Wool: the technical fibre

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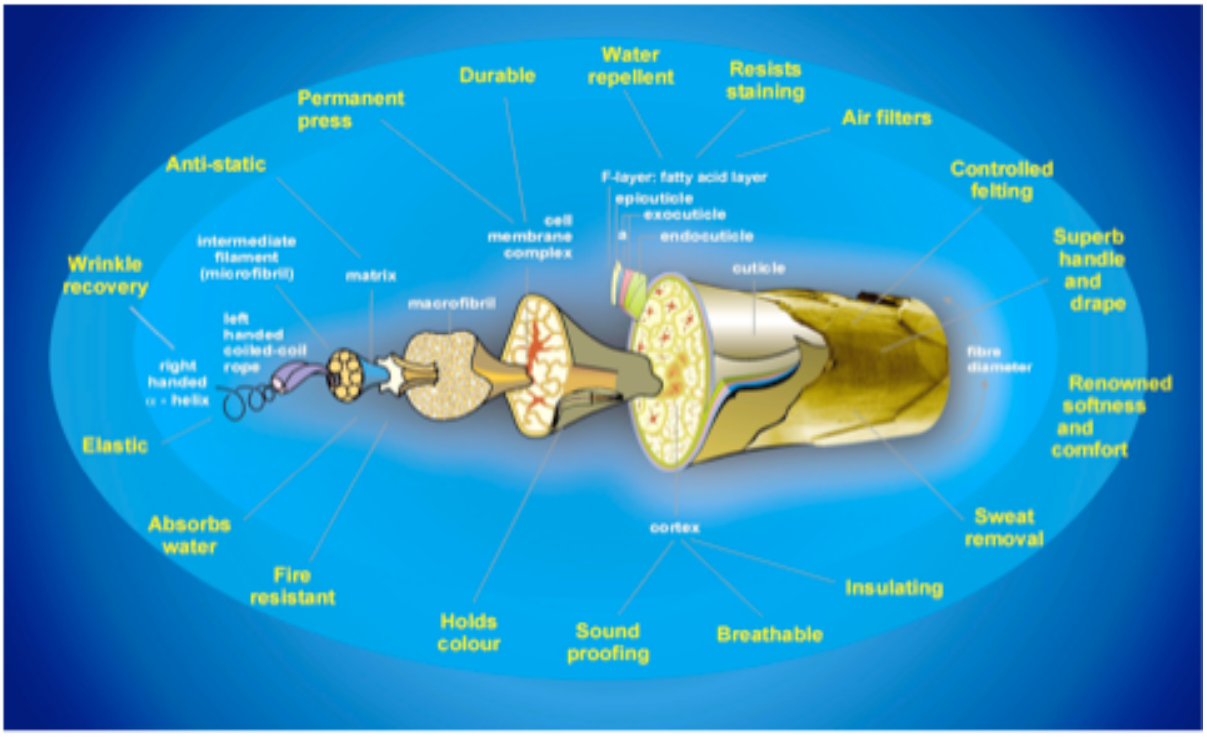
We are familiar with wool in its traditional role as an apparel fibre. This lecture will highlight the technical features of wool and illustrate some of new initiatives at CSIRO where wool is being used in technical applications.

I invite you to take a journey into the fibre. Surprisingly, we don't find just a disorganised soup of wool molecules. Rather, layer upon layer upon sub-layer of structures emerge.

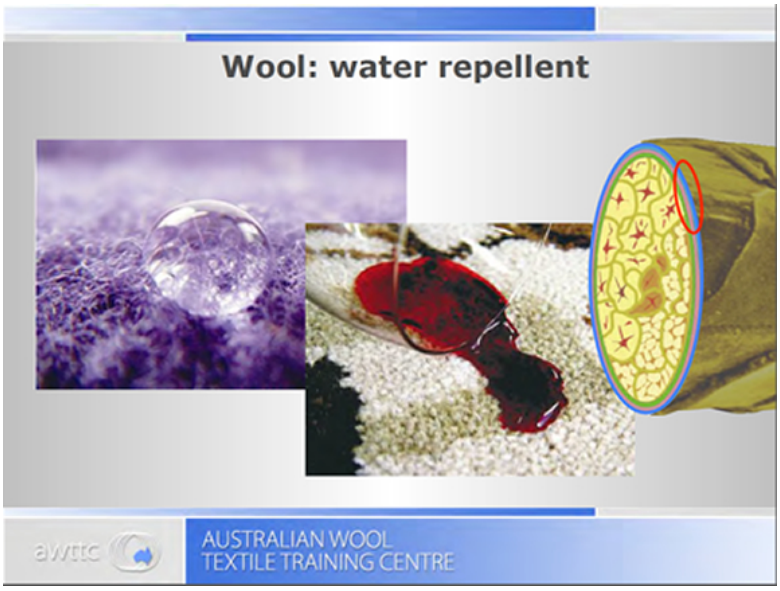


Firstly, the outside scales have been carefully engineered as a multi-layer structure. Looking into the body of the fibre, we see an organised assembly of cells. Indeed, it is this level of organisation that is linked to the wonderful fibre crimp.

A closer look into an individual cell reveals a composite structure of filaments or rods embedded in a matrix somewhat like a fibreglass structure, where glass fibres are embedded a resin structure. A closer examination reveals how the filaments or reinforcing rods are formed from the basic helical protein molecules.

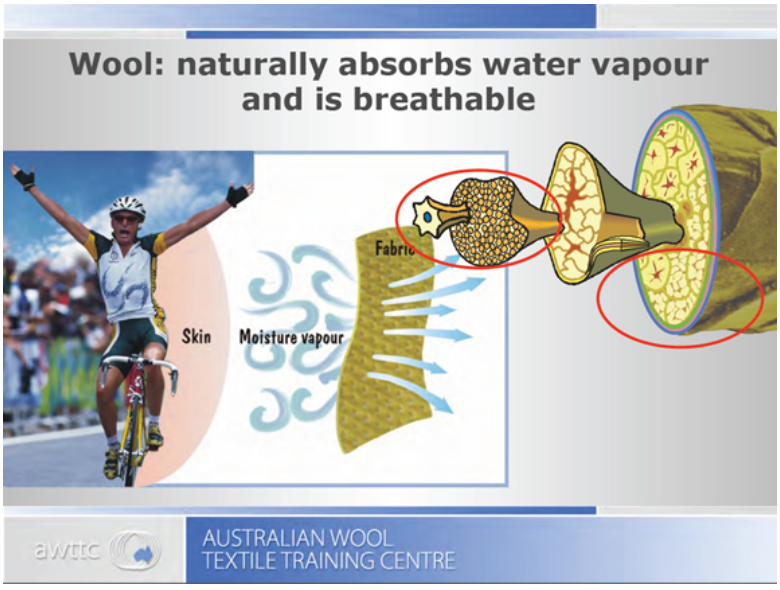
Now, the exciting news is that many of these sub-structures are on the nano-scale, so wool is truly Nature's natural nano-composite. This complex layered nano-structure is the key to wool's many and varied properties.

We now have a good understanding that the many layers of nano-structure are the key to wool's wealth of fibre properties. As you know, it is a truly amazing array of properties. In the next few minutes we will look at a few example



Wool is naturally water repellent. This is caused by the outermost layer of the structure of the well known scales, which has a fatty or waxy layer that is naturally incompatible with water. This is very useful if you are a sheep standing in the rain and equally useful for us if we are caught in a brief shower.

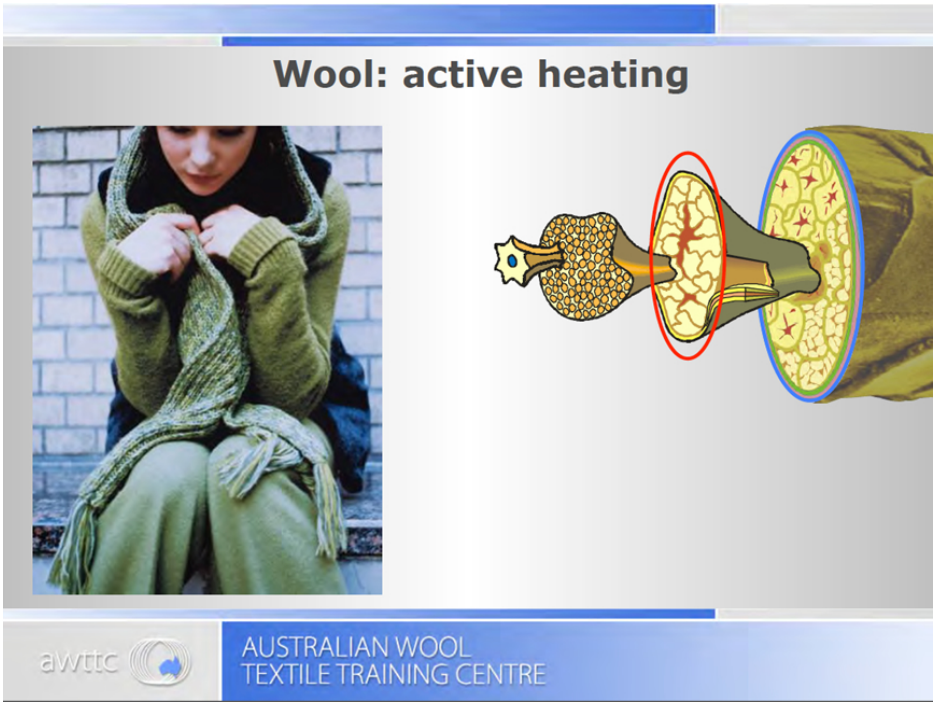
This feature also contributes to wool's natural stain resistance characteristics.



As we know so well, wool is excellent at breathing and absorbing moisture vapour, which is a key aspect of clothing comfort.

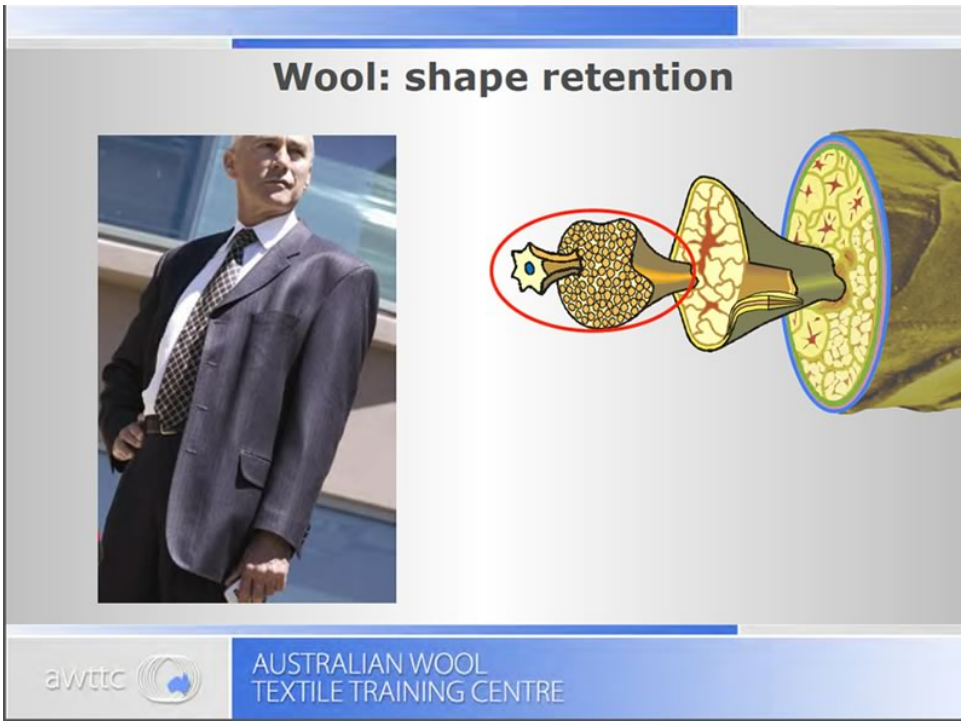
This contrast with the previous benefit arises from two other nano-structures in the fibre working together.

- Remember that at the fine level, the structure is like reinforcing rods in a matrix. The matrix material is rather like a sponge in its ability to absorb and re-emit moisture vapour – and the fibre absorbs up to 30% of its own weight.
- The things that look like cracks in the structure act as channels so the moisture vapour can rapidly penetrate inside the fibre; the full benefits of the absorption can very rapid indeed.



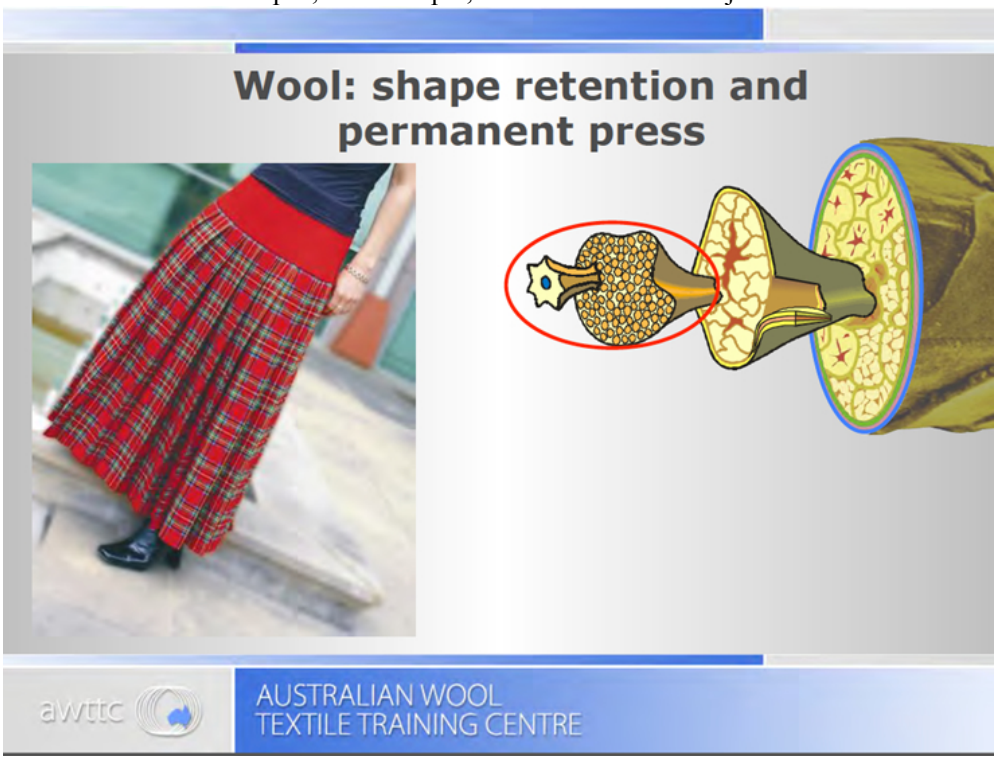
A special feature of wool is that it actively gives off heat as it absorbs moisture. In fact a kilogram of dry wool placed in a damp environment, releases about the same amount of heat as an electric blanket running for eight hours. This provides a wonderful added bonus in sleeping under wool.

Equally, this effect can actively reduce thermal shock to the body during the transition from indoors to outside.

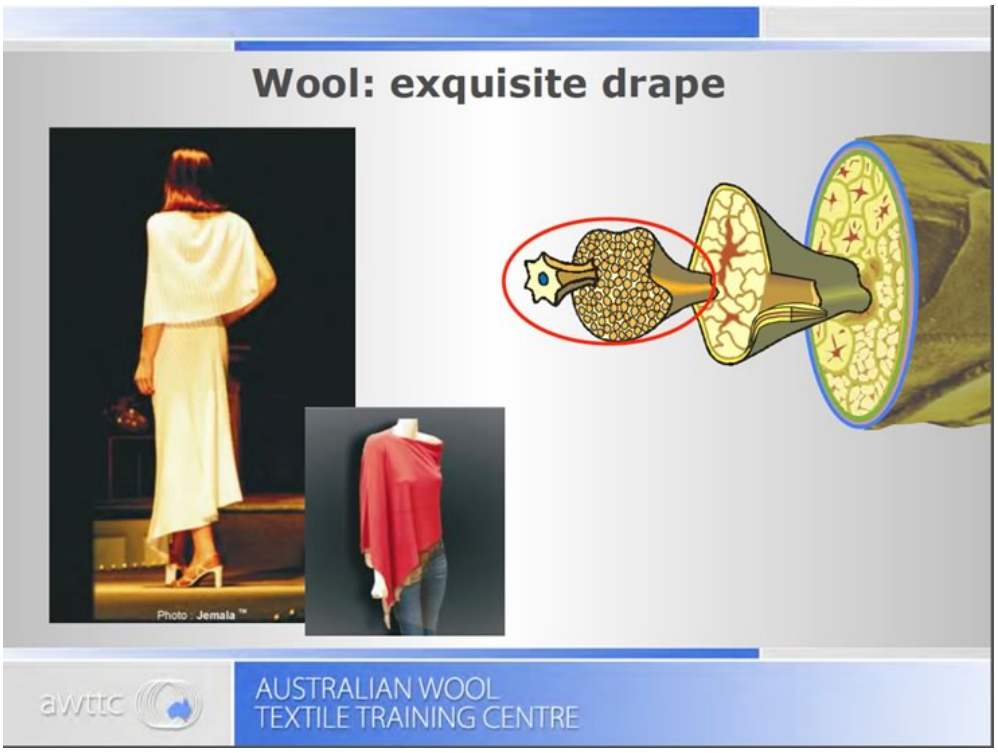


Travellers are familiar with the trick of gently steaming a wool suit in the bathroom on arrival at their destination to remove any creases from the suitcase. This characteristic of wool arises from the filament-matrix nano-structure. The warmth and moisture causes the matrix to soften and the relatively stiff filaments are able to bounce back to their original

configuration, removing any creases or wrinkles. Once the suit is removed from the hot, steamy environment, the matrix returns to a stiff structure and the filaments are 'frozen' back into their straight configuration. This property is also used by the tailor to form stable three-dimensional shapes; for example, in the shoulders of a jacket.



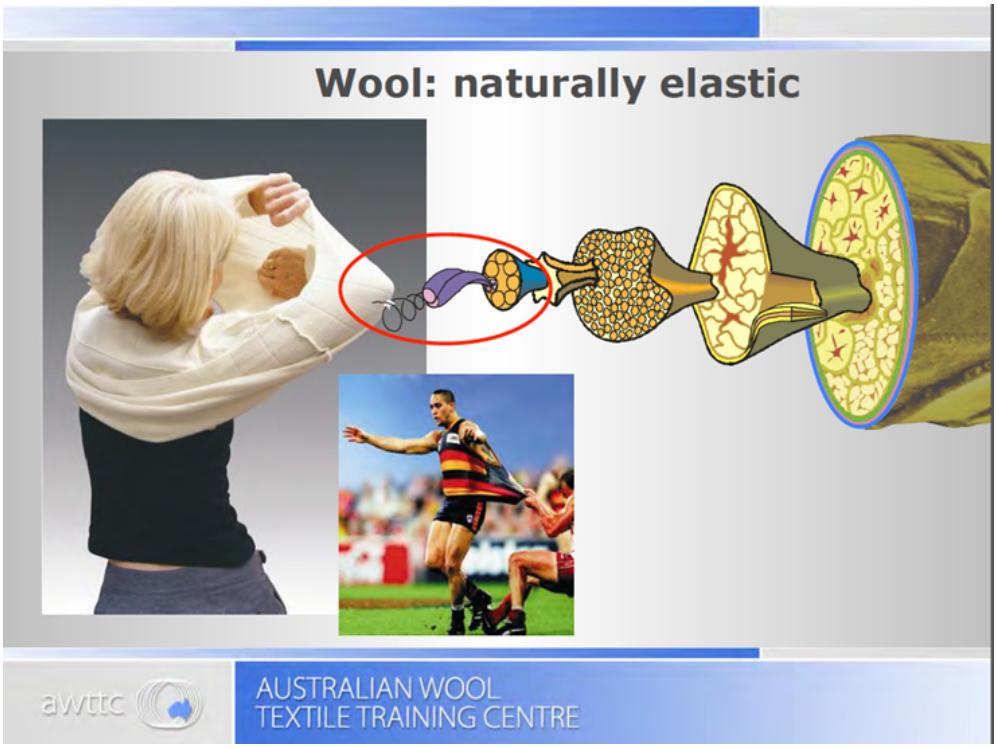
This feature has been extended by science through a chemical process that can permanently set the filament-matrix nano-composite into a particular shape by rearranging chemical bonds.



Being able to set a fabric structure is the key to wool's wonderful drape. As a result of the weaving or knitting process, yarns are distorted. This mechanical force is felt right down to the level of the filament-matrix nano-structure. Setting, that is, rearrangement of chemical

bonds, relaxes the strains and makes the fibres and yarn happy with the bent shapes and this gives the fabric flexibility and drape.

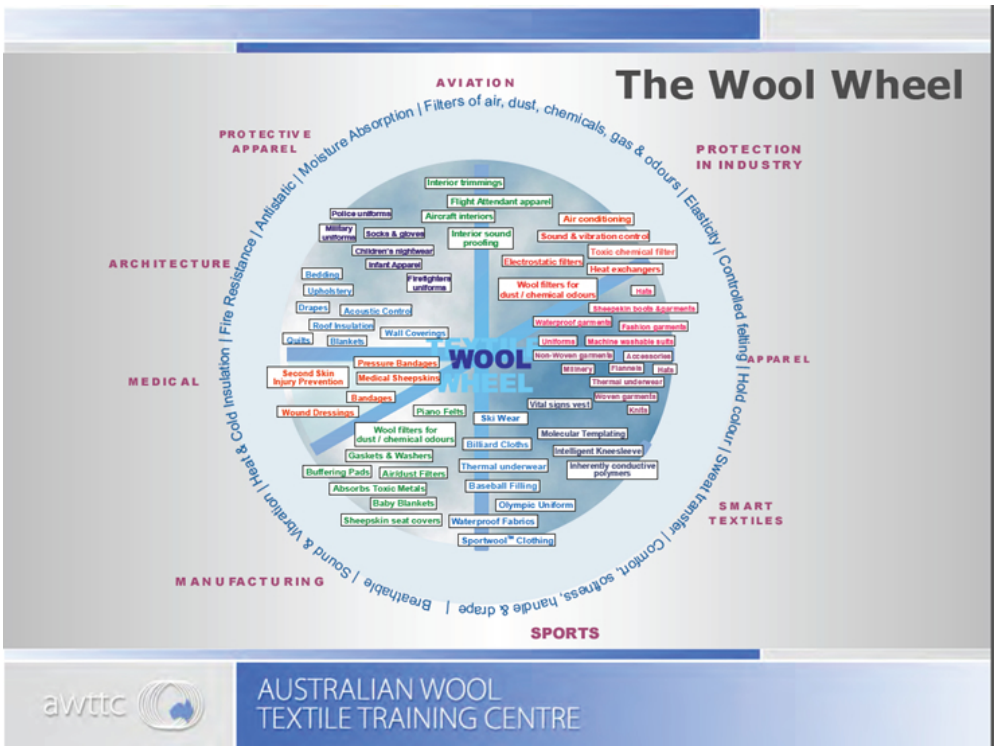
We sometimes forget wool's important natural fire resistance, which makes it a critical choice for particular applications. Wool is difficult to ignite, and is self-extinguishing, forming a cool char. The water, nitrogen and sulphur contained in the matrix component of the fibre are major contributors to this benefit. Indeed, these compounds are often added to other materials as fire retardants.



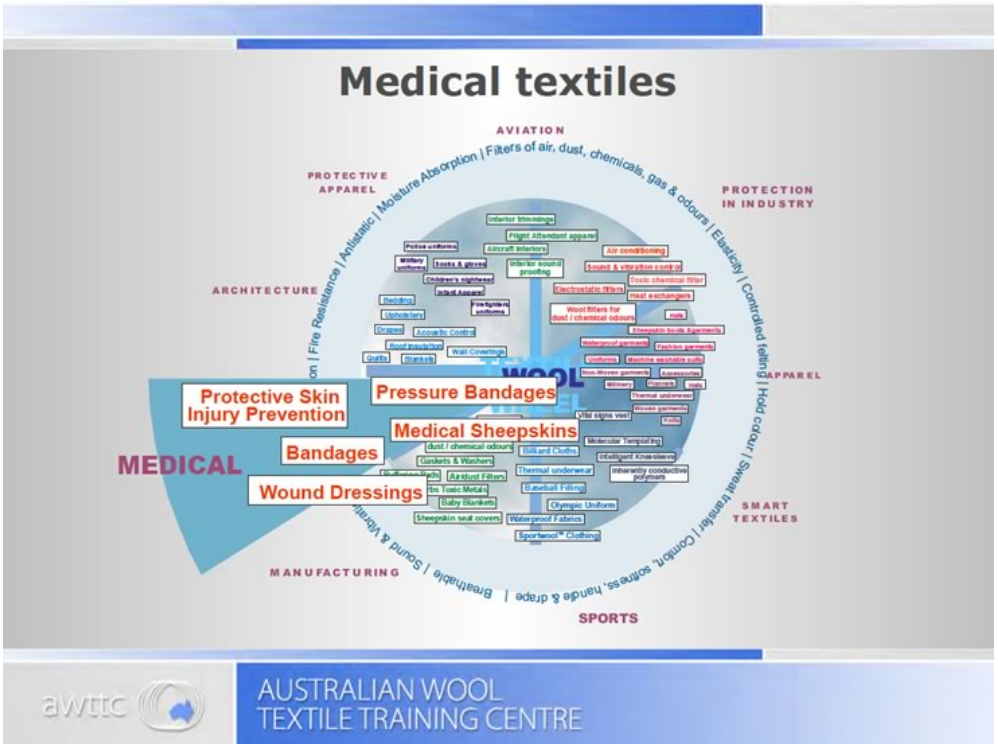
Wool's elastic nature is also amazing. We tend to take for granted wool's wonderful recovery from stretch but, remember, this feature is the envy of some of our competitors.

The stiff filaments in the filament-matrix nano-composite gives wool this terrific advantage.

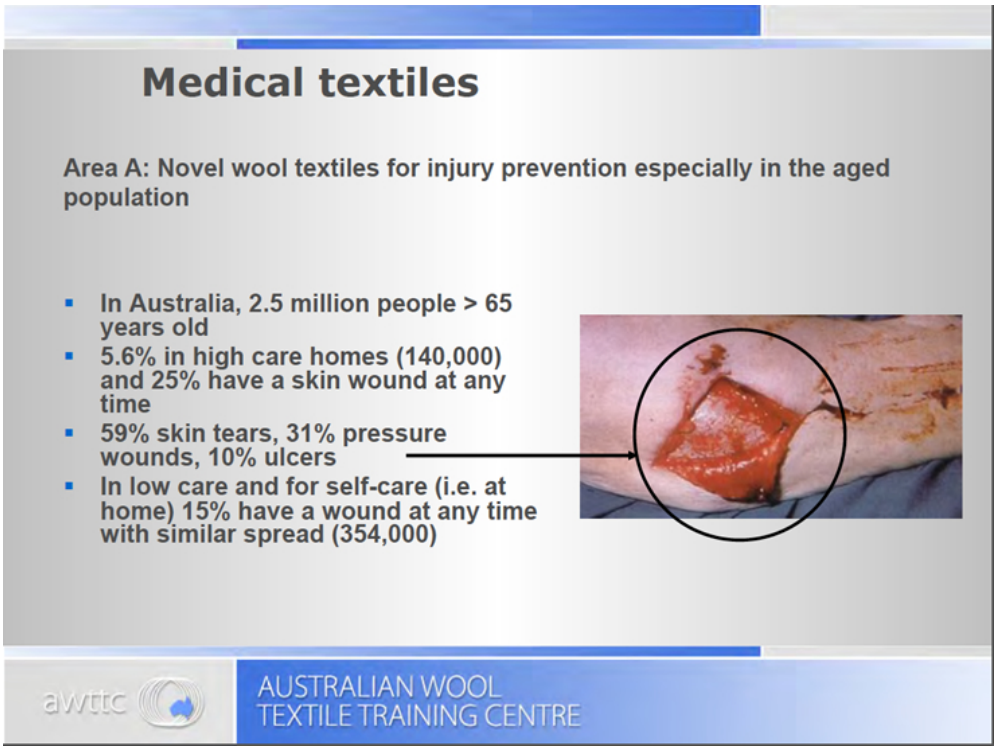
I have illustrated with just a few examples how the complex and multi-faceted structures of the wool fibre deliver such a wonderful array of consumer benefits.



The wide range of applications of wool is shown schematically in the above diagram. Wool's application is clearly much wider than traditional apparel. I will now illustrate a couple of specific examples of wool's application as a technical fibre.



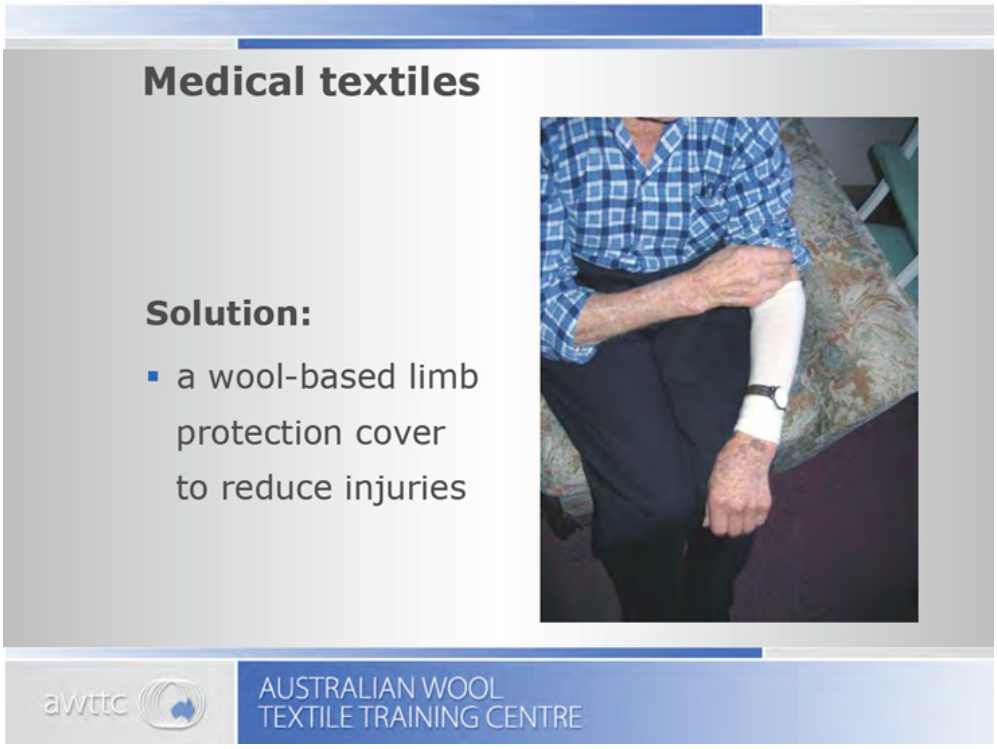
Medical textiles is a rapidly growing field and wool has specific advantages in some medical applications.

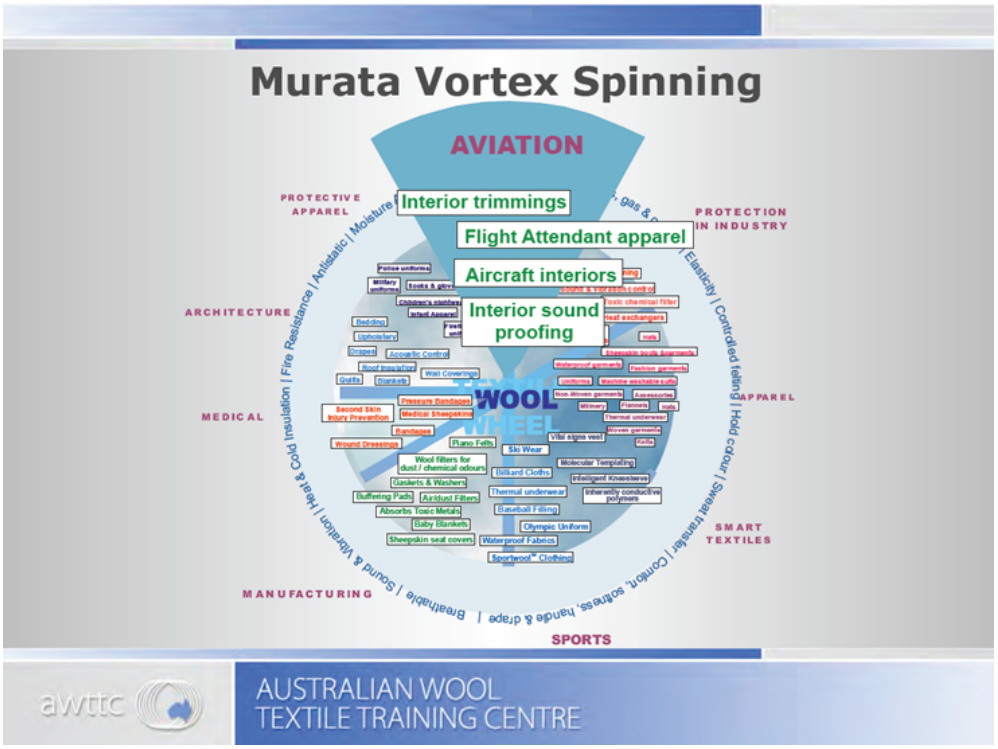


Medical Textiles

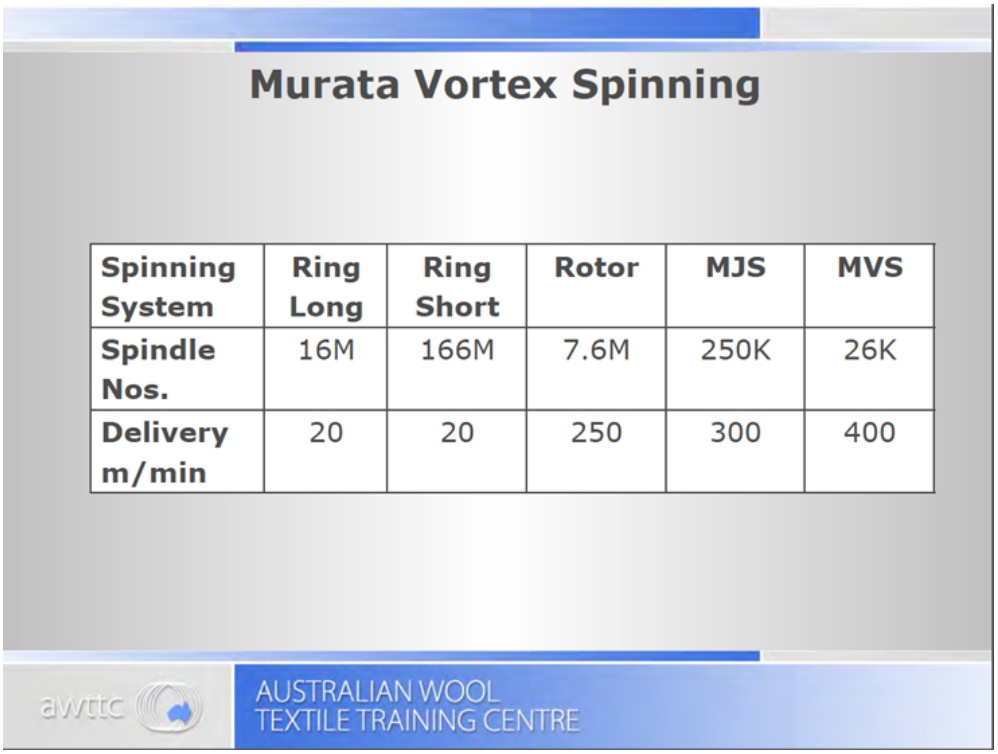
Area A: Novel wool textiles for injury prevention especially in the aged population

One important area is injury prevention, especially for the aged population. The slide above gives some statisitics on the size of the problem. It is known that some form of limb cover can significantly reduce injuries. CSIRO has recently developed a wool product for this market that utilises the wonderful comfort and breathability properties of wool fabrics.





Wool also has a significant market in the aviation industry, for uniforms and aircraft interiors and trimmings. CSIRO has developed a technology package for spinning a range of wool blend fabrics using the relatively new Murata Vortex Spinning system. This system was originally developed for short-staple spinning and its increased spinning speed is particularly attractive.



Spinning System	Ring Long	Ring Short	Rotor	MJS	MVS
Spindle Nos.	16M	166M	7.6M	250K	26K
Delivery m/min	20	20	250	300	400

The benefits of the CSIRO technology are reduce the spinning costs by approximately 30%, while maintaining good handle and wear properties in the resultant fabrics. This exciting new development is currently being transferred to a number of commercial mills.

In conclusion, wool has a large range of interesting and useful technical features, largely due to its complex structure, which can deliver consumer benefits in a wide range of applications.

Further reading

John D. Leeder. (1984. *)Wool – Nature's Wonder Fibre*, Ocean Grove, Vic.: Australasian Textile Publishers and J.D. Leeder.

http://www.merinoinnovation.com/awi/en/Home/about+merino/Benefits.

Morton, W.E. and Hearle, J.W.S., [1993] *Physical Properties of Textile Fibres*, 3rd Edn, Manchester, UK.: The Textile Institute.

Rippon, John et al. (2003) Wool, in *Encyclopedia of Polymer Science and Technology*, New York : Interscience Publishers.

Questions

1. The internal structure of the wool fibre is:
    a. Similar to other fibres
    b. Quite complex at the nano scale with many different components
    c. There is little internal structure
    d. All of the above
    e. None of the above.
2. Wool garments can be water repellent because:
    a. The waxy surface layer of the wool fibre is naturally hydrophobic
    b. Wool garments heat up and vaporise any water
    c. Wool fibres can't absorb water vapour
    d. All of the above
    e. None of the above.
3. Wool products can be particularly warm because:
    a. Wool is a good insulator
    b. Wool fibres generate heat as they absorb moisture
    c. The crimp in individual wool fibres enables it to trap air
    d. All of the above
    e. None of the above.
4. Wool products are breathable because:
    a. The internal nano-structures of wool fibres do not absorb water, so the fibres stay dry
    b. The internal nanostructures are able to absorb and re-emit moisture vapour
    c. Wool molecules break down to give off water
    d. None of the above
    e. All of the above.
5. Which of the following statements are true?
    a. A sustained fire requires fuel, heat and oxygen.
    b. Wool is naturally flame retardant.
    c. Wool never burns.
    d. All of the above.
    e. None of the above.

6. In hot, humid environments:
    a. Wool fibres exibit rubber or plastic like properties
    b. Wrinkle in wool garments can be removed
    c. Wool acts like human hair
    d. Wool becomes hard like a glass
    e. All of the above
    f. None of the above.
7. Wools has applicability as a technical fibre because:
    a. It is a natural product
    b. It is relatively inexpensive
    c. Its complex structure gives it a range of useful characteristics
    d. Its mechanical properties
    e. All of the above
    f. None of the above.