies remained in the cold store at the zoo for two years, along with the bodies of newborn and suckled black bears, born and suckled while their mothers were 'hibernating' and taking no food or drink for four months. Elsie visited Olav several times during those two years. Each time he took her to the cold store to view the frozen bodies, and she realized that nothing was going to be done with them unless she lent a hand. So she offered to go and help.

Elsie got a grant from the Smithsonian Institution, the laboratory was cleared of all other work, and they had a hectic few weeks dissecting the animals, weighing and measuring the various parts of the body and preparing the material for analysis. This was rather a complicated job, wrapping up and labelling the various parts of the body from so many animals. Elsie thoroughly enjoyed being associated with it all, and getting her hands, or rather rubber gloves, dirty again. A paper describing this study was published, and another, on the nutrition and growth of suckling black bears, appeared later. This work gave Elsie many new problems to think about in comparative nutrition.

Active retirement, 1985–2000

After she 'retired' from her 'day job' in the 1980s Elsie took on many responsibilities, notably the presidency of the British Nutrition Foundation from 1986 to 1996, chairmanship or lead position in several national and international committees, and the presidency of the Nutrition Society and the Neonatal Society. She was fêted, especially in America (the one other place in the world that she might have considered working), where she was a distinguished visitor to many universities; and her association with the Children's Nutrition Research Centre at Baylor College of Medicine in Houston, Texas, was particularly important to her. A new Medical Research Council Unit for Human Nutrition Research was established in Cambridge in 1998 and, much to Elsie's great delight, it was named the Elsie Widdowson Laboratory. In 2000 the new Food Standards Agency was set up in London, and the library in their new building was named after Elsie too. Both these places have permanent exhibitions about Elsie, including many of her original papers.

For Elsie, the pinnacle of her achievement was reached when, in 1993, she became a Companion of Honour (figure 4). With her usual modesty, she could not understand why she had been selected for this singular honour, although she was utterly delighted to receive it.

Figure 4. Elsie at the award of her Companionship of Honour at Buckingham Palace in November 1993. Left to right: Dr Margaret Ashwell, Dr Elsie Widdowson, Dr Eva Crane (*née* Widdowson) and Dr Dorothy Rosenthal. (Reproduced with kind permission from the British Nutrition Foundation.)

Personal recollections

What do I remember most about Elsie? First there was no 'otherworldliness' about Elsie Widdowson. Once, after she had heard the chairman's perfectly accurate introduction before her giving a very distinguished lecture at the American Dietitians' Annual Conference in Washington, her retort was 'Well, you can take all that with a pinch of salt'. In her lifetime of research, Elsie saw the wheel reinvented many times over, but she always retained her humility, her intuition, her sense of excitement for discovery and debate, evaluating and fitting each new piece of the jigsaw into its appointed place with immense delight.

Second, I was fascinated by the fact that she never stopped experimenting—even in her nineties. I once walked through an airport metal detector and looked round to see where my companion, Elsie, had got to. Eventually she reappeared. 'That's better', she said; 'I did the experiment and now I know the answer'. 'Answer to what?' I enquired. 'Why you can walk through with no difficulty, yet I always set the alarms ringing', she said. 'I've decided there could only be three explanations. It's either my hearing aid, my hairpins or my suspenders. So I did the experiment and I went through again without my hearing aid.' 'And did it help?' 'Yes', she said, 'it removed 90% of the noise.' There was a certain flawed logic here, but I knew how happy she was to solve something by 'doing' the experiment.

The third virtue that shone through was the care that Elsie took to do her homework before she went to speak to any group of people and how she tried to personalize her presentations to any group of people. A teacher friend of mine once asked if Elsie would spare the time to speak to the Sixth Form at his school. I only mentioned the name of the school to Elsie a few days before we went. It was a co-educational boarding school that prides itself on its strict vegetarian lifestyle, and I thought I had better warn Elsie that she would be certain to get some questions about vegetarianism. 'The name of that school rings a bell', she said. 'I think it was one of the schools that we went to when we were studying the children's diets back in the 1940s.' When the day of the visit came Elsie delighted the children by showing them a graph proving that their counterparts in the 1940s had eaten between 1 and 2 ounces of meat a day which was only just less than the national average!

Last but not least, Elsie loved encouraging young people. Her thatched-cottage garden beside the Cam at Barrington was a haven of tranquillity, replete with several pet cats, an extensive apple orchard and a vegetable garden—the latter providing practical nourishment for her many visitors, who would always be greeted as if they were the most important person in the world.

To some, Elsie presented a supremely competent, professional, commonsensical and wise woman whose incisive mind could always dissect out the essential elements of an issue. For others she was a smiling granny figure wielding her enormous influence across the world of science in a quiet, modest and unassuming way, with a twinkle in her eye and amusement in her voice. For others again she was a practical countrywoman, happy with her vegetables and fruit trees in her beloved garden or listening on the radio to *The Archers* or to Alistair Cooke's *Letter from America*, whose easy, uncomplicated style she greatly admired and shared.

What advice would Elsie Widdowson give to a young scientist? This is the thought I believe she would most like me to leave with you:

> If your results don't make physiological sense, think and think again! You may have made a mistake (in which case own up to it) or you may have made a discovery. Above all, treasure your exceptions. You will learn more from them than all the rest of your data.

Honours

1928 BSc, University of London
1931 PhD, University of London
1948 DSc, University of London
1970 Sanderson-Wells Lecturer, University of London
1975 Honorary DSc, University of Manchester
1976 Fellow of The Royal Society
1979 Commander of the Order of the British Empire

1981 James Spence Medal, British Paediatric Association
1982 Second Bristol Myers Award for Distinguished Achievement in Nutrition Research
1983 First European Nutrition Award, Federation of European Nutrition Societies
Boyd Orr Memorial Lecturer, the Nutrition Society
1984 Rank Prize Funds Prize for Nutrition
1985 E.V. McCollum International Lecturer in Nutrition and Award
1986 Atwater Lecturer and Award
1988 Nutricia International Award
1989 Muriel Bell Lecturer, Nutrition Society of New Zealand
1992 First Edna and Robert Langholz International Nutrition Award, American Dietetic Association Foundation
1993 Companion of Honour

Honorary Offices held

1977–80 President, The Nutrition Society
1978–81 President, The Neonatal Society
1986–96 President, The British Nutrition Foundation

Acknowledgements

I thank the British Nutrition Foundation for allowing me to pursue my dream and write a biography about Elsie while she was still alive. Because of this, I know that the parts of Elsie's life and career I have recounted in this memoir are exactly those for which she would want to be remembered. Whenever I talked about Elsie in her presence using excerpts from her biography, she would always joke that she could not have written a more perfect obituary herself.

All the photographs were originally part of Elsie's personal collection. They were subsequently used for the British Nutrition Foundation biography and I thank the British Nutrition Foundation for permission to reproduce a few here.

The frontispiece photograph was received by The Royal Society in 1981, and is reproduced with permission from Godfrey Argent.

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