THE CONTRIBUTIONS OF TWO AUSTRALIAN WOMEN SCIENTISTS TO ITS WOOL INDUSTRY

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By the early 1960s there was a general decline in the consumption of wool, Australia's leading export. Prices were falling and it became clear that wool was suffering from the competitive advantages of the artificial fibres then starting to flood world markets. If the wool industry were to compete successfully, a high quality fleece would have to be produced by growers and the disadvantages of felting and shrinking would have to be overcome. Two Australian women scientists addressed these problems. One was concerned with the genetics of sheep breeding; the other worked on the physics of wool fibres to reduce their limitations in the textile product. The paper examines the major contributions made by these women in meeting the threat to the Australian wool industry posed by the development of synthetics.

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The conventional wisdom that Australia rides on the sheep's back arises from a profound economic reality. Before World War II, wool dominated the Australian economy. It was both the most important single rural product and the most important export.[1] Though secondary industry developed markedly after the War, the role of wool as an earner of foreign exchange was maintained into the late 1950s.[2] In fact, in 1950 its share of total export earnings was nearly 50 per cent.[3] Prices had risen by leaps every year after the War, and in 1951 there was an unexpected excalation caused by the fact that the United States suddenly needed wool for military clothing in the Korean War.[4]

Nevertheless, the development of synthetic fibres had been worrying the industry from the 1940s. The annual reports of the Australian Wool Board[5] make reference to this threat almost yearly up to the late 1950s, and the threat was a real one. The need to meet it and to maintain buoyancy in world markets presented the wool industry with major challenges. In the following decades the work of two Australian women scientists, Dr Helen Newton Turner and Dr Rachel Makinson,[6] did much to solve some of the problems.

This article deals with the contributions of these two scientists to the wool industry, drawing on archival material as well as interview transcripts. It is derived from a major study being carried out by the author of eminent Australian women scientists who were active during and after World War II. It describes how the research findings of two scientists helped a major Australian industry, and it illustrates the valuable and diverse contribution made by women to Australian science. As Australia becomes more conscious of its heritage, it is timely to document the work of its scientists. Although there have been relatively few women scientists of note, their contribution should be acknowledged both to give a balanced picture of the history of Australian science and to provide examples to encourage Australian school girls to consider studying and later working in science.

There is only one product 'wool', but the number of synthetic fibres capable of being developed is almost without limit. While the sudden rise in wool prices in 1951 no doubt delighted the woolgrowers, the attraction of synthetics was undeniable — they were cheaper, their prices were stable and their production could be more easily controlled than that of wool. Although wool prices stayed reasonably high, they fluctuated during the 1950s and early '60s and then began to decline, reaching a major trough in the '70s, the direct result of competition from synthetic fibres.[7]

In the six years 1952-58, the proportion of synthetic fibres used for clothing rose from about 16 per cent to about 22 per cent of the global consumption of all fibres.[8] This was of great concern to Australia. By far the greatest number (over 70 per cent) of sheep in Australia are and were merinos, a breed which produces a fine wool for clothing. Wool for clothing was seen, and promoted, as a luxury fibre, yet it was precisely in the wealthy countries which could afford so-called luxury clothing that man-made fibre consumption was rapidly rising and wool consumption falling. Another trend which repressed the buying of woollen goods was a fashion in the 1950s for light-weight suits and dresses, in part a result of the growing use of air conditioning in the United States.

Wool has a combination of remarkable characteristics. It is durable, it is flame resistant, and it is a good insulator. No-one was able to produce an artificial fibre which had these qualities and characteristics. Although the oil crisis of 1973 increased synthetic fibre prices and thus reduced the disparity with those of wool, synthetics remained cheaper, they did not shrink, they were easily washed, would drip dry and they would retain pleats. In reaction to this competition, the Wool Board launched promotions and advertising campaigns emphasising the superiority of wool. Despite criticism, a comprehensive evaluation of the campaigns found that promotion of their product was certainly of benefit to woolgrowers and that it should be continued.[9] Efforts to educate the public to recognise quality in clothing included a plan to make compulsory the labelling of all textile garments with the material of manufacture. The scheme was due to start in 1950, but in 1954 the required legislation was still not in place in Australia, despite yearly complaints by the Wool Board.

The disadvantages of shrinkage in laundering had been under discussion since the late 1940s. By the early 1960s, this problem, as well as the possibility of permanent creasing and the manufacture of washable non-iron fabrics made from wool, was being investigated and the available techniques were being adopted by some manufacturers. In 1964, the Woolmark campaign was launched by the International Wool Secretariat[10] "to give a clear identity to products made of pure new wool, to invest them accordingly with the stamp of quality and so, in the long-term, free wool from a restrictive price relationship with synthetics".[11] In 1968, a 'washability' standard was added to Woolmark for certain classes of product.[12]

While synthetics manufacturers examined the possibilities of blending their fibres with wool,[13] the Australian Wool Board considered this to be a move to associate their products with wool. In its 1954 *Annual Report,* it stated categorically that "wool is the supreme fibre" and that it would "not assist the synthetic fibre interests to reap any advantage by association with wool".[14] In 1958, the Executive reaffirmed its policy of "publicising only products made wholly of wool".[15] The Board adamantly refused to fund any research which involved synthetics in the belief that promoting wool mixtures would also promote the competing fibre. This proved to be a very shortsighted policy. Rachel Makinson of the Division of Textile Physics of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) had experimented with blends and discovered that if a small percentage of certain synthetics were used, it would be to the benefit of wool. She was, however, forbidden to make her findings known and to this day they have not been published. Not until 1971 did the International Wool Secretariat introduce a "Woolblendmark" to promote blends rich in wool but with a percentage of synthetics,[16] a move which was highly contentious.

Given these problems, it was hardly surprising that Australia devoted a large share of its research money to many different aspects of wool improvement and sheep production. By the late 1940s, Australian universities had trained the first generation of agricultural scientists.[17] The Government had long been supporting rural research and, once CSIRO was established, channelled funds mainly through that organisation. Industry also contributed through statutory Rural Industry Research Funds. Producers were levied and had some influence in recommendations on areas of research and expenditure allocations.[18] The Wool Research Trust Fund, created in 1957, also contributed heavily to CSIRO, which, after the War, had set up three Divisions (Protein Chemistry, Textile Physics and Textile Industry) dealing with different aspects of research into wool processing. Even in the mid-1970s, 97 per cent of the funding of its Division of Textile Physics was still from this source.[19] Both at CSIRO and at some universities the prime research objectives were to improve both the quantity and quality of Australia's wool and to overcome some of its inherent limitations, such as felting and shrinking, to make the processed fibre more marketable.

It was against this background that Helen Newton Turner and Rachel Makinson, both research scientists with CSIRO, made their significant contributions to the wool industry. Newton Turner, an animal geneticist, worked on the production side to improve the quantity and quality of wool; Makinson, a textile physicist, addressed the problem of felting and shrinkproofing on the processing side.

Helen Newton Turner began her professional life as an architect, but in 1931, during the depression, joined CSIRO as a clerical officer. Having an aptitude for mathematics, she became statistician to the then Division of Animal Health and Production and in 1956 transferred to the recently created Division of Animal Genetics to take charge of sheep breeding experiments. From that time, she led a research team working in quantitative or population genetics with the aim of using genetic methods to improve sheep production. The techniques had been developed in Britain and the United States in the 1940s and Newton Turner was one of the pioneers of their use in Australia. Most characteristics of sheep are controlled not by a single, but by a large number of genes; large-scale experiments are necessary to estimate the genetic parameters involved. If a ram (or ewe) has certain desirable characteristics, it is important to know the extent to which this superiority is heritable — that is, how much will be demonstrated in the offspring. Breeding experiments had been started by CSIRO before Newton Turner took charge, but as no random control group had been set up, there was nothing against which to measure progress. One of the first steps was to introduce such a control group. She also initiated experimental work on the different characteristics of wool.

The average weight of fleece in Australia had increased greatly since the 1840s, but with time the rate of increase had slowed down considerably. It was known that the average diameter of the wool fibre was important in determining the quality of the wool and the acknowledged wisdom at the time was that crimps were a guide to diameter. Studmasters had therefore been breeding sheep with more crimps per inch along the staple in order to obtain fine diameters. One of the first things Helen Newton Turner and her team undertook was to encourage textile researchers to establish whether crimps were in fact the chief guide to quality. Wool quality as measured by crimp had certainly been raised by breeding, but research showed fibre diameter to be the main indicator of quality. Fibre diameter cannot be seen by the naked eye; it has to be measured by instruments. The weight of the fleece is also important, of course, but it is the average fibre diameter which determines the quality of the wool and therefore its ultimate use. The experimenters found that fleece weight could be raised much more rapidly if diameter were controlled than if crimp were controlled, because of a negative association — the more crimps there are, the lower is the weight.

A major line of research was to establish the heritability of important characteristics, such as wool weight, body weight, fibre diameter, staple length and follicle density. Also to be established was whether the level of heritability is high enough for an animal to be selected for breeding on its own measured performance, or whether relatives should be taken into account as well. Correlations between these characteristics are also relevant. One of the important achievements of Newton Turner and her team was to establish that for Australia's main merino strain (medium wool) the heritability levels of important characteristics are all high, while the correlations are mainly small, except for a high negative between wool weight and crimp number. The New South Wales Department of Agriculture was also working along similar lines and there was contact and collaboration between the two groups. It was the CSIRO group, however, which continually stressed the importance of measuring diameter instead of assessing it by crimp. The results, already available in 1954, enabled the first Fleece Measurement Conference for Flock Improvement, organised by CSIRO, to conclude that if the recommendation of the researchers — that is, to add measurement to eye assessment — were followed, the rate of genetic progress in increasing fleece weight could be more than doubled.

The existence of a small positive correlation between fleece weight and fibre diameter meant that selection for higher fleece weight alone would result in a coarser wool. More than one characteristic has to be considered. Newton Turner was always an advocate of the technique of independent culling levels — that is, choosing sheep with the highest fleece weights while ruling out those whose average fibre diameter was too high. Animals with too much skin fold were also rejected, as these do not necessarily produce more clean wool and lead to problems with flystrike and shearing. Another way of selecting superior parents is by using an index which involves not only measurement but complex calculations of fineness, weight of clean wool and body weight. The index is a formula which would have been difficult for the average breeder to use in the days when there were no computers to make the calculations. Nowadays graziers can send their samples to measuring laboratories and receive an index from which they make their selections; those who have their own computers can do the calculations themselves. Nevertheless, it has since been shown that, according to circumstances, the technique of independent culling levels is sometimes no less efficient than the more complex index method, and sometimes it is rather more.

Resistance to the idea of measurement came from both the stud breeders and the wool classers. The latter had been classing wool by eye and touch for generations and did not want to accept the finding that fibre diameter was more important than crimp and touch; in fact, Newton Turner was accused of taking away their livelihood. The growers were slow to accept the idea, partly because they were too conservative to adopt new methods quickly, partly because measurement was costly. Samples had to be sent to a laboratory for measurement of percentage clean yield and fibre diameter, an expensive process. However, now that wool is sold according to measurement rather than visual appraisal, breeders are more willing to use the technique in selection.

Increasing the number of sheep was another problem addressed by the CSIRO research team. The obvious way is by raising the number of lambs born. It had been generally believed that selecting for twins was a waste of time because there was no genetic factor involved and their production was largely dependent on environment. Newton Turner showed that this was not the case. In experiments with both the medium merino and the Booroola merinos, the number of lambs born per 100 ewes mated was quickly raised to 210, compared with an Australian average of about 85. The Booroola experiment was based on ewes born as triplets or quadruplets and rams born as quins from a flock in which the Seears Brothers of Booroola, near Cooma, had been selecting for multiple births. This strain is now known worldwide, as it is the only merino among a handful of prolific breeds in the world. The research group acknowledged, however, that multiple births would only be economically worthwhile in environments where the feed was good.

Thus the first major contribution of this scientist was to introduce objectivity into breeding. The next step was to introduce objective methods into marketing, and though she did not contribute directly in this area, she played a major role as a communicator of the new methods. She travelled around the country talking to studmasters, trying to persuade them to use measurement in their breeding programmes instead of judging animals by eye. By 1973 the Wool Board could report that "the benefits of using objective measurement as an aid to sheep selection are now well established".[20] With a colleague (S.S.Y. Young), she wrote a standard text, *Quantitative Genetics and Sheep Breeding,* which has been widely used in sheep growing countries. She lectured to breeders in short one-week seminars all over Australia and "held them in the hollow of her hand".[21] For years she broadcast on the ABC's *Country Hour* and became known to many people in country areas. And she did not confine her efforts to the breeders; she tried to influence the decision-makers — she had access to senior administrators and they listened to her. In February 1990 she was elected a Fellow of the Australasian Association of Animal Breeding and Genetics, together with two other Australians and a New Zealander who were sheep breeders. All four had been active in trying to persuade the industry to use objective measurement to improve sheep production.

Newton Turner's third contribution was as an educator. She was co-supervisor of PhD and MSc students from several Australian universities, some of whom were officially undertaking their work at the university, but in fact worked with her at CSIRO. She took groups of students from India, Pakistan and Argentina for several weeks at a time and trained them in the new methods, while individuals from other countries also worked with her and her team. She helped to train graduate sheep and wool extension officers in all State Departments of Agriculture and afterwards maintained contact with them. Over many years, her influence through her students has been immeasurable.

As this article is concerned with the Australian wool industry, it is not appropriate to talk of her work and influence on sheep breeding in developing countries except to say that it was extensive. Almost yearly, she was an invited speaker to overseas conferences in Europe, the United States, the USSR, China and Japan, at most of which she led an Australian delegation. She undertook consultancies in South America, South East Asia, China, the Middle East, India and Pakistan, sometimes at the request of the governments of the countries concerned, sometimes for the Food and Agriculture Organisation of the United Nations and the Australian Development Assistance Bureau. In Australia, she served on many official committees concerned with animal production and worked with non-government organisations such as the Australian Council for Overseas Aid. In her writings, she has campaigned for the conservation of animal genetic resources. The list of the honours she has been awarded is impressive. The citation for the award of a DSc by the University of Sydney reads in part, "The scope of the work is immense. It represents over 30 years of research directed towards the single objective of improving the economic value of the Merino sheep" and "the amount of work is prodigious . . . the quality . . . is outstanding". Suffice it to say that it is hard to imagine any single person who has contributed more to a major industry.

By the very nature of her work, Rachel Makinson's contributions to the wool industry are more difficult to describe and their application less direct than those of Helen Newton Turner. She is a physicist who transferred her interests and career from radio physics to textiles in the mid-1940s and became the world's leading authority on the felting, friction and shrinkproofing of wool, her textbook still being the standard reference in the field. Working in CSIRO's Division of Textile Physics (which was active in the measurement work that Helen Newton Turner was advocating), she approached the problems relating to the characteristics of wool from a specialist point of view.

In order to promote wool so that it was as attractive to consumers as synthetics, it was necessary to make it shrinkproof. After the War, washing machines became more common and garments made from synthetic fibres could be washed by machine. It was important from the industry's viewpoint that woollen garments should become machine washable and also shrinkproof. From 1964 there is constant reference in the annual reports of the Wool Board to shrinkproofing and machine washability. Shrinkproofing had been used on knitting wools and some woollens for several years, but the processes had been arrived at empirically. While they were successful there was of course no problem, but when something went wrong during the treatment — and it often did — no-one knew why or how to overcome it. When Makinson began to work on the problem, the only well-known method of shrinkproofing involved a process of chlorination which severely damaged or completely removed the protective scales from the fibre of the wool (a degradative treatment).

Felting and shrinking are closely related; both are caused by friction of the fibres against one another. Because all the scales of a wool fibre point in one direction, it is easier for the fibre to move in one direction. If the fibres are "agitated in water, some with pressure on them, the individual fibres move preferentially in one direction, becoming entangled and consolidating the structure of the assembly".[22] In other words, the entangled fibres become matted and cannot be separated out again; this is known as felting. The tighter the structure of a piece of woollen material, the less it will felt (or shrink) because the density of the fibres resists movement. The finer the wool, the more rapidly it will felt, and merino is a fine wool.

In order to study shrinking, it was necessary first to study felting. To study friction was essential as it underlies both processes. And to study friction in wool, it was also necessary to study friction in other materials. Rachel Makinson began, therefore, to work on friction, about which very little was known, because the essence of the problem lay in elucidating its causes. By the late 1940s, she had succeeded in developing a semi-quantitative theory of the relation of the scales to the difference in friction in the two directions along the wool fibre.

By the late 1960s, milder degradative shrinkproofing methods than chlorination were in use which did not necessarily remove the scales or even damage them to any extent which was microscopically perceptible. Makinson found that it was the softening of the scales which such treatment entailed that led to the shrinkproofing. She worked out a much improved method of measuring the degree of friction and of using the results for purposes of calculation. Her method was adopted in all subsequent studies of friction in her Section, thereby considerably increasing productivity. By the early 1970s, she had demonstrated that chlorination, to be effective by itself as a shrinkproofing process, did not have to remove the scales on the fibres at all and she established a general theory of the relationship between softening of the scales and shrinkproofing. She presented her theory at the fourth International Wool Textile Research Conference at Berkeley, California. It was very well received and was subsequently put into effect by workers in the field.

There is another method of shrinkproofing apart from the degradative process of attacking the cuticles of the fibre chemically. This is to add a polymer to the surface of the fibre. It had been assumed that there was only one mechanism by which any polymer acted to prevent felting. Accepting this view, Rachel Makinson began looking for the single mechanism by which a particular cause achieves a particular effect. She designed, as others had before her, 'crucial' experiments in order to discover the hypothesised single mechanism. She found, however, that dealing with the physics of complex biological materials required a very different approach from that of traditional physics, in which the cause of a particular event can be isolated and controlled. By the mid 1950s, she had succeeded in demonstrating that polymers could act by a multiplicity of mechanisms and that felting could be prevented by any of them.

There are two main methods of shrinkproofing by polymer deposition. One works by bonding the fibres, the other by masking the scales. In the latter, a chemical treatment is involved in the process. By the 1970s, a version of this method, the chlorine/Hercosett process, was the one most commonly used in commercial shrinkproofing. Industry was using the method quite empirically and, not surprisingly, often had inexplicable failures with it. Rachel Makinson's achievement was to elucidate the process and explain the mechanism by which it worked. She showed that the Hercosett polymer swells in water. It is coated onto the wool as a very thin film which does not of itself mask the scales; then when, in the wet state, the polymer is swollen to the required thickness, the scale masking takes place. She later explained the role of pre-chlorination in this process. Once these facts were known, it was possible to remedy the situation when the process failed. Improvements can only be developed on the basis of understanding. Once the mechanism was understood, it was then possible to look for other swellable polymers for shrinkproofing.

In 1975 she demonstrated to the fifth International Wool Textile Research Conference in Aachen, Germany, yet another mechanism for shrinkproofing, thereby opening up a further possibility for easier and more economical processes. In this case, scientific knowledge was the essential component for improving an industrial process. Before Rachel Makinson, the problems of wool felting and shrinking had been addressed only by chemists. Now physics provided the link between the chemical treatment and the technological result: without this link, the processes could be only vaguely understood. Rachel Makinson had the right scientific background and the scientist's approach. She read widely, quite away from the subject. (For example, it was known that some of the failures in shrinkproofing techniques were caused by the use of certain oils and conditioners, but no explanation for the effect had been advanced. That oils might shrink polymers was an idea that suggested itself to her when reading about the water repellent agents used by the United States in rescuing planes from the sea after the War.)

Her work was fundamental to the understanding of the nature of fibre friction and fibre movements during felting, of the mechanisms of shrinkproofing and the relation of the chemical to the physical effects. Of one of her papers it was said, "Makinson's work, which has all the signs of having been carried out with meticulous care, has clarified a confused situation".[23] Of another: "In a multitude of papers, often almost meaningless, about fibre physics, here is one that is quite brilliant".[24] Perhaps it is not surprising that she was the first woman to become Chief Research Scientist and Assistant Chief of Division in CSIRO.

The difficulty of transferring any scientific knowledge to people who are not willing to deal with it can be immense. It is a problem often encountered when technology is applied in the absence of fundamental research. As she herself has said, "the technology often runs ahead of the science".[25] The men in the mills at first did not want anyone interfering in their work; they did not want to listen. The Wool Board was aware of the problem. It stated in 1958, "As in most industries, a gap exists between the scientific research work and its practical application to the finished product. The Australian Wool Board's intentions are that the gap be closed, to the ultimate benefit of the consumer and of the wool fibre".[26] And in 1960 it stated, "Technical developments coming forward from CSIRO lead the world; the Bureau believes it has an obligation to ensure that the knowledge of such research is taken to the wool manufacturing trade and to the woollen mills in the most efficient and expeditious way".[27]

The resistance to new ideas, to the findings of scientific research, was as strong in Rachel Makinson's area of enquiry as in Helen Newton Turner's. Both women were involved in pure research and neither was forced, as is so often the case today, to target her research in a specific direction. Yet both did so. Newton Turner says that though her research was not required to have a practical objective, she believed in the importance of applying her findings. Makinson also wanted the results of her efforts to be of practical benefit and felt that her work should facilitate the improvement of existing shrinkproofing processes and the development of new ones. However, because she was a woman, the type of applied research she could undertake was restricted by official attitudes. For example, despite the original and important work she was doing, it was many years before approval was given by her Section Head for her to meet visiting industrial VIPs and to go into textile mills, a very necessary part of her research. This is one of the reasons why she concentrated on the pure physics of wool.

Though interest in shrinkproofing waned soon after her retirement in 1982 and her collaborator was assigned to other work, it is interesting to note that the Wool Board's 1983-84 *Annual Report* speaks of the development of a new shrinkproofing treatment developed by CSIRO which was expected to be exploited worldwide by the International Wool Secretariat.[28] No specific aspect of her work was ever adopted as a basis for any new technological development or applied with total success to improve current methods, although another swellable polymer was developed. Once one successful treatment is in use, a major economic advantage has to be foreseen before another will be introduced to supplement it. Nevertheless, she could write to Helen Newton Turner in 1981, "I wrote my book in the hope that all the knowledge which I and others had accumulated could be got into the consciousness of trouble-shooters, developers and millmen, so they need not approach their problems purely empirically. I think that is happening now. The men in charge of shrinkproofing in the two mills we are dealing with have read at least the most directly relevant sections of the book".

Today wool may not hold the pre-eminent position it once held in the Australian economy, but in 1989 it was again the country's leading export; it accounted for 12.7 per cent of total exports in the financial year 1988-9,[29] having climbed to this level from about 11 per cent in 1976-7.[30] Despite the steady decline in the proportion of wool in global fibre consumption (from 12 per cent in 1940 to five per cent in 1984),[31] world consumption of wool has been increasing in the last few years by between two to three per cent annually.[32] Global consumption of Australian wool has also increased,[33] and today Australia is the major supplier, producing, in value terms, nearly two-thirds of the world's wool.[34] The work of two women during a critical period in Australia's economic development contributed immeasurably to this result.

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