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FOREWORD

I am very pleased indeed to have the opportunity to make a personal contribution to this issue of the *Food Preservation Quarterly* and to pay tribute to the distinguished career of Dr. J. R. Vickery and the outstanding contribution he has made in the field of industrial scientific research in Australia. He has set a pattern of achievement which is worthy of study by both scientists and industrialists concerned with the task of encouraging progress in industry.

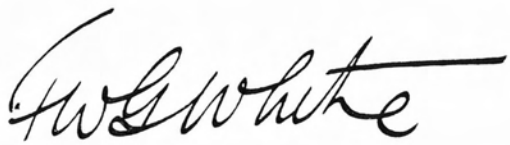
Dr. Vickery is a distinguished scientist. His early training in Melbourne and at Cambridge University fostered in him the best traditions of scientific achievement. He has striven throughout his career to ensure that his Laboratory leads the field in the quality of its research, and there is no doubt that his personal research and that of his colleagues is highly regarded throughout the scientific world.

Excellent research and research leadership are essential prerequisites to industrial progress, but these alone are not sufficient. Dr. Vickery is unique in his personal knowledge of the problems of the food industries of Australia. He has a multitude of friends amongst the professional men in these industries and their aspirations and hopes he has always viewed with great understanding. This understanding, indeed, provides the soundest basis for the conduct of effective industrial research.

When Dr. Vickery was invited to accept a post with the Council for Scientific and Industrial Research in 1931, he had already had experience in the food sciences in England and New Zealand. In C.S.I.R. he was a pioneer, for this was a new field for research in Australia. He immediately became the trusted adviser of the Council and it is undoubtedly to his originality of thought and administrative wisdom that we must attribute the steady and successful growth of the Division of Food Preservation.

He and his colleagues have successfully faced the challenge of major national problems. The successful transport of Australia's many foodstuffs to distant overseas markets has been their concern since the beginning. The Second World War brought new problems particularly relating to food processing. As the food industries have grown so has their requirement for more sophisticated food science. Under Dr. Vickery's guidance the science of food has developed in Australia to meet the needs of the industries.

Dr. Vickery, in his retirement, will have the satisfaction of leaving a distinguished group of colleagues to carry on this essential work in admirable laboratories. He can contemplate a career which has brought him recognition throughout the world as a distinguished research scientist and has been a major influence in the prosperity and progress of his country.



Chairman,

Commonwealth Scientific and Industrial Research Organization

J. R. Vickery, O.B.E., M.Sc., Ph.D., F.R.A.C.I.

Foundation Chief of the CSIRO Division of Food Preservation

Presented by the staff of the Division, July 7, 1967

JAMES RICHARD VICKERY

A Career in Food Science and Scientific Administration

JAMES RICHARD VICKERY, born in Ballarat, Victoria, on July 9, 1902, entered the University of Melbourne in 1921. He enrolled initially to study engineering, but soon switched to science. He graduated B.Sc. with majors in chemistry and physiology, including the University Exhibition Prize in the latter subject. In the Chemistry Department, one of the lecturers was Dr. A. C. D. Rivett, who was soon to become Professor, and who was subsequently to have a strong influence on Vickery's career. Vickery began post-graduate studies in biochemistry under the guidance of the late Dr. W. J. Young. His first adventure in scientific research was a study of the freezing of beef, and it had several features worthy of note. In the first place, it was a cooperative study involving two physicists, Cook and Love, and two biochemists, Vickery and Young. Vickery, the junior biochemist, was responsible for the biochemical and histological work. His opposite number, the junior physicist, was the late G. A. Cook, who was secretary of CSIRO from 1944 to 1953. The results of the study confirmed some earlier findings of British and German workers, and showed that several factors affected the extent to which changes occurring during freezing are reversible during thawing. Forty years later, we have some additional knowledge of the phenomena, but little understanding of the irreversible changes that take place during freezing. A second feature of the above study was that it was done at the request of a committee, the Committee for the Freezing of Beef, set up by the Australian National Research Council. Thirdly, the authors acknowledged the generous cooperation of the Victorian Department of Agriculture, the Institute of Science and Industry, and the University of Melbourne.

These three features — the recognition of an applied problem by an *ad hoc* committee, its investigation by a multi-discipline team, and the cooperation and assistance offered by interested groups — constituted a pattern that Vickery was to encounter many times in the course of his career and was to use with great success.

While still at the University of Melbourne, Vickery took some further courses in the biological field, and graduated M.Sc. in 1925.

1926–31 — Cambridge, Liverpool, and New Zealand

For the next five years Vickery was overseas, first at Cambridge, then at Liverpool, and later as a member of a team studying the freezing and storage of New Zealand lamb. His study at Cambridge was made possible by the award of an 1851 Exhibition Scholarship, which made him ineligible to receive one of the full research studentships that had just been established by C.S.I.R. He was, however, offered a grant from the Science and Industry Endowment Fund of £50 per annum for two years, and in return entered into a bond, giving C.S.I.R. an option on his services for three years at the end of his two years in England. These arrangements were supported by Rivett, who had now resigned from the Chair of Chemistry at Melbourne to become the first Chief Executive Officer of C.S.I.R. Rivett had plans for a group to carry out research on the cold storage of perishable commodities (e.g. meat) that Australia was exporting to the United Kingdom and Europe, and he looked on his former student as a member and possible future leader of this group.

This then was the situation when Vickery departed for the Low Temperature Research Station in July 1926. His work at Cambridge was under the supervision of Sir William Hardy, F.R.S., a distinguished physiologist who had a profound influence on Vickery's career. Hardy had gathered together some able scientists at L.T.R.S., and had been very successful in using the knowledge and skills of colleagues trained in many scientific disciplines in the study of applied problems confronting the food industry. Like so many who came after him, Vickery was given an extension to his studentship. This enabled him to study oxidative changes in fats in the

renowned school of Professor T. P. Hilditch, F.R.S., at Liverpool. The subsequent report on the yellowing of the abdominal fat of frozen rabbits earned for the author some unexpected publicity in the London *Times*, which satirized the formal prose of the report, and wrote of the problem of 'bunnies' yellow tummies'.

In 1929, after receiving his Ph.D. from Cambridge, Vickery was appointed an officer of C.S.I.R. to carry out cold storage investigations. Almost immediately he left England for New Zealand, via Australia. In New Zealand he joined a team, led by Dr. Ezer Griffiths, F.R.S., of the D.S.I.R. National Physical Laboratory, to study the freezing, storage, and transport of lamb exported from New Zealand to the United Kingdom. After some six months in New Zealand the team travelled to England, studying the physical conditions under which the lamb was being transported. Then, after a few months of working in the National Physical Laboratory, Vickery returned to Australia via the United States in April 1931. The report of the New Zealand studies by Griffiths, Vickery, and Holmes (1932) is one of the classics in meat science. The first nine chapters cover the physical studies by all three authors, and the last seven chapters, with Vickery as sole author, describe the effect of physical and biological factors on the meat.

1932–37 — Brisbane and Beef Research

Until his return to Australia in 1931, Vickery had been training for his future career. Now he was to become a leader, and Rivett acted swiftly to bring this about. While still in England, Vickery had been encouraged to study the conditions under which Australian refrigerated produce was marketed. Now, immediately after his return, he was given the task of surveying the Australian refrigerated foods industry and of drawing up plans for research. At the same time, C.S.I.R. had received requests from industry to undertake research on the preservation of beef in the unfrozen (chilled) condition. Argentine and Uruguay were landing chilled beef in England in acceptable condition, but Australia had not succeeded in doing so because it was much farther from the market.

The Queensland Meat Industry Board, through its Chairman, the late Mr. E. F. Sunners, offered to build and maintain laboratories and cold rooms at its abattoir at Cannon Hill, Brisbane, if C.S.I.R. would provide the staff. Rivett readily accepted this generous offer. A C.S.I.R. Section of Food Preservation and Transport was established, and Dr. J. R. Vickery was appointed Officer-in-Charge in September 1931, at the age of twenty-nine. Six months later the new laboratories at Cannon Hill were occupied, and the following month Vickery found time to marry. The next six years at Cannon Hill were exciting — filled with investigations, achievements, and planning. Vickery himself was actively involved in the experimental work on chilled beef; indeed for the first year the scientific staff at the Brisbane abattoir comprised only himself and a veterinarian, W. A. Empey. They had one technical assistant, a part-time typist-librarian, and an extremely modest budget. In 1933 they were joined by a microbiologist, W. J. Scott, and two years after the experimental work began the first commercial shipment left the Brisbane abattoir.

Industry was very keen to apply the new techniques, and in 1938 some 26,000 tons of chilled beef left Australia. This represented about one-third of the exports of quarter beef. The speed with which Vickery's recommendations were adopted by industry was very impressive, and was largely due to his energy and foresight in seeing that the various parties were informed as soon as sufficient evidence was to hand. The shipping industry incurred heavy expenditure to build gas-tight chambers to maintain 10% carbon dioxide in the storage atmosphere to retard microbial spoilage. By 1936 most of the technical difficulties causing unsatisfactory shipments of chilled beef had been removed. The experimental work was completed by 1938, and the principal results published the following year in two bulletins by Empey and Scott (1939)* and Scott and Vickery (1939).†

* Empey, W. A., and Scott, W. J. (1939).— Investigations on chilled beef. Part I. Microbial contamination acquired in the meatworks. Bull. Coun. scient. ind. Res., Melb. No. 126.

† Scott, W. J., and Vickery, J. R. (1939).— Investigations on chilled beef. Part II. Cooling and storage in the meatworks. Bull. Coun. scient. ind. Res., Melb. No. 129.

In the midst of the activities on chilled beef, Vickery was busy planning for the housing and staffing of a larger group, in a region better suited than Brisbane for work on temperate fruits and other products. In these matters, Vickery was guided and assisted by Rivett and also by W. J. Young, who had been appointed consultant to the Section, and by Hardy, who maintained close interest in the development of food research in Australia until his death in 1934. Arrangements were finally made with the Metropolitan Meat Commission, Homebush, N.S.W., to make available buildings in which laboratories and cold rooms were constructed. These were occupied in 1938.

1938–45 — Homebush and World War II

At Homebush, the appointment of additional staff and the return of trainees from overseas increased the range of skills that could be brought to bear on problems. The greatly improved cold-storage and laboratory facilities led to an expansion of fruit storage investigations, which had commenced in Melbourne in 1932 as a cooperative venture with the Victorian Department of Agriculture. The N.S.W. Department of Agriculture contributed to the cost of the new facilities at Homebush, and from 1938 to the present day one or more of its fruit research officers has been stationed in the Division's laboratories. Work on the preservation of fish and fruit juices was commenced, and Vickery himself became interested in the causes of rotting in shell eggs, a form of wastage that sometimes developed to a serious extent during the distribution of Australian shell eggs in England. There was marked variation between and within consignments from various parts of the country. There were plenty of suggestions for the cause but very few facts. With the assistance of the Egg Producers' Council and local investigation groups in five States, Vickery had soon organized a series of experimental shipments with eggs of known history and with replicate lots exported and retained for storage in Australia. These experiments proved convincingly that the causes of wastage were in treatments that the eggs received on the poultry farms in Australia, and not shipboard conditions or the English weather. This definition of the central problem provided the firm foundation upon which Vickery and various colleagues subsequently were able to make detailed studies of the microbiology of egg cleaning and to develop measures for preventing wastage.

The outbreak of World War II in 1939 brought a multitude of changes. There was a prompt cessation of some types of trading and many changes were made to utilize shipping space more efficiently. There were surplus supplies of foods that could no longer be exported, and a search began for means of preserving foods without refrigeration or in a concentrated form. At this time the Australian food industry was ill equipped to make sweeping changes: apart from a few companies canning fruits, and others a limited range of meat products, there was little food processing. Industry had few technically trained people, and Vickery and his colleagues soon became occupied with enquiries and *ad hoc* investigations on behalf of government departments, industry, and the armed services. The Section of Food Preservation was raised to the status of a Division in May 1940, when the scientific staff numbered 14 and the annual budget was about $35,000 (see the graph on page 55). In the following year the Division launched a new extension organ, the *Food Preservation Quarterly*, for the purpose of bringing about a more rapid dissemination of the results of scientific investigations to the food industry. Now in its 27th volume, its circulation has increased steadily and it is highly regarded in Australia and many overseas countries.

By 1942, with the entry of the United States into the war and the spread of the war throughout the Pacific, Australia was becoming an important source of military rations for the region. The Division became very largely concerned with work in canning and dehydration; additional appointments were made and some staff seconded from other laboratories. The amount of advisory and extension work increased considerably. Dr. Vickery visited New Zealand to advise on meat and vegetable dehydration, several schools of instruction in the technology of canning and dehydration were given for civilian and military groups in Australia, and food specifications were prepared for Government departments. Additional laboratory accommodation was provided almost every year during the war, and, because of the urgency and limitations on finance and

materials, the standards were often less than desirable. The laboratory was working under difficult and crowded conditions. Even so, the five-year programme on shell eggs was continued, and substantially completed by 1943. At this time the scientific staff numbered 28, or twice the 1940 level. By 1945, after six years of wartime operation, the Division had 15 scientific staff in the canning and dried foods sections, five in microbiology, two in physics, and one in fruit storage, nearly all working on short-term problems. The Division was now widely known and much sought after for advice on food technology, but many of the scientific staff had no worth-while opportunity for demonstrating their capabilities in scientific research. Over the six war years only 20 scientific papers were published from the Division. All this was soon to change.

1946–55 — Post-war Developments

After World War II, Vickery was like the conductor of a small orchestra which he wished to augment and have play more difficult works. His aim was to develop a multi-discipline laboratory on the storage and preservation of food.

Most wartime projects were discontinued as soon as circumstances permitted: canning and dehydration projects with short-term objectives were terminated within a year, but some longer-term investigations were continued until valid conclusions could be drawn, and experimental programmes on meat drying, in which the defence authorities were interested, continued for ten years. Research on the simultaneous cooling and drying of wet solids was resumed, and work commenced on the calculation of the sterilization value of the heat processes used in canning. A fresh start was made with research on shell eggs, with Vickery himself an active investigator. Satisfactory control measures against bacterial rotting were developed, and research turned to the more difficult problems associated with quality changes in shell eggs. Microbiologists began fundamental studies on the properties of bacterial spores and a quantitative study of microbial water requirements. Substantial chemical programmes were undertaken on non-enzymic browning.

Vickery recognized that biochemical and physiological studies of plant tissues were an essential basis for controlling the metabolic activities of fruits and vegetables. He therefore appointed a plant physiologist to take charge of the Division's fruit storage investigations and gave him supporting staff, some of whom were located at the Botany Department at Sydney University. Collaborative work at the University of Melbourne and with the CSIRO Division of Plant Industry soon followed. There was at this time a scarcity of facilities in Australian universities for post-graduate training of students in plant physiology and biochemistry. On the recommendation of Vickery, a joint CSIRO–University Plant Physiology Unit was established at the Botany Department of Sydney University, with R. N. Robertson (CSIRO) and F. V. Mercer (Sydney University) as joint leaders. In this way, Vickery obtained for his Division a first-class facility for research in plant physiology without incurring the heavy capital expenditure needed to build new laboratories. The Unit rapidly became an acknowledged centre of plant physiological research in Australia, and is frequently mentioned as an example of successful CSIRO–University cooperation in research.

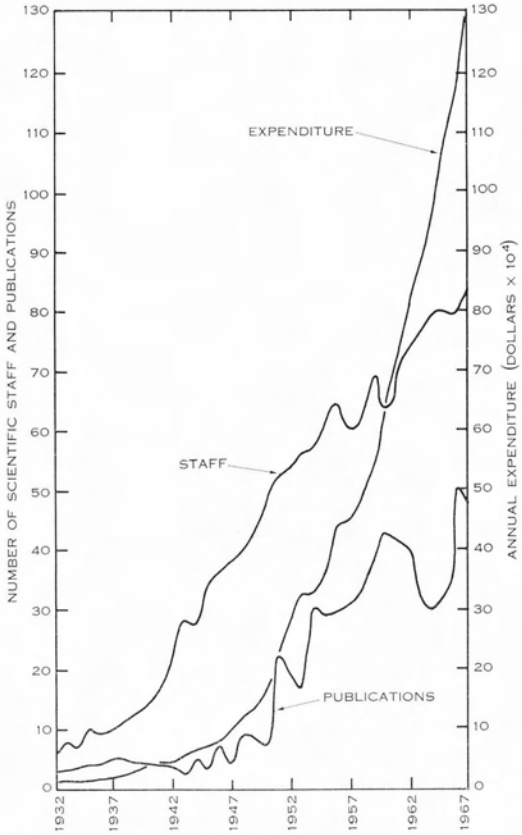
Vickery was arranging cooperative research in other spheres also. In 1948 a Citrus Wastage Research Laboratory was set up at Gosford, N.S.W., as a joint venture with the N.S.W. Department of Agriculture. The laboratory, which has since been rebuilt and enlarged, has contributed substantially to the improvement of the handling and marketing of citrus fruit in Australia.

By 1955 Vickery and his Division had achieved a high reputation throughout Australia and overseas. He was collaborating in many ways with universities, government departments, and the food industry. The Division was doing scientific and technological research of high quality, and publishing a scientific paper every two weeks. A committee set up by the Executive to review the work of the Division endorsed its programmes and policies, and strongly recommended the provision of new laboratories for the headquarters of the Division.

1956–61 — Planning and Building

Planning and building the new laboratories was a major task that extended over a period of five years. Following the acquisition of a site at North Ryde, plans were prepared for a

series of buildings, including two large laboratory blocks and associated facilities for food processing and cold storage. These plans were approved by the Works Committee of the Commonwealth Parliament in 1956. A contract for construction of the laboratories was let in May 1959, and they were occupied in May 1961.



Growth of Division of Food Preservation, 1932–67.

This was the event for which the Division and its Chief had been waiting. In the largest CSIRO project since World War II, the Division had been provided with new laboratories which cost about $1,300,000 and occupied 70,000 sq ft of floor space. The staff was no longer overcrowded, the research facilities were excellent, and the surroundings pleasant. The laboratories were officially opened on September 18 by the Hon. Dr. D. A. Cameron, Minister-in-Charge of CSIRO, and a three-day International Food Science Conference followed. Vickery was visibly moved by the tributes paid to him at the opening ceremony, and expressed his delight at the facilities now available to his Division. Regrettably, the death of Sir David Rivett in April 1961 prevented Vickery from sharing his feelings with his lifelong mentor and friend.

The years preceding the transfer to North Ryde had not been without difficulties, for in 1959 Vickery had lost two of his senior colleagues. E. W. Hicks, who had been closely associated with him since 1933, his deputy for many years and the leader of the Physics Section for 20 years, died unexpectedly in November. Earlier that year, R. N. Robertson, Assistant Chief and leader of the Fruit and Vegetable Storage Group, had been appointed to the CSIRO Executive. He was succeeded as Assistant Chief by W. J. Scott.

The period 1956–61 brought with it a number of indications of the growing stature of the Division of Food Preservation. Several members of staff became visiting scholars in universities and research institutions overseas, or were sought as authors of reviews on fields of research. There was also an increasing flow of overseas scientists to work in the Division while on sabbatical leave or on fellowships. Vickery was himself invited to participate in numerous activities outside Australia, but he was obliged to decline many of them. He did, however, accept an invitation from F.A.O. and W.H.O., to serve on a panel of scientists who met in Rome in 1956 to formulate principles governing the use of food additives. The following year he was invited by the British Ministry of Agriculture, Fisheries and Food to advise the government on the development of meat research in Britain. He spent the first half of 1958 visiting many of the agricultural research centres in the British Isles, and recommended the establishment of a meat research institute adjacent to one of the provincial universities possessing facilities for research in animal production. This recommendation was adopted and a Meat Research Institute at the Veterinary Department, University of Bristol, at Langford, is due for completion late in 1967.

At the conclusion of his mission in Britain, the Government of Pakistan sought his advice on food technology research laboratories in that country.

Vickery was now a world figure in food science, and the Institute of Food Technologists, an international body with headquarters in the U.S.A., conferred on him its International Award for 1960, in recognition of his outstanding efforts to promote the international exchange of ideas in the field of food technology.

1962–67—More Planning and Building

The more extensive laboratories and workshops at North Ryde enabled Vickery to increase the laboratory and engineering staffs, but additional laboratories were soon required for the protein chemists and electron microscope group, both of whom had been housed at Sydney University.

With its improved facilities and a higher proportion of its staff on the one site, the tempo of research increased. Communications were improved within the Division, and with science and industry in the outside world. There were more meetings of the scientific staff, more seminars, committees, demonstrations, open days, and meetings with industry. The output of scientific publications rose to about one per week. Over the five-year period, staff increased by about 25% and annual expenditure almost doubled.

In the midst of all this activity, Vickery had two important objectives. One was the pursuit of his own research on egg quality, which had been aided by a grant from the United States Department of Agriculture. He was particularly interested in the biological effects of cyclopropene fatty acids in the diet of the hens, and became increasingly resolute in reserving 20% of his time for experimental work.

The second objective was the expansion of meat research. He realized that the Division was devoting only 15% of its resources to work on meat, though the meat industry was by far the largest section of the Australian food industry. In 1959 and 1960, he had recommended to the CSIRO Executive that meat research be expanded but the proposals had languished for lack of finance. An opportunity to take up the matter again arose in 1962. In August of that year there was an International Poultry Science Congress in Sydney and a conference of European meat research workers in Moscow. As a member of the organizing committee, Vickery had a strenuous time at the Sydney Congress and, during the meetings, acquired an acute infection. Nevertheless, with the aid of antibiotics and jet aircraft, he attended the Moscow conference during the following week. After the conference he visited European meat research laboratories, and attended the first International Congress of Food Science and Technology in London, where he was leader of the Australian delegation.

Immediately after his return to Australia, Vickery reported on the large investment in meat research in European countries, where the volume of production was less than in Australia. He prepared submissions on beef research for the CSIRO Executive to place before the Australian Cattle and Beef Research Committee. At the Committee's request, these were modified to provide for research on other meats as well. In 1963 the Committee made a substantial grant towards the cost of constructing a new laboratory in Brisbane. In 1964 W. J. Scott was appointed leader of the meat investigations, and plans were laid for construction of the new meat research laboratory in two stages. The first was completed in 1966, and toward the end of that year the Australian Meat Research Committee agreed to provide an annual grant of up to $405,000 for research on all meats and to contribute, with CSIRO and the Australian Meat Board, to the cost of Stage II. On May 31, 1967, Stage I was officially opened by the Chairman of the Australian Meat Board, Mr. J. L. Shute.

The concluding years of Dr. Vickery's career in CSIRO brought many signal honours. He was made a member of the Executive Committee for the International Congresses of Food Science and Technology, the first of which was held in London in 1962, the second in Warsaw in 1966. In 1964 he was one of three distinguished lecturers at the celebrations at Cambridge to commemorate the centenary of the birth of Sir William Hardy. He spoke on Hardy's Contribution to the Application of Science in the Food and Refrigeration Industries. In 1966 he delivered the first International Lecture to the Food Group, Society of Chemical Industry, London, on The Scope and Status of Food Science (see p. 59). In the same year

the Australian branches of the Institute of Food Technologists conferred on him the Australian Award for his meritorious contributions to the Australian food industry. In 1967, in a fitting climax to his career, Dr. Vickery was made Foundation President of the newly formed Australian Institute of Food Science and Technology, and the Queen honoured him with the award of an O.B.E.

Retrospect

Dr. Vickery's greatest achievement in the course of his long career is undoubtedly the CSIRO Division of Food Preservation. He was its architect and builder, and he leaves it housed in two fine modern laboratories: the headquarters at North Ryde, N.S.W., and the Meat Research Laboratory at Cannon Hill, Qld. He brought to his task the highest ideals in scientific leadership and administration, and great patience in the pursuit of long-term objectives. He was skilful in selecting staff and possessed to a marked degree the art of having them work happily together. Under his leadership the Division's research programme was given a wide scope and high quality.

Dr. Vickery is held in high esteem by the food industry, in the development of which he has played an important role. The research facilities he established, the teaching facilities he encouraged, the resultant flow of technical personnel, and his readiness to assist industry and to participate in the activities of their associations—all these have had a marked effect on the development of the Australian food industry.

In his position as Chief of Australia's national food research laboratory, Dr. Vickery has been responsible for providing much of the technical knowledge for the development of Australia's export trade in food. He established and maintained close and harmonious relations with government, university, and international bodies. He retires as a national and international figure in food science, leaving an unbroken trail of goodwill for those who must follow him.

W. J. Scott

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The Scope and Status of Food Science*

By J. R. Vickery

The First International Lecture of the Food Group of the Society of Chemical Industry, delivered in London on September 21, 1966.

IT is an appropriate time, after 40 years' continuous work as a food scientist, to look back over this long period in an endeavour to assess how we food scientists stand in relation to the general advance of science, and also to attempt to define our limitations and some of our achievements.

If in this paper an undue number of illustrations from Australian contributions appear to be given, I do so only because I am more intimately acquainted with them and not because I believe that they excel work done elsewhere.

Acceptance of Food Science

It is not certain when the term 'food science' was first widely used; probably it was during the war or early post-war years. It was certainly not used in the early twenties; one's work in those days was considered to be part of applied chemistry or biology, depending on one's scientific interests. Food science was certainly not accepted as a distinct discipline in the same sense as were agricultural science and veterinary science.

The demand, during World War II, for the services of food scientists, and their sterling contributions to the war effort greatly enhanced their status and led to their acceptance by governments, by industry, and by other scientists. While this wartime acceptance was the outward manifestation, the real reasons, in this country at least, lay in two events—firstly, the development of a major body of knowledge in several branches of food science between the two world wars, notably in the science of meat, fish, and fresh fruits, and secondly, the formation of the Food Group of this Society in 1932. The Food Group brought together for the first time scientists of many disciplines to share their knowledge and to build up the body of principles we know today as food science. Perhaps the most potent force in this direction was the series of excellent symposia which the group organized early in its history.

It was not long before people interested in food science and technology formed new institutions. The movement started in 1940 with the formation of the American Institute of Food Technologists, which quickly grew in strength and influence in the North American continent. The establishment of similar institutions in other countries followed quickly after the Second World War. International cooperation and exchange of food scientists increased rapidly after 1946, and these led to the meeting of the 1st International Congress of Food Science and Technology in London in 1962. We now look forward to the early formation of an International Union of Food Science.

The growth of food science as a separate discipline can also be traced in the establishment of scientific journals devoted to its needs. *Food Research* (now the *Journal of Food*

* With acknowledgments to *Chemistry and Industry*, 1967, pp. 109–14.

Science) was founded in 1936, *Food Technology* in 1947, *Advances in Food Research* in 1948, and the *Journal of the Science of Food and Agriculture* in 1950, and many more since that time.

I expect that academic recognition is the hallmark of respectability for a branch of learning, and this recognition came to food science in this country in the establishment of at least five university departments, starting with the Department of Food Science in what is now the University of Strathclyde. This academic growth has been paralleled in many countries, and particularly in the U.S.A. In Australia, we now have two such departments.

Scope of Food Science

During the last 40 years or so, we have seen an astounding growth in the breadth and depth of our knowledge of animals and plants from which our foods are derived. This has been particularly true of biochemistry, which has deepened our understanding, and often control, of many changes taking place in foods. In the preparation of egg powder, the enzyme, glucose oxidase, is now used to remove glucose from the pulp before drying, and catalase is used to remove the hydrogen peroxide produced during the reaction; this is done without affecting the flavour or other properties of the dried product. If we so desire, certain drugs administered to animals just before slaughter can be used to control the rate of post-mortem glycolysis in muscles, thereby changing the quality of the meat.

The scope of food science and the possibilities of producing better and more stable foods have increased enormously in recent years with the growth in knowledge in general science. This is evident particularly in the powerful tools now at the disposal of scientists. The various forms of chromatography—gas–liquid, column, and thin-layer—have revolutionized analytical chemistry and biochemistry. We hesitated for several years before deciding to enter the field of research on food flavours but, with the advent of new mass spectrometers which had high scanning rates and could be directly coupled to high-quality gas–liquid chromatographs, we believed that at last we had the tools to perform flavour studies efficiently. Using this new equipment, the results we have obtained so far on off-flavours in frozen peas have, I believe, justified our early hopes (Whitfield and Shipton 1966).

New vistas for food science have been created by recent advances in our knowledge of photosynthesis. Can the organelles of plant cells—the chloroplasts and mitochondria—be put to work *in vitro* to produce acceptable foods? In other words, can we take this photosynthetic system from plants and make it work for us in biochemical syntheses on a factory scale? This may be feasible only by supplementing cultures of organelles with protein-synthesizing enzymes and synthetic messenger-R.N.A., thus combining the use of an efficient protein-synthesizing system with the ability of chloroplasts to synthesize amino acids from carbon dioxide and ammonia, using light as the energy source. I believe that the possibility is worth exploring, and it may result in better proteins being synthesized than by growing yeasts and algae for human consumption.

I have used the term 'food science' without defining it, but before attempting to do so it will be desirable to look into the relationship of food science to pure and applied sciences. Sir Cyril Hinshelwood (1965), in his presidential address to the British Association for the Advancement of Science, pointed out that 'the relation of pure science to applied science is exceedingly subtle and complex. The urge to explore, understand and depict nature is by no means the same thing as the desire to master and control it, nor are the relevant talents and abilities the same. Some men of science have had a keen desire to see their discoveries turned to practical account: others have been indifferent.'

Most of us in food science are interested in practical ends, and, this being so, we should be concerned only that our work is good science and not worry unduly whether it is pure or applied. About 40 years ago, the late Sir William Hardy (1925), the first superintendent of the Cambridge Low Temperature Research Station, put it very well: 'eight years ago, when our board was founded and the staff recruited, the latter found themselves confronted with a novel task in applied science and with a good deal of basal science still to seek. This does not mean that plain physiology and pathology, biophysics, biochemistry and pure physics did not supply much of what was wanted. It means that the knowledge they offered had been obtained for

quite other purposes, and needed adapting here and extending there to fit it for the solution of the kind of problem which the very diverse industry to be served was likely to present.'

As one who received most of his research training under Sir William Hardy, I have always worked in accordance with this empirical approach. When my colleague, Mr. F. S. Shenstone, and I started our work on the cause of pink discoloration in eggs, as part of a programme on the effects of dietary constituents on egg quality, we had a very practical aim in view. We found that the causal agents were the cyclopropenoid compounds, malvalic and sterculic acids, which comprise about 1–2% of the total fatty acids of crude cottonseed oil and which occur in many other seed oils in the family Malvales (Shenstone and Vickery 1956, 1959). When these compounds are laid down in the yolk fat, they greatly increase the permeability of the yolk membranes and inhibit the enzymic dehydrogenation of stearic acid to oleic acid when they are present in concentrations as low as 150 p.p.m. It was not long before we were rather deeply involved in studies of the chemical and biological properties of these fatty acids (Shenstone, Vickery, and Johnson 1965), but I do not think we ever considered whether we were working in pure or applied science; our main concern was for a solution to a rather baffling problem in food science.

Many acceptable definitions of food science are possible; I put forward the following: 'Food science concerns the discovery and application of knowledge of the physical, chemical, and biological (including nutritional) properties of foods and their constituents, and the changes they undergo when subjected to handling, preservation, processing, storage, and distribution.'

As in the case of other recognized branches of applied science, such as medicine, food science involves an integrated use of many disciplines including physics, chemistry, biochemistry, physiology, botany, microbiology, entomology, and engineering: many food scientists would also include experimental psychology, which may play an important auxiliary role in the future. Thus, in food science, we endeavour to use the body of knowledge in many branches of science for the solution of the complex problems with which we are continually confronted.

While emphasizing the importance of an integrated approach to the problems of food science, I would not wish to belittle the individual contributions which 'pure' scientists have made, such as, for example, by many microbiologists in the food-borne diseases. Nevertheless, some of the most elegant and momentous investigations have involved the integrated approach. There are, of course, many classical examples but one will suffice. Before the year 1920, the heat processing times and temperatures needed for non-acid canned foods were derived empirically. In the period 1920–23, however, the work of Bigelow and Esty (1920), Bigelow *et al.* (1920), Esty and Meyer (1922), and Ball (1923) in the United States placed heat processing on a scientific basis for the first time, through their joint work on the temperature coefficients for the killing of bacterial spores and on the physics of heat transfer in canned foods. The determination of heat processes which will ensure freedom from *Clostridium botulinum* toxins soon became simple routine. More recently, Stumbo (1949) in the U.S.A., Hicks (1951) in Australia, and Gillespy (1951) in Britain, using more elegant methods based on the populations of bacterial spores in discrete volumes of food, have made the techniques for the determination of safe processes even more precise. One should add, however, that very recent studies have cast considerable doubt on the validity of current assumptions about the kinetics of disinfection, from which safe heat processes are derived. I do not expect that this will cause any loss of sleep for those in the canning industry, because the currently accepted processes have stood the test of time, and outbursts of botulism in canned foods have always been due to gross departures from recommended heat processes.

The food scientist's interests must include a close examination of the conditions of food production. He cannot be content with a complacent acceptance of food as delivered from the farms, abattoirs, and fishing vessels: he can seldom improve its quality after arrival at the factory. One way of effecting significant improvements in food quality will derive from a much more detailed study of the factors, operating during production, which subsequently determine the flavour, texture, keeping quality, and other attributes of the preserved or processed foodstuff. In the case of meat this may mean detailed studies of the effects

on quality of breed of animal, its patterns of growth, and the way it is handled on the farm and during its journey to the abattoir. For vegetables it certainly includes variety, conditions of growth, and the biochemical state of the tissues at the time of harvesting. Food scientists will often have to get this information themselves, for agricultural and veterinary scientists may not be interested although they may happily cooperate if the initiative is taken by the food scientist. I recall, with some feeling, our early experiences in studies of potatoes some 20 years ago, and I think it is of some interest to recall that the late Dr. L. H. Lampitt (1932), the first Chairman of the Food Group, described similar frustrations in the first symposium held by the Food Group. We were bluntly informed that neither the agricultural scientists nor the farmers were interested in anything but the yield per acre of healthy tubers of the desired size range. They were indifferent to culinary and processing qualities. Nevertheless, we went ahead with our studies and I am glad to say that, by 1956, the major breeders of potatoes in Australia were including culinary and processing qualities among the factors governing the acceptance or rejection of all new varieties.

I do not wish it to be thought that agricultural scientists are always obstructive. You will recall many examples of fine cooperation, such as the breeding of varieties of peas and beans suited to mechanical harvesting. Nevertheless, the food scientist will often have to take the lead if he is not satisfied with the quality of the food entering the factory.

Limitations in Food Science

Despite the apparent acceptance of our discipline and its broadening scope, we should realize that there are limits imposed upon us both by the community and the nature of foods and their environment. I propose now to examine briefly some of these limits.

Human Conservatism

It is unfortunate that the populations of underfed countries, where the need to accept new foods is greatest, show extreme conservatism, and expect new foods to conform to traditional forms. Subrahmanyan and his colleagues at Mysore, India, devised a useful new food from ground-nut proteins and tapioca flour, but they had to extrude it in a form similar to rice before it was acceptable to the Indian public (Bhatia and Subrahmanyan 1959). Conservatism also retards the work of many other food and nutrition scientists in their efforts to promote nutritionally superior foods, for instance, the Incaparina type devised by the Institute of Nutrition of Central America and Panama (Anon. 1964).

In well-fed countries, on the other hand, people are often surprisingly receptive to new forms of foods. In the last 10 years in Australia, the consumption of dehydrated soup mixes and frozen vegetables has increased by 300% and 500% respectively. On the other hand, acceptance of new foods in technologically advanced countries can sometimes be very slow. Over 80 years elapsed between the commercial introduction of the tomato and its general acceptance as a staple item in the diet.

Public Health Requirements

There is a locally famous sign outside a food factory in Sydney, which reads 'what you eat today walks and talks tomorrow'. This, I think, can be a reminder to food scientists that the foods for which they are responsible must be not only attractive and nutritious but also safe. Unlike the scientist in most branches of industry, the scope and inventiveness of the food scientist are severely restricted by the limitations imposed by considerations of public health.

In respect of food additives, the manufacturer and his technical advisers face a serious dilemma. On the one hand, the chemical industry is offering an increasing range of food additives, many of which could help materially in the manufacture and marketing of food products. On the other hand, the manufacturer faces a growing public concern with the effects on health of intentional and adventitious food additives. As so often happens in such public controversies, the generated heat far exceeds the light. An ounce of sound biochemical and toxicological evidence is worth far more than a megaton of speculation, and it is pleasing now to see an increasing weight of evidence on the safety of additives coming from research laboratories, including the British Industrial Biological Research Association and the Food Protection and Toxicology Centre of the University of California. It might be added that the latter institution was the concept of two well-known

food scientists, Dr. George Stewart and Dr. Emil Mrak.

Through the work of a growing army of scientists we seem to be reaching a more balanced view on the use of food additives. In my opinion, pesticide residues in food constitute a far greater problem than intentional additives. Nevertheless, these intentional additives must be relatively harmless, they should not appreciably impair nutritive value, and they should be used only when no other aids to manufacture are commercially feasible. For instance, however desirable it may be in the interests of stability during distribution, we should not add sulphur dioxide to foods that contribute substantially to the daily intake of thiamin.

Severe microbiological standards are often imposed by public health authorities or are self-imposed by the manufacturer. There is every indication that these restrictions will tend to become more severe. In the four years 1961–1964, the average annual reported cases of food poisoning in England and Wales were 11,380 in 4686 incidents (Vernon 1965). Many epidemiologists believe that less than 50% of all cases are officially reported. Even in advanced countries there is no evidence for a diminishing incidence of food poisoning, particularly salmonellosis, and we can therefore expect more onerous conditions to be imposed, with consequent additional routine and research work by food scientists. In this respect, I draw your attention to the world-wide repercussions of the outbreak of typhoid fever in Aberdeen in 1964, an incident caused by contaminated canned meat (Scottish Home and Health Department 1964). This swiftly led to the imposition of much stricter hygiene in canneries. In Australia, all canners were forced to chlorinate water used for cooling heat-processed cans, even in Melbourne which had boasted having the world's purest city water supply!

Biological Barriers

The biological properties of foods and their constituents are often such as to restrict the efforts of the food scientist to improve the initial and keeping qualities of foods, or perhaps one can say that they are challenges to his skill. Many examples among fruits, vegetables, and meats can be given. Fresh fruits and vegetables are living materials and we usually assume that their drift to senescence can be delayed by storage at low temperatures, and the lower the temperature the better they will keep. However, with some fruits and vegetables, for example bananas and a few varieties of apples, reduction of temperature below a level well above 0°C will cause rapid breakdown of the plant cells and consequent inedibility as, for example, in bananas held below 10°C. Despite extensive research work over many years, we still have no useful clues to the cause of these catastrophic changes occurring over an interval of only a degree or two.

The biological properties of many foods are often manifested under what are biologically extreme conditions, as, for example, muscle in a dying state after an animal is slaughtered. In this respect, the food scientist is at a serious disadvantage compared with his colleague in pure biology, who normally tries to select optimum conditions for studies of the properties of living matter because it is so much easier. The food scientist has to accept conditions as they are, and this may account for our apparent slowness in solving several outstanding biological problems in food science.

Non-acid, canned foods such as meats and most vegetables generally have to be overcooked to ensure the destruction of bacterial spores which may be entrapped in the contents. The extraordinary resistance to heat possessed by many kinds of spores frustrates the food scientist in his efforts to effect improvements in the quality of non-acid canned foods. My colleague, Dr. W. G. Murrell, is making progress toward an understanding of the properties of the spore which confer high resistance to heat (Murrell and Scott 1966), and it may be possible in the future to lower this resistance and therefore to permit lighter heat processes. In the meantime, however, we have to devise empirical methods as, for example, accelerating heat transfer and aseptic canning to produce better canned foods.

Contributions of Food Science

As food scientists, we are, of course, highly dependent on advances in general science for a deeper understanding of the nature of foods. In turn, all sound research studies on the basic aspects of food science may make useful contributions to the general pool of scientific

knowledge. Food science, as part of general science, is therefore subject to the same criteria in assessing merit as obtain in any other branch of science. A catalogue of the achievements of food scientists and their contributions would be too burdensome; if a list were compiled, it would be very formidable. One may, however, mention two important contributions.

In studies associated with post-mortem changes in muscle, Marsh (1951), working at the Low Temperature Research Station, Cambridge, discovered the relaxation (or Marsh) factor, which plays an important part in controlling the contractile processes in muscle. This discovery gave rise to an intensive world-wide study of its properties and mode of action, and it is now known that the Marsh factor produces relaxation by withdrawal of Ca^{++} ions from the contractile systems.

The investigations by Scott (1957), working in our laboratory in Sydney on the influence of environmental water activity on the growth of microorganisms, made a major contribution to general science because they placed the water relations of bacteria, yeasts, and moulds on a quantitative basis. Moreover, they made a basic contribution to food science because they enabled us to predict with considerable accuracy when microbial growth might be expected in stored foods.

A number of general concepts in science have been adopted and amplified in food science. Typical examples are: the interaction of amino and carbonyl groups (the Maillard reaction) in relation to non-enzymic browning of foods; the effects of available water on microbial growth; and equilibrium relative humidity. I believe that it is the use of these and other basic concepts that distinguishes a food scientist from scientists in other disciplines. A trivial case will illustrate this point. Some years ago, the ration of an Australian soldier serving in the tropics included 1 lb of fruit cake each week. Supplies, however, rapidly became mouldy, and the army authorities took the problem to a university department of microbiology. Their remedy was to pasteurize the cake surfaces and the containers immediately after packing, but, of course, it was found that the cakes became mouldy soon after the containers were opened in the tropics. The army then brought the problem to our laboratory, and we suggested a change in recipe which would give a reduced equilibrium relative humidity in the cake at which the rate of mould growth would be so slow as to be commercially insignificant. The army thereafter had its cakes, and ate them too, without further loss.

I have often heard the taunt by academic scientists that a great deal of our work in physics, chemistry, biochemistry, and other sciences concerns very mundane, and apparently unexciting, aspects of science. In other words, we are often working in unpopular fields. I do not think that this accusation is generally true, but very few of us can jump on the band wagons of nuclear physics and genetical biochemistry, to name two fields of current popularity. If we are true to our calling as food scientists, we must continue to direct our work to a greater knowledge of food constituents and the changes they undergo, as well as to associated problems of human nutrition and public health, without thought of their popularity but only of the need.

In our own laboratories, I think we can usually offer research workers a wide range of interesting and absorbing problems, but in only one or two instances can we say that they are in fields currently popular or fashionable with scientists generally. Perhaps this point of view can best be illustrated by referring to work on egg-white proteins now being conducted in our laboratory by my colleague, Mr. M. B. Smith. Chemists and biochemists are currently conducting very little basic work on these proteins, but food scientists must know much more about them if they are to reach a better understanding of the properties of egg products and of the changes taking place in shell eggs. In particular, work on ovalbumin may appear to be rather unrewarding because it has no known biological activity, it is rather large for a single-chain molecule, and it denatures irreversibly. Yet, out of such apparently dull material came the rather surprising discovery recently, by Smith (1964), that during the storage of shell eggs for a week or so, most of the ovalbumin undergoes a spontaneous intramolecular re-arrangement to form *S*-ovalbumin, which has, among other properties, greater resistance to heat denaturation. It is highly probable that the deterioration of the functional properties of the whites from stale

eggs, as compared with fresh eggs, is due to this previously unrecognized change in the major constituent, ovalbumin. This and other egg-white proteins must therefore continue to interest food scientists.

Contributions to Food Industry

One has only to look around the supermarkets and food shops to see the wide range of new and improved foods now available to consumers, and also to visit modern food manufacturing factories and observe their high efficiency and study the new processes and equipment which were not available even 20 years ago, to realize the many contributions made to the industry. The constant flow of technical enquiries to the research associations and to the government-financed food research laboratories, clearly indicates the pools of new knowledge which various branches of the food industry and government departments are now able to use.

There have been so many contributions by food science to the food industry that it is difficult to select a few typical examples.

The work of chemists, biochemists, and physiologists has transformed bacon curing from an uncertain art to a series of closely controlled operations in all stages from the farm to the housewife's shopping basket.

Forty years ago, severe wastage frequently occurred in cargoes of apples forwarded from Australia and New Zealand to the U.K. The pre-war physiological studies by Kidd and West (1924) at Cambridge, and the engineering investigations by the late A. J. M. Smith (1926), led to a precise control of temperature and atmospheric composition in ships' refrigerated cargo spaces which has virtually abolished wastage during transport.

The chemical industry has given us a wide range of entirely new packaging materials. By a close study of the properties of the food and the permeabilities of these films to water vapour and to atmospheric gases, food scientists have been able to select packages which not only ensure good mechanical protection of the food but also give satisfactory keeping quality during the period of marketing.

Food engineers have made many far-reaching contributions which have brought about not only large reductions in labour costs but also better and more uniform food products. There have been great advances in dehydration by improvements to the traditional use of hot air, such as puff and foam-mat drying, and by the introduction of freeze-drying, for which I predict a bright future when it is possible to convert the process to continuous operation and greatly to decrease drying times.

Conclusion

Food science has made great progress in the breadth of its endeavours and in the depth of its probings in the last 40 years. It has prospered in the more genial climate of public opinion on science. It may be recalled that, in the early years of this century, the Secretary of the British Board of Agriculture stated that 'I cannot conceive the circumstances in which the Board will be at all interested in scientific work'. Yet, for over 25 years, the Ministry of Agriculture has had a large and active food research laboratory, as well as numerous laboratories devoted to various aspects of agricultural and veterinary science.

At the Food Group's symposium on Food Science Research in the United Kingdom, held in 1965, several speakers expressed concern at the shortage of first-class recruits for research and development (e.g. Wilkinson 1966), and I believe that this shortage occurs in almost every country. We are not attracting a reasonable proportion of outstanding physicists, physical chemists, biochemists, and chemical engineers. I cannot suggest a remedy, but I believe the position merits enquiry by national institutes of food science, in conjunction with appropriate university departments.

We have many large gaps in our knowledge of foods, which will be difficult to fill unless we can attract better scientists. One example only need be mentioned. At a time when there is increasing manufacture of dehydrated foods, the texture of many products after rehydration is unsatisfactory. We do not seem to be able to restore the water in the precise amounts to the sites from which it was extracted. This calls for a more intensive study of the state of water in foods, but unfortunately there are only a few laboratories studying the problem seriously.

Another conclusion I should like to draw concerns research aimed at helping one or more branches of the food industry or raising

the quality of food available to consumers. If these be the aims, then it will be highly inefficient to separate research workers on basic food science from those engaged mainly on applied aspects. There are such great possibilities of mutual stimulation of ideas and interests that to separate the two groups will necessarily impair the usefulness of each. In any event, the food scientist in such a laboratory should not worry whether his work can be classified as pure or applied, but he should be concerned only that it is soundly conceived and executed.

Finally, I should like to draw attention to the obligations resting on food scientists, in conjunction with fellow scientists in agriculture and economics, to combat the growing threat of world shortage of foods. While I am not pessimistic about our ability to feed the world's rapidly increasing population, we shall have to plan and work strenuously in the next 10 years or so to avert a crisis. The wide-spread application of current knowledge will go far, in a short term, to maintain the present *status quo*, but, in the longer term, we shall have to seek new forms of food from hitherto neglected sources.

Some progress is already being made through the extraction of fish flour from fish hitherto wasted, and through the preparation of high-protein fractions from cereal and legume seeds and leaves previously used as stock feeds. Nevertheless, research work on these and other animal and vegetable sources must be accelerated if we are to be prepared to meet the crisis which seems likely in the next 25 to 30 years.

One of the steps which may need to be taken in this crisis is the mobilization of food scientists specifically to explore new food sources. It may well be asked how this can be done effectively when most of the trained people reside in highly industrialized countries. It is impracticable to move large numbers to laboratories in the under-developed countries, not the least difficulties being that the best workers are likely to be young, have heavy family commitments, and do not wish to be culturally isolated. I suggest that one solution may be the establishment of an internationally coordinated research programme. In such a programme, a series of special research laboratories working on 'new' foods might be set up in several industrialized countries, either as separate establishments or as units attached to existing food research institutions. These would work in collaboration with institutes in under-developed countries: short-term exchanges of research workers would probably be essential to the smooth development of the research programmes. The cost is likely to be high, but the possible contribution to human welfare in the next few decades may well be crucial.

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Forty Years of Research on Meat

By E. C. Bate-Smith and M. Ingram

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THIS review will try to trace briefly the parallel development of meat research in Britain and Australia, from 1926 to the present day, in tribute to the important part played by Dr. J. R. Vickery.

The Nineteen Thirties

1926 is an appropriate starting-point because it was in September of that year that J. R. Vickery arrived in Cambridge from Sydney, and started on his lifelong journey as a food scientist (although no one in those days would have so described the profession that he has done so much to promote). The Low Temperature Research Station had then been in active existence for only four years and its Meat Section, headed by Dr. T. Moran, for three. Under its Director, Sir William B. Hardy, Moran and H. P. Hale had already made notable contributions to the biophysics of freezing of muscle. Vickery and E. C. Smith joined their team almost on the same day, the one to work on mammalian, the other on amphibian muscle, their contributions being essentially biochemical and physiological. While this was not the only laboratory in the world where the preservation of meat was being studied at that time, it was the only one where the study was aimed at an understanding of the essentially biological nature of the changes taking place in muscle after death, and of the changes brought about by the freezing of living, or once-living, tissues. A feature of this work was the insistence on accuracy in the measurement and control of temperature, an ideal that could be realized by the provision of constant-temperature storage facilities at any desired temperature between $-20°C$ and $+30°C$.

The declared practical basis of this work was the improvement of transport of frozen meat from the dominions and chilled meat from South America. Actually two ideal targets were always in mind—a completely reversible process of freezing and thawing quarters of beef, and a method of extending the storage life of chilled beef so that it could be shipped in this much more valuable form from the distant dominions. On both these objectives just as much effort was expended in the field as in the laboratory, by means of shipboard surveys of meat in transit, in which Australia and New Zealand took a leading part. The formation of the Food Preservation Section of the (then) C.S.I.R. of Australia, with Vickery as Officer-in-Charge, was an outcome of these early collaborative investigations.

At this period, 'drip' and 'freezer-burn' were the enemies. The former was overcome, so far as smallish pieces of meat were concerned, by rapid freezing; and it was at this time that the now great quick-freezing industry had its beginnings. Such pioneers as Zarotschenzeff ('Z') in America and Smethurst in England are today almost forgotten, together with the pioneer work at Karlsruhe, Cambridge, and Brisbane. By the mid 1930s, research on the freezing of packaged meat had been taken up in many other laboratories in many other countries, but in England and Australia the problem was still how to preserve beef for transport in the form of quarters without causing irreversible damage to the tissues. It was at this point that the concentration of effort in both countries was transferred to chilled beef, by the discovery of the preservative action of relatively low concentrations of carbon dioxide (Moran, Smith, and Tomkins 1932).

This chance discovery originated from a

test to see what would happen if the CO_2 were allowed to escape into containers cooled by solid CO_2, which was then being introduced as a refrigerant. It was known that high concentrations of CO_2 would cause discoloration of the lean meat, and it was assumed that high concentrations would be needed to have any appreciable effect on the growth of moulds and bacteria; but, surprisingly, 20% was sufficient to suppress the growth of moulds completely, and 12% was enough to double the storage life of meat exposed to it, without the colour of the meat being seriously affected. In Australia, however, it was found that this would not control spoilage sufficiently in practice, unless the numbers of bacteria were unusually small initially and the temperature was strictly controlled near freezing point (Empey and Vickery 1933). These requirements led respectively to investigations of meatworks hygiene (Empey and Scott 1939) and chilling procedure (Scott and Vickery 1939), which were classics of their kind and established Australian research in the front rank in this field.

There could be, however, no better illustration of the difference that exists between the solution in principle of a technical problem and the exploitation of that solution in practice, than the failure to establish a trade in chilled beef from Australia and New Zealand. The initial suggestion that it would be impracticable to maintain the desired concentration of CO_2 in the storage space (10–12%) was immediately confounded by an *ad hoc* demonstration by one of the shipping lines. The practicability of the process, *as a process*, was established, and by the outbreak of war in 1939 exports had reached the promising level of 26,000 tons per annum. Perhaps, but for the interruption, these would have expanded to a steady volume, but the essential difficulty was never surmounted. In order to fill a ship with chilled meat, the meat has to be waiting at the port for the ship to load. Chiller quality meat was simply not available in the quantity required for this to be done. The establishment of a chilled meat industry would require a reorganization of beef production in the exporting countries.

At the fundamental level, the most interesting feature of the 1930s was the development of knowledge about the relations between stress of the live animal, post-mortem biochemical changes in muscle, ultimate acidity (pH), and the various properties of meat related to its acidity (pH). Because of the war, a systematic review was only published later (Bate-Smith 1948), when this work could be taken up again (cf. below). Another notable event, just before the curtain fell, was the demonstration of the bacteriological basis of bone taint in beef, made by W. J. Scott while working in Cambridge at the Low Temperature Research Station (Haines and Scott 1940).

The War Years

So far as meat in particular was concerned, the picture changed abruptly with the outbreak of war. Chilled meat shipments were suspended and all imported carcass meat was frozen. From then on, for many years, the problems were not to be of quality, but of quantity. Economy of shipping space was a vital consideration.

The immediate effect of this was that ways had to be explored of packaging beef with as little departure as possible from the traditional form in which beef is distributed in Britain—in sizable joints. With the bone removed, rectangular packages could be stowed solidly like bricks—at such a density, in fact, that if the holds were filled the ships would sink! Shipments were made in this form for service requirements; and certain workers in Cambridge and Sydney had visions of this being the starting-point of an entirely new practice in shipping beef from the Antipodes, which has indeed now taken place.

Before long, however, even the economies effected by such methods were proving inadequate to keep pace with the sinkings of refrigerated ships, and still more drastic steps were called for. These were forthcoming in the form of dehydration. By a fortunate chance, just before the war Dr. F. Kidd, then Superintendent, and Dr. R. Gane, of the Low Temperature Research Station, had foreseen the possibility of using the 'vacuum-ice' process, as it was then called, of removing water from foods as a method of preserving their fresh quality without the need for refrigerated storage. (A provisional patent for the process, later to become so well known as 'freeze drying', is in the name of Franklin Kidd, and is dated 1939.) This process, although giving products which when recon-

stituted surpassed in quality anything that could then be produced by conventional drying processes, was quite unready for development on the scale needed to replace the imports of refrigerated foods; but it had given an entirely new conception of the quality that carefully dehydrated foods might attain and, above all, it had shown what further steps were necessary to *preserve* that quality during subsequent storage. The problem now in all commodities was to blueprint methods for dehydrating them on the thousand-ton scale, with an initial quality as nearly equal to that of the freeze-dried prototype as possible, and to provide for their packaging—under wartime conditions of container shortage—with the exclusion of oxygen that experience had shown to be necessary.

Work began on meat dehydration in both England and Australia, but the approach to the problem was rather different in each country. In England, with an eye especially on the South American producers, workers concentrated on dehydrated beef. In Australia the available material was predominantly mutton. It was soon realized that there was no time to perfect a method of dehydrating substantial pieces of meat—a coarse mince was the best that could be looked for as an immediate objective. The Australian method had several ingenious features. To overcome the time and labour of de-boning the carcasses of lamb and mutton, the carcasses were autoclaved whole with a 'skewer' inserted along the spine, and when this skewer was withdrawn the ribs and vertebrae came away with it and the flesh could be put through the mincer almost without the assistance of the butcher. The dehydrated meat, known to us as 'Vickery mutton', was an excellent product but some comment was aroused by its flavour. This was at first described as 'merino flavour', since so much of the available meat was from this breed; but some of us thought it was due, at least in part, to the high temperature of the autoclave causing creatine to be converted into creatinine. Australian post-war work on dehydrated mutton is described in a series of papers by Howard, Prater, and Coote (1956–62).

The British process involved part-cooking as an essential feature, followed by dehydration in the form of a coarse mince in a streamlined drier based on the Torry kiln. The product was compressed into tapered cans, and these when sealed could be kept indefinitely without gas-packing, because the very little residual oxygen was absorbed by the meat without giving rise to off-flavour (Sharp 1953). Plants with a production capacity of 60,000 tons per annum were erected as a contingency in South America, but the need to use them to this capacity fortunately never materialized.

Quantities of dehydrated meat were, however, employed in service rations. In the development of these rations for the European theatre, the Low Temperature Research Station took a leading part. In the Far East, Australian food scientists played a similar role, their activities being especially concerned with storage of perishable foods under tropical conditions. However, members of the staff of the Low Temperature Station were also involved in this theatre, setting up plant for dehydrating meat in India for supplying troops in Burma. Their efforts were somewhat unrewarding, because of the very low yield of meat from the emaciated sheep and goats that were available.

The philosophers' stone of meat research at this period was a method for dehydrating steak. Perhaps the reason for this was that only with this could there be any commercial future for meat dehydration after the war. Although it was not achieved — and has still not been achieved with any measure of success — much progress was made in dehydrating, and reconstituting, meat in substantially larger pieces than the standard coarse mince. When, later, the 'accelerated freeze drying process' was developed at the Ministry of Food's Experimental Factory (Rolfe 1958), whole steaks of meat and fish were dehydrated; but, in commercial practice, its use has been virtually confined to small pieces for dried stews and soup mixes.

Whalemeat

Even in the years before the war, depletion of the whale population was becoming a matter of public concern. It was common knowledge that the large amounts of whalemeat that could not be profitably processed for oil were thrown overboard, and it was reported that much of this represented good edible meat. Under the leadership of Commander Marr, of the Colonial Service (Discovery Investigations), a small team set out on the *F.F. Terje Viken* in 1939 to study the

possibilities of reclaiming this meat for human food.

The information they gathered was promising enough for further expeditions to be sent after the war when there was a desperate world shortage of food. Commercial exploitation of their recommendations was just beginning when some Scandinavian whalemeat of very inferior quality was distributed to the public, and killed the trade. However, a great deal of scientific information came out of these expeditions (Sharp and Marsh 1953; Robinson *et al.* 1953). One of the observations made was that whale muscle, contrary to well-established belief, did in fact undergo *rigor mortis*, but only after a very long period after death. The reason for this delay was the high concentration of myoglobin in the muscle. It is interesting to remark that Dr. Bruce Marsh of New Zealand was a member of one of these expeditions, and when he returned to England he stayed on at the Low Temperature Research Station and there discovered the 'relaxing factor' in muscle, which bears his name.

The last act of the whalemeat story took place, in fact, in Australia, when Dr. H. L. Webster was asked to make observations of the redox potential in the muscles of whale carcasses, to confirm the theory that the carcasses of meat animals are preserved from putrefaction for several hours after death because this redox potential is at first comparatively high (Ingram 1962).

The Post-war Years

The immediate post-war years were marked by a world scarcity of meat — even more severely felt in Britain than during the war itself. Meat was rationed for nine more years, and during this period of control by the Ministry of Food a number of 'combined operations' were mounted with the southern dominions. Attempts were made to revive the shipment of chilled beef from New Zealand, but the difficulties of meeting the ships with a steady flow of chiller-quality meat proved too great, and this promising trade has not been resumed.

However, a committee was set up by the Ministry to encourage cooperative research between the three countries, and a vigorous programme of research was begun to try to settle the question whether, given raw material of equal quality, frozen beef was, in fact, in any way inferior to chilled when judged by the quality of the ultimate cooked product. These experiments were in full swing (and the answer appeared to be that it was, in reality, the quality of the *carcass* that mattered, and not the method of preservation) when rationing and Ministry control came to a sudden end, and Nature (in the shape of private enterprise) was allowed to take its course. In these investigations, a leading part was played by the late Mr. N. E. Holmes, originally a member of the staff of C.S.I.R., Australia, then seconded to the Ministry of Food, and finally employed as a food technologist by F.A.O.

It was during this period that the New Zealand Meat Industries Research Laboratory was set up, with Mr. Norman Law as Director, and various collaborative experiments in methods of shipment were undertaken with the Refrigerated Cargo Research Council, the Low Temperature Research Station, and the Ministry of Food, with which N. E. Holmes also was associated. The useful conclusions were taken up directly by the shipping companies, and none of this work has ever been published.

Alongside the trade in frozen meat, there were odd experimental shipments to test further possibilities of shipping meat unfrozen. Several used ultraviolet lamps, but it is scarcely possible to reconcile the opposing demands of general illumination and tight stowage. The most interesting was a shipment of beef quarters in 100% nitrogen, which turned out very well, the quarters having been shipped in small gas-tight tanks. But, in a ship's hold, it is impossible to prevent 'breathing'; and theoretical reasoning suggests that introduction of only a small proportion of oxygen might suffice to produce conditions almost equivalent to those in air, though the question has not been carefully examined.

From our viewpoint, the most interesting work of this period was a long series of investigations on the effects of pre-mortem treatment of beef cattle, carried out jointly by A. Howard, Officer-in-Charge of the CSIRO Meat Research Laboratory at Cannon Hill, Qld., and R. A. Lawrie, of the Low Temperature Research Station. It was convenient to carry out these experiments in Australia rather than Britain, because there

are fewer legal restrictions on the manipulation of live animals. The outcome of these investigations was a series of eight papers (Howard and Lawrie 1956–60), sufficiently important to be published separately in Australia and in Britain.

The initial object was to see whether the relations between treatment of the animal before slaughter and quality of its meat after slaughter, which had been discovered with pigs at Cambridge before the war, were equally applicable in the treatment of beef cattle. It was found that the relations were fundamentally the same, with the most important practical difference being that beef animals are much more resistant to all forms of stress like fatigue than are pigs. Only by extreme measures was it possible to produce meat of a high pH in beef animals; but, when this was done, it possessed the same qualities as with pork, in its dark colour, high water-holding capacity, and gelatinous texture. Parallel experiments explored the effect of these variations on the freezing of meat and its quality after thawing. It is interesting that the very first paper reported a toughening as a result of inappropriately rapid freezing; this, in retrospect, seems clearly to foreshadow more recent New Zealand demonstrations of the similar toughening of frozen mutton. Another off-shoot was a bacteriological demonstration that the rate of growth of slime bacteria on beef was influenced by the time to *rigor mortis* independently of pH (Brown, Coote, and Meaney 1957); but attempts to repeat the experiments were unsuccessful, as were attempts to discover the biochemical basis of the presumed relation, so this intriguing observation has not been pursued.

Besides the work on the physiological basis of beef quality, the CSIRO laboratory at Cannon Hill became engaged in work on ozone and on freezer-burn. A review (Ingram and Barnes 1954) of earlier British work on ozone had emphasized the discrepancy between the large concentrations needed to inhibit bacteria in laboratory experiments with ozone and the small concentrations claimed to be effective in practice; and Kaess (1956) began a thorough investigation of the chemical reactions between the ozone and the meat, the importance of which had been emphasized in the British survey. The work on freezer-burn came later, and culminated in the description (Kaess and Weidemann 1962) of conditions of freezing that are capable of minimizing the defect; these conclusions represented a substantial advance on earlier work, which instead had emphasized the prevention of evaporation during storage (cf. Sharp and Marsh 1953).

During this period, work in Cambridge was revealing the importance of redox potential in controlling the anaerobic putrefaction of meat, as already mentioned (Ingram 1958); and it became possible to take a more general view of the numerous connections between the bacteriology of meat and the post-mortem biochemical changes (Ingram 1962). At the same time, biochemical work (reviewed by Bate-Smith and Bendall 1956) was paving the way for the demonstration that pale watery muscle in pigs is the consequence of an unusually rapid rate of post-mortem glycolysis in the animals concerned (reviewed by Bendall and Lawrie 1964). Very recently, knowledge of the biochemical mechanism of this glycolysis has been greatly improved by a series of collaborative investigations, between Dr. R. P. Newbold, of CSIRO, and Dr. R. K. Scopes, of the Low Temperature Research Station, who spent $2\frac{1}{2}$ years at North Ryde on an Australian scholarship (papers in preparation).

Throughout this post-war period, Vickery's main research effort was directed elsewhere, notably to work on plant products and on the preservation of eggs (see accompanying article). His continuing interest in meat was, however, signalled by various review articles and, especially, by a neat paper on the sulphide staining of meat cans (Johnson and Vickery 1964), which showed that the evolution of H_2S from heated meat is yet another of the properties dependent on pH (acidity) and hence related to the condition and treatment of the live animal at slaughter.

Latterly, however, as events show, Vickery's main energies in the meat field must have been devoted to the administrative preparations for the new CSIRO Meat Research Laboratory, which was opened at Cannon Hill, Qld., on 31 May, 1967. To crown a lifetime's interest in meat research, Dr. Vickery has seen, just before his retirement, the completion of this new building as a fully fledged offshoot of his Division's main laboratory in Sydney, and the natural development from the famous, if small,

Cannon Hill laboratory that was opened in 1932. He himself played a major part in its creation, and there his lifelong colleague and friend, Dr. W. J. Scott, is now Officer-in-Charge. As if to emphasize the traditional connection between meat research in Australia and Britain, the authors of this article have just taken part in an almost exactly parallel evolution in Britain; and this augurs well for everybody's hopes that, in the future as in the past, close contact between the two countries will be maintained in research on meat.

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Fifty Years of Research on Egg Quality

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The past half century has witnessed a remarkable development of scientific knowledge about egg quality. Paced by a general upsurge in basic research in the physical and biological sciences, this specialized field has made dramatic progress that has carried over strongly into the commercial marketing and preservation of shell eggs. Research on egg quality has involved scientists and institutions from North America, Europe, and Australia, working in informal but effective collaboration and cooperation. Much of the progress that has been made resulted from a concentration of effort by research groups over a span of time, under the stimulation of vigorous and effective leadership. This review will reflect that particular aspect of the subject by frequent reference to names of research centres and their leaders. Thus it will have special relevance to the primary purpose of this commemorative issue of the Quarterly, that of honouring Dr. J. R. Vickery, one of the leaders in food research in general and egg quality in particular.

Quality Defined

Let us first define what is meant by quality. A generally accepted definition states that it is made up of those properties of a food that affect consumer acceptance. These properties include: sensory attributes such as appearance and colour, aroma and flavour, and texture; shelf or storage life; functional properties such as whipping and emulsifying power; and freedom from infective agents such as *Salmonella* bacteria. Frequently now, nutritive value and freedom from foreign substances are also being included as important attributes of quality.

In this review primary emphasis will be placed on the sensory properties, storage life, and infective agents, since most of the research on egg quality has been carried out on these attributes and most of the progress made thus far has concerned them.

The Early Years

Beginnings

While many zoologists of the 17th and 18th centuries took a keen interest in the egg as a suitable subject for histological and embryological research, most of their work had little relevance to egg quality. Then, too, French chefs have, for a very long time, probed the secrets of the egg in cookery. They learned much about what can be done with eggs for this purpose; yet the end result of their efforts has not been a systematic body of scientific knowledge about egg quality, but rather a collection of recipes for elegant dishes for the connoisseur.

A study of the world's scientific and technical literature on eggs suggests that the beginning of research on egg quality probably occurred in the first or second decade of the 20th century. Dr. Mary Pennington, of the United States Department of Agriculture, seems to have been a leader in these early efforts. During this period, there was a tremendous upsurge in farm poultry production in the mid-western United States. Efforts to market the very large spring surplus of eggs led to an expansion of the cold storage industry, so that the bulk of these eggs could be kept in satisfactory condition until a demand developed for them the following winter. This state of affairs posed some serious problems.

Since little information was available at the time about the proper conditions for the cold storage of eggs, Dr. Pennington's group had the task of finding out how best to select and package eggs for storage and to condition the storage rooms. While much of what was done would not be classified as research today, the group did accomplish a great deal. For example, Jenkins and Pennington (1919) established the necessity of storing only the freshest eggs produced during the early spring months, using only clean sound-shelled eggs,

with temperatures near freezing and high humidity in storage rooms, and avoiding excessive 'sweating' of eggs.

Experimental Work Emerges

Systematic research based on well planned and executed experiments also began to emerge during this period, and was conducted by this same group. Early studies centred on the weight losses that occur during storage; the efficacy of mineral and vegetable oils for reducing these losses; and precise temperature requirements for cold storage. A good deal of work was also done on factors affecting spoilage by bacteria and moulds during storage. Results of these early studies showed that while the contents of sound eggs as laid are nearly always sterile the shell surface almost never is. While storage room humidity and air circulation were recognized as having important effects on the growth of moulds on the shell, no specific studies aimed at determining optimal conditions were reported during this period. Physico-chemical studies carried out by Jenkins *et al.* (1920) showed that there is an increase in ammoniacal nitrogen level and a transfer of water from the albumen to the yolk during cold storage.

A group to work on egg quality at the Low Temperature Research Station of the Department of Scientific and Industrial Research was formed in the 1920s in England, under Dr. T. Moran; it, too, began to publish on the cold storage of eggs. Some elegant studies on the effects of freezing and thawing on shell eggs were reported by Moran and Piqué (1926). These studies showed that if eggs are allowed to freeze at temperatures below $-6°C$ the yolk becomes stiff and pasty when thawed. However, it was shown that eggs may be supercooled to temperatures as low as $-11°C$ without visible change. The optimal temperature for retention of embryo viability was found to be near 10°C, but it dropped off sharply below or above that temperature.

The Great Upsurge

From a study of the scientific and technological literature of the time, as well as from personal recollections (*c.* 1930), it can now be recognized that a major upswing and reorientation of research on egg quality were in the making by the end of the third decade of this century. More well-trained chemists and biologists were entering the egg quality field, not only in government laboratories but also in universities and even in the egg marketing industry. They were an aggressive and ambitious lot, bent on upsetting the tenets of 'traditionalists' by developing scientifically valid bases for egg quality criteria and their measurement, and also principles for egg storage and handling practices. Several research centres were established during this period of tremendous effort, which continued until World War II, and some very capable leaders appeared on the scene to direct the research work. A capsule account of these centres, their leaders, and the key accomplishments during this period follows.

Cornell University

Dr. Paul Sharp, and the vigorous group under his leadership, attacked a wide range of quality problems for nearly a decade at Cornell. Perusal of their publications reveals a number of substantial contributions concerning the establishment of quality criteria and methods for measurement of yolk index, percentage of thin white, albumen score, and flavour score (Sharp and Powell 1930; Sharp 1932, 1934); the key role of carbon dioxide in the preservation of interior quality (Sharp and Whitaker 1927); inefficiency of candling as a means for measuring interior quality (Stewart, Gans, and Sharp 1932*a–f*, 1933*a,b*); the effect of relative humidity on mould growth on eggs in cold storage (Sharp and Stewart 1936); and the effect of packaging material on the flavour of cold-stored eggs (Sharp, Stewart, and Huttar 1936).

Other studies at Cornell by van Wagenen and his colleagues during this period led to the development of another index for albumen quality—albumen score—by van Wagenen and Wilgus (1935), and to the establishment by van Wagenen and Hall (1936) and van Wagenen, Hall, and Wilgus (1937) of the heritability of albumen quality.

University of California

A few years after the Cornell programme got under way, a very similar effort was initiated in California under the leadership of Drs. Holst and Almquist, who were later joined by Drs. Taylor and Lorenz. This group and their successors have maintained a very active research programme on egg quality right down to the present.

This group also made a number of important

contributions to egg quality during the 1930s, including the establishment of shell quality (Holst, Almquist, and Lorenz 1932) and percentage of firm white as criteria, and their measurement (Lorenz and Almquist 1934*b*); seasonal decline in egg quality (Lorenz and Almquist 1936); inadequacy of candling for determining interior quality (Almquist 1933); malvaceous weeds as a cause of a pink white defect (Almquist and Lorenz 1932); and a genetic basis for interior quality (Lorenz and Taylor 1940).

Washington State University

Work at this institution began early, with Dr. St. John, whose research was mainly concerned with the rheological properties of the thick white and with physico-chemical differences between thick and thin white (St. John and Green 1928, 1930). A broad programme of research got under way a little later under Professors Carver and Heiman, who were joined by Dr. Wilhelm.

These workers, with their collaborators, made a variety of important contributions towards establishment and measurement of albumen index and yolk colour index as specific quality criteria (Heiman and Carver 1935, 1936); relation of albumen index to other measures of albumen quality (Heiman and Wilhelm 1937*a*); factors influencing the transfer of pigments from the feed to the yolk and the resultant colour (Heiman and Wilhelm 1937*b*); seasonal changes in egg quality (Wilhelm and Heiman 1938); inheritance of interior quality (Wilhelm and Heiman 1936); and effectiveness of oiling soon after laying for interior quality preservation (Evans and Carver 1942; Evans 1942).

D.S.I.R. Low Temperature Research Station

By the 1930s the group at Cambridge had developed a very active research programme. Drs. Moran and Haines, and their colleagues, were mainly engaged in research on cold storage, including environmental means for reducing weight losses and means for reducing spoilage due to the invasion of the egg by moulds and bacteria.

Haines (1939) published a monumental work that brought together the world's literature on the latter subject and also summarized the very considerable work and significant findings of the Low Temperature Research Station on the egg's built-in defences, modes of infection, effects of washing, types of spoilage and the responsible organisms, and factors influencing microbial growth in the egg following invasion.

Moran (1939) and his co-workers made a number of studies on controlled atmosphere storage. He demonstrated the adverse effects of high levels of CO_2 (full gas storage) in causing excessive shrinkage of the thick white but otherwise providing good keeping qualities. Comparative studies of ordinary, partial, and full gas storage showed the efficacy of the second method.

Other Research Centres

In a number of other universities, government laboratories, and industrial firms individual workers were active in egg quality research during the 1930s. Of these, two of the more important were Raymond Haugh (1933, 1937), of Kraft Foods Ltd., who became world-renowned for his Haugh unit for measuring the quality of the thick white, and Dr. Funk (1937, 1938), at the University of Missouri, who investigated poor sanitation and management in laying houses as causes of dirty eggs and the use of sodium hydroxide in washing eggs.

World War II and Beyond

World War II brought about drastic changes in egg quality research. In some cases, programmes were phased out completely owing to loss of staff and graduate students, and in others they were substantially changed to allow for war-related projects.

The end of the war in 1945 brought other changes in quality research, arising from the increasing importance of specialized commercial laying flocks, which began to dominate the industry while production on mixed farms declined. This led to more uniform production throughout the year and a sharp decline in cold storage of eggs. The trend to larger and larger flocks has also made more practicable the application of scientific advances in genetics, physiology, nutrition, and pathology to the industry.

For our particular purpose, it will again be appropriate to look at the progress in egg quality research during this period by focusing our attention on centres, their leaders, and the accomplishments.

CSIRO Division of Food Preservation

Egg quality research, especially on the problems of egg washing, had been started by

this organization shortly before World War II, but was temporarily shelved after war was declared because no further export shipments could be made and because of the urgent need for research of more direct concern to the war effort. However, the programme was resumed immediately after peace came in 1945, and an analysis of the nature of wastage in eggs exported from Australia was published (Alford *et al.* 1950).

Drs. Vickery and Scott led a team effort on the egg washing problem, which resulted in the several key discoveries opening the way to successful cleaning of dirty eggs. These were the important findings by Gillespie, Scott, and Vickery (1950*a*,*b*) that the water compartment of egg-washing machines then in use harboured and actually permitted multiplication of spoilage bacteria there, and that spoilage bacteria can easily penetrate the outer shell structure, down to the inner membranes, during washing. Unless quickly destroyed, these organisms will then penetrate the inner membranes and cause spoilage by growth in the albumen and/or the yolk (Gillespie and Scott 1950). Gillespie, Salton, and Scott (1950) studied the use of disinfectants in egg-cleaning machines, and Salton, Scott, and Vickery (1951) and Scott and Vickery (1954) investigated pasteurization of the eggs in shell for destruction of these bacteria.

Another important post-war project on egg quality was the study by Dr. Vickery and his group of the pink white defect, which had been a problem since the 1920s when it was observed in eggs from hens fed cottonseed meal. In the 1930s, pink whites were shown by Lorenz and Almquist (1934*a*) to result from the consumption of malvaceous weeds. Shenstone and Vickery (1956, 1959, 1961, 1962) showed that this defect is specifically caused by the presence of malvalic acid or sterculic acid in the feed, or both. Later work, partly sponsored by the United States Department of Agriculture's Foreign Agricultural Research Programme, was reported by Shenstone, Vickery, and Johnson (1965). Shenstone and Vickery (1958) also investigated the effects of oiling on maintenance of quality.

Iowa State University

Egg quality research at Iowa State had its beginnings before World War II, but reached a high level during and after the war period. Professors Belle Lowe and George Stewart first teamed up to study the functional properties of eggs, and especially the effects on these properties of processing and preservation practices applied to the egg contents. Several specific performance tests were developed, and the precise time/temperature tolerance data for pasteurizing were developed for albumen and mixed albumen and yolk by Hanson, Lowe, and Stewart (1947), Payawal, Lowe, and Stewart (1946), and Slosberg *et al.* (1948).

A parallel series of studies was undertaken on ways and means of controlling the microbiological quality of eggs and their products, especially for the elimination of *Salmonella*. This particular programme later came under the leadership of Dr. Ayres, who was later joined by Dr. Forsythe. Pasteurization times and temperatures were established for whole egg by Winter, Greco, and Stewart (1946) and Winter *et al.* (1946), and a unique method was developed by Ayres and Slosberg (1949) for inactivating *Salmonella* in albumen, which consists of heating it in the dry state.

Another programme on the storage life of dehydrated eggs resulted in the establishment by Stewart and Kline (1941), Kline and Stewart (1948), and Kline *et al.* (1951) of the key roles of glucose and moisture content in the deterioration of colour and solubility.

D.S.I.R. Low Temperature Research Station

The egg quality work of this laboratory was largely shifted to dehydration problems during World War II, when a variety of projects was successfully carried out. Incidentally, some effective cooperation on dried egg developed between American, English, and Australian workers during this period.

The early war work of this group, under Bate-Smith, Hawthorne, and Brooks, clearly showed the nature and extent of the quality problems in dried whole egg (Bate-Smith, Brooks, and Hawthorne 1943; Bate-Smith and Hawthorne 1945; Bennion, Hawthorne, and Bate-Smith 1942). The roles of low storage temperatures, added carbohydrate, and low moisture in improving the initial quality and storage life were important contributions (Hawthorne and Bennion 1942; Brooks 1943; Brooks and Hawthorne 1943; Hawthorne 1943, 1944).

After the war the research programme gradually reverted to studies of shell eggs,

especially problems arising from washing and cold storage. A significant contribution was the development by Brooks (1955) of a quick and simple test for washed eggs.

National Research Council of Canada

This group was very active during World War II, especially in egg quality research related to dehydration. The team headed by Drs. Gibbons, Pearce, and White made several significant contributions on development of fluorescence and refractive index tests for solubility (Pearce, Thistle, and Reid 1943; White and Grant 1943); heat damage due to improper drying and storage conditions (White and Thistle 1943; White and Grant 1944); and *Salmonella* infection and its control by pasteurization before drying (Gibbons and Moore 1944*a*,*b*; Gibbons, Moore, and Fulton 1944; Gibbons, Fulton, and Reid 1946).

U.S. Department of Agriculture (Beltsville Station)

This group, under the leadership of Drs. Wade Brant and Carl Norris, carried on a very effective research and development programme for a period of years after World War II. Especially noteworthy was their work on quality standards for shell eggs and quality control schemes, taking into account genetic, nutritional, physiological, and pathological factors, and recognizing the limitations of candling (Brant, Otte, and Norris 1951; Brant 1951; Brant, Otte, and Chin 1953); electro-mechanical methods for quality control, especially the blood spot detector (Brant, Norris, and Chin 1953) and the green rot detector (Mercuri *et al.* 1957); shell porosity and shell membranes as barriers to microbial invasion (Kraft, Elliott, and Brant 1958; Kraft, McNally, and Brant 1958).

Over the years the Beltsville Station has also carried on considerable work on genetics of egg quality. Recently, Quinn (1963) has been able to show the feasibility of combining breeding for egg quality and egg production.

U.S. Department of Agriculture (Western Regional Laboratory)

This group became active in egg quality research in the latter part of World War II, when an intense programme was developed on the storage life of dried egg products. Fevold *et al.* (1946) demonstrated the value of low moisture and low storage temperature on retention of flavour and functional properties of whole egg. Low pH and low oxygen levels were also shown by Lightbody and Fevold (1948) to be effective in prolonging shelf life, and Boggs *et al.* (1946) published a paper on the effect of lipids in the dehydrated egg on its palatability.

Kline, Gegg, and Sonoda (1951) discovered a reaction in dried whole egg and yolk between glucose and the phospholipid, cephalin, which causes a serious off-flavour. Removal of the glucose prior to drying effectively stabilizes these products, as Hawthorne and Brooks (1944) had shown, and additives were used to offset damage to beating power. This group also demonstrated the feasibility of pasteurization of liquid albumen for the destruction of *Salmonella* (Kline *et al.* 1965).

Lineweaver and his group (1965) at the laboratory have also studied pasteurization techniques. Of special significance was the greater heat tolerance of liquid albumen obtained by the use of aluminium salts and lowered pH in pasteurization for elimination of *Salmonella*.

Garibaldi and Bayne (1960, 1962*a*,*b*) have shown the important role of iron in the spoilage of shell eggs by *Pseudomonas*. Their finding has special significance in the washing of dirty eggs because of the predominance of this organism and the possibility of contamination from the wash water.

University of California

Egg quality research continued here throughout the period under discussion, with major emphasis on genetic, physiological, nutritional, and pathological aspects on the production side, and on washing of eggs and consumer studies on the marketing side.

Taylor and Lerner have carried on extensive studies on the heritability of quality factors. Shell texture (Taylor and Lerner 1939) and blood spotting (Lerner, Taylor, and Lowry 1951) have both been shown to be heritable factors. Taylor (1960) published a review on the inheritance of quality factors.

Lorenz and his group carried out extensive studies of egg washing in the 1950s. Significant findings included the desirability of not re-using the wash water and of maintaining the water at temperatures higher than the eggs during washing (Starr, Lorenz, and Ogasawara 1952).

Brant and his group (Walters *et al.* 1966)

have developed and field tested an egg washer of superior performance. Important design features include water supply of controlled pressure, temperature, and detergent–sanitizer content, means for wetting the shell prior to scrubbing, cutting nozzles for removal of loose dirt, scrubbing section using rotating brushes of abrasive-coated nylon bristles, egg rotating device, cutting nozzles for rinsing, and a separate hot-air dryer. Brant, Starr, and Walters (1966) have also recently published an excellent annotated bibliography on egg washing.

Stewart and his collaborators studied consumer reaction to interior quality factors. Their surveys (Sanborn *et al.* 1959) showed that consumers reacted quite unfavourably to blood spots, but were much less discriminating about different levels of albumen quality, although they did prefer a thick viscous albumen to thin watery ones.

Other Institutions

A very considerable number of independent research workers in a variety of institutions and agencies have also been active in the post-war egg quality field. While there is not space to discuss all of them, a few of the more important must be mentioned: Evans, Bandemer, and Davidson (1960), at Michigan State University, for contributions made in chemical studies of discolorations caused by cottonseed feeding (also Evans *et al.* 1954); Tyler and Geake (1964) and Tyler and Moore (1965), at the University of Reading (England), for histological and chemical work on shell structure and factors affecting strength; and Funk (1943, 1948, 1950, 1955), at the University of Missouri, for further work on washing and pasteurization of shell eggs.

Epilogue

Thus ends a brief historical account of egg quality research over the past half century. It is clear that there have been tremendous accomplishments by scientists around the globe. Though much has been accomplished, much remains to be done. For the future, it would be a good thing to see some emphasis placed on other quality problems. While nothing has been said about nutritive value, this is one of the most important qualities of eggs. The protein content of the egg is high and its quality excellent; vitamin levels (except for ascorbic acid) are high, and a variety of the essential minerals are found in eggs. We need to know more about all of these nutrients, how to control their levels through the use of breeding, nutrition, and other factors, and the effects of processing and preservation upon them. Convenience in use is another quality criterion that has not been mentioned yet, and more work is needed here. Then, too, we know little about the functional properties of eggs despite their importance in manufactured foods such as cakes, pies, salad dressings, and candy. And, of course, much remains to be done on keeping eggs free of harmful bacteria, viruses, and toxic materials. The ever-widening use of pesticides has increased the danger of toxic residues whose entry into eggs will need further study.

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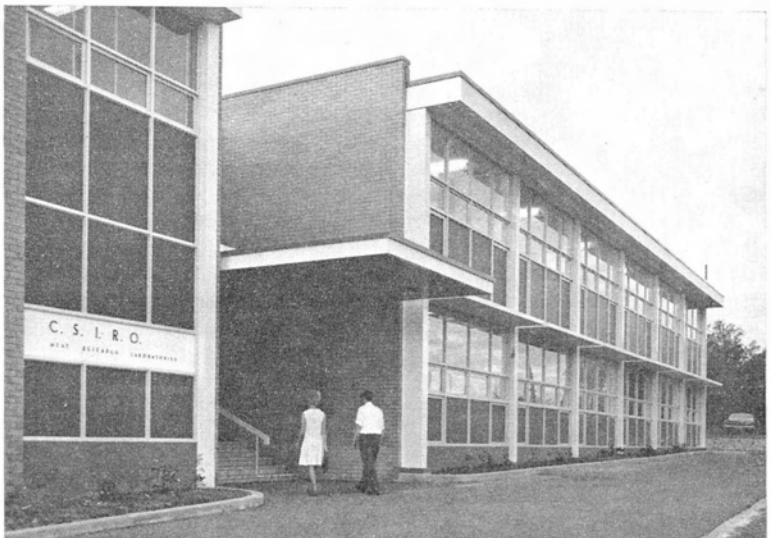
Opening of the CSIRO Meat Research Laboratory

A HISTORIC EVENT took place on May 31, 1967, when the new Meat Research Laboratory of the Division of Food Preservation was officially opened at Cannon Hill, Qld., by Mr. J. L. Shute, O.B.E., Chairman of the Australian Meat Board, in the presence of a representative gathering of 130 people.

In the absence overseas of the Chairman, Sir Frederick White, the CSIRO Executive was represented by Mr. C. S. Christian, who referred to the opening of the Laboratory as a major step in the advancement of research in Australia, and mentioned that CSIRO had 10 Divisions in Queensland in 18 different laboratories and field stations, many working on problems of direct consequence



to the beef cattle industry. Mr. Christian stated that the northern parts of Australia could carry eight times as many beef cattle as at present, and that it was essential to obtain a better understanding of the complex changes that meat could undergo, in order to enhance its quality and sell it on competitive markets. He explained that the Meat Research Laboratory was being built in two stages. The first segment, now about to be officially opened by Mr. J. L. Shute, was for research on beef. In the second part, planning for which had already begun, it was intended to do research on other meats, especially mutton and lamb.

Mr. Shute, in opening the Laboratory, said that it would be of very great value to the meat industry. In 1965 Australia was the world's largest exporter of beef, and meat was its third most valuable export. The industry would now be buttressed by a meat research centre operated by CSIRO. He was particularly pleased that the new Laboratory would contain a section to which industry could refer its everyday technical problems.

In thanking Mr. Shute, Dr. Vickery referred to him as an outstanding and very far-sighted leader of the Australian meat industry. He went on to recall that it was towards the end of July 1932 that the late Senator McLachlan opened the first Meat Research Laboratory in the Brisbane abattoir at Cannon Hill. Now, nearly 35 years later, CSIRO was opening fine premises of its own. His own connection with the meat industry went back over 40 years, and he had had the honour of leading a meat research team since 1932.

Until quite recently, Australian research on meat was not commensurate with the importance of the industry. There were four research officers working on meat in 1938, and 25 years later there were still only four. Since 1963 all this had changed. Dr. Scott already had a team of nine research scientists, eight experimental officers, and about 25 others, with more appointments to be made.

In the course of outlining the research being undertaken at the Meat Research Laboratory, Dr. Vickery stated that emphasis would be placed on the problems associated with meat export, but the results obtained would contribute very greatly to the efficiency of the local industry and the acceptability of its products. A wide range of skills was needed in dealing with meat, and the Laboratory would use a variety of scientific disciplines. It was intended to do a great deal more on sheep meats, particularly mutton. Other work to which it was proposed to give attention was the microbial contamination of meat, which was particularly important in small goods and packaged meats. Public health authorities were becoming greatly concerned with the pathogens carried by meat and other foods. The Laboratory would also be studying the variability of meat, which greatly vexed consumers and was imperfectly understood. Engineers and physicists at the Laboratory would seek more reliable data on which to base the design of cooling and freezing rooms. Investigations had already begun on mechanical methods of removing the skin from sheep and lambs.

It was the desire of CSIRO to build close personal contacts between technical personnel in the industry and the Laboratory. To this end, a Meat Research Advisory Committee had been set up, which would help to keep CSIRO acquainted with the problems of the industry. For its part, CSIRO would convey the results of its work to the industry through many channels, including a series of Meat Research Letters.

Dr. Vickery concluded by stating that he looked forward with great optimism to the future of the Meat Research Laboratory. He was sure that Dr. Scott and his research team would achieve much more in the next few years than had been possible in the last 35 years.

Guests at the official opening had the opportunity to inspect the laboratories, which stand on a 15-acre site in Wynnum Road, Cannon Hill. The buildings, which have a total floor area of 22,100 sq ft and cost $582,000, comprise a two-storey air-conditioned administration and laboratory block, and an ancillary services building. There are also animal pens on the site. The administration wing contains the library and offices, the air-conditioning and water treatment plant, the electrical substation, and the switch room. In the laboratory wing there are 13 laboratories with associated special purpose rooms, two cold laboratories, and four constant temperature rooms. The ancillary services building contains the refrigeration plant, refrigerated meat-preparation room, four cold rooms (including two gas-tight cold rooms), and workshops.

Valedictory Functions

Sir Frederick White (*right*) and Dr. W. J. Scott (*left*) farewell Dr. J. R. Vickery. In the background is a mural depicting the work of the Division of Food Preservation.

THE RETIREMENT of Dr. Vickery as Chief of the CSIRO Division of Food Preservation was marked by several memorable functions. The Council of Australian Food Technology Associations tendered him a complimentary dinner at the Hotel Australia, Sydney, on June 20, when about 200 persons from the numerous and diversified sections of the Australian food industry and from Government departments met to do him honour. The CSIRO Executive, his fellow chiefs in CSIRO, and University colleagues arranged a similar function at the Killara Golf Club, Sydney, on June 30.

The staff of the Meat Research Laboratory at Cannon Hill, Qld., farewelled Dr. Vickery on June 26, and the main valedictory function took place at the Divisional Headquarters at North Ryde on July 7. The staff of the Division had subscribed for a portrait of Dr. Vickery by the Sydney artist W. E. Pidgeon, and this was unveiled by the Chairman of CSIRO, Sir Frederick White. It now hangs in the entrance foyer of the laboratories at North Ryde. Dr. W. J. Scott, Assistant Chief of the Division, presided over the unveiling ceremony and spoke of the personal qualities that had caused the staff to hold their Chief in such affection. Many goodwill messages were received from scientists in other parts of Australia and overseas.

In the evening Dr. Vickery and his family were guests at a social gathering, where the history of the Division was recalled in happy vein by the President of the Food Preservation Staff Club, Dr. N. S. Parker, who presented Dr. Vickery with an oil painting of an Australian scene, entitled "Mallee Hillside".

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