Lightweight wool structure and properties

Dr Tony Pierlot

CSIRO

Outline

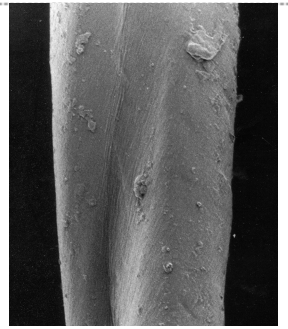
Fibre properties

- Physical structure
- Chemistry
- Attributes of wool
  - Water sorption
  - Hygral expansion
  - Tensile properties
  - Wrinkle recovery
  - Tailorability/setting
  - Felting

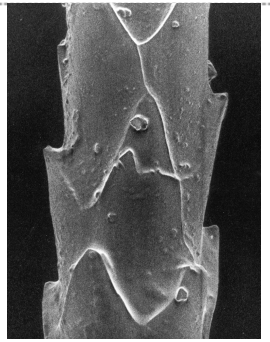
Wool

- Made up of protein (amino acids)
- Crosslinked - hard and resistant
- Belongs to a group called keratins, which includes:
  - hair
  - fur
  - beaks
  - feather
  - nails
  - quill
  - hooves
- Fibre keratins (wool, hair, fur) have different physical structure.

Images of different fibres



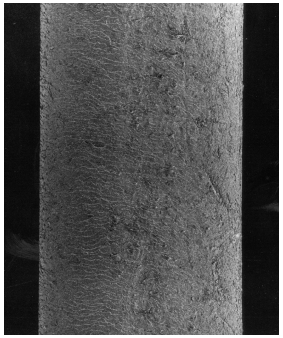
Cotton



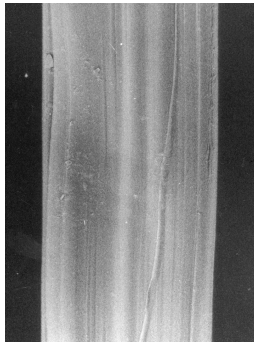
Cat hair

Wool

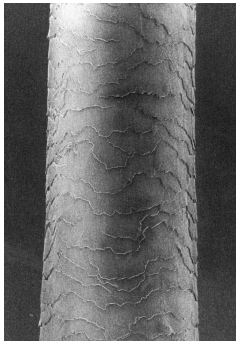
Flax



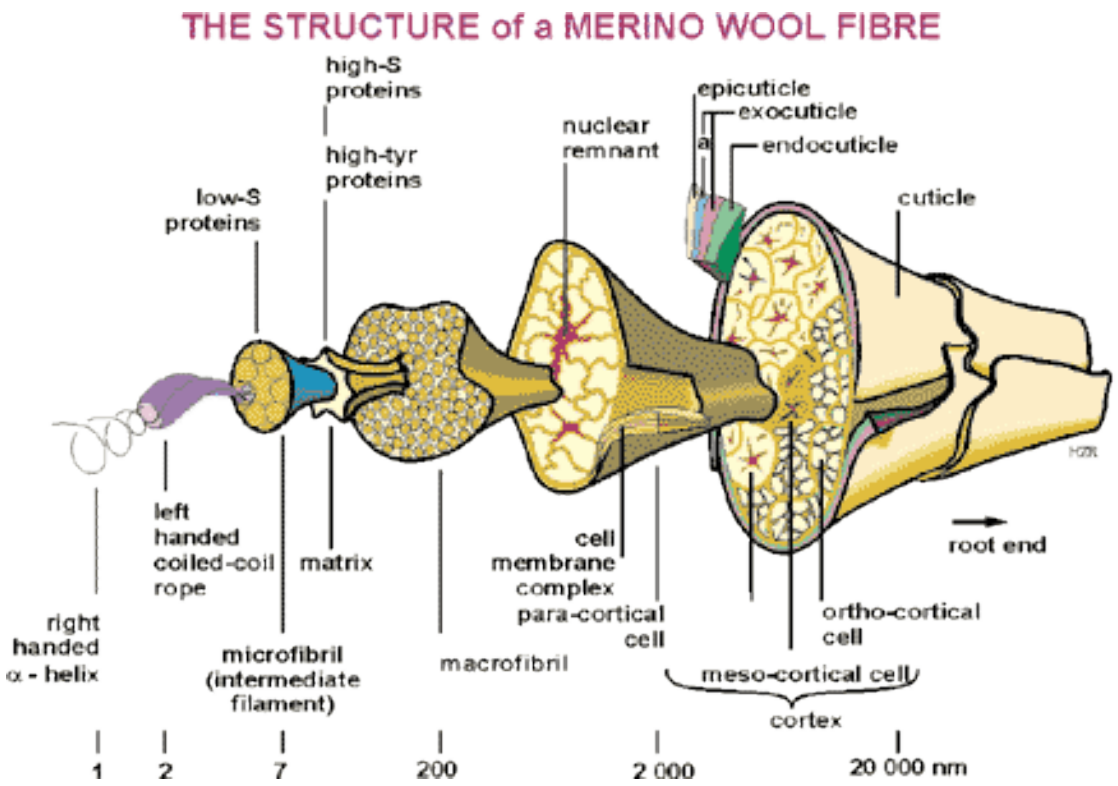
Pig bristle

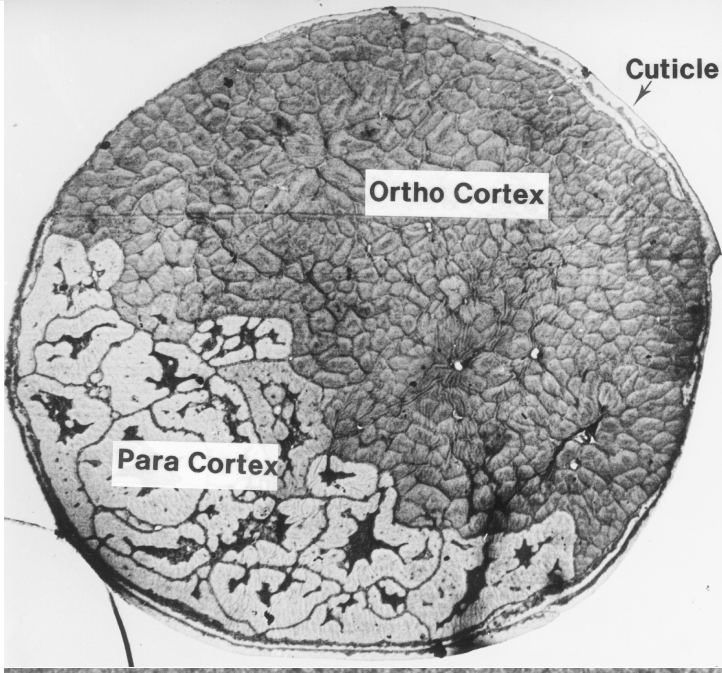


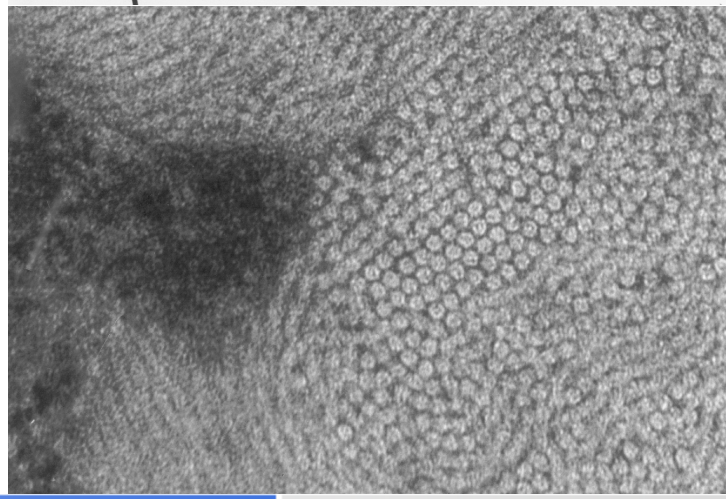
Silk



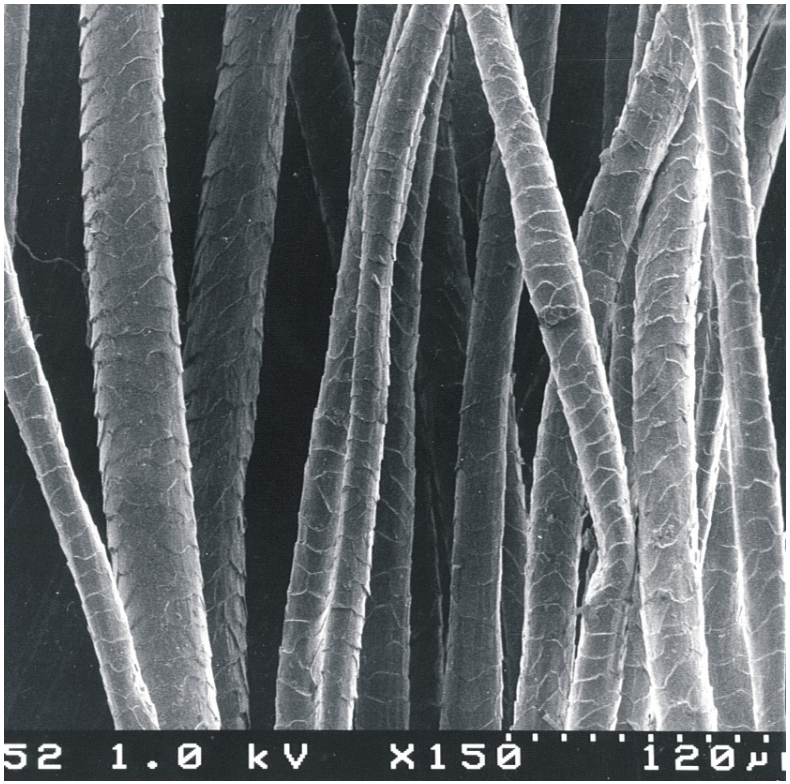
Hair







Tender wool

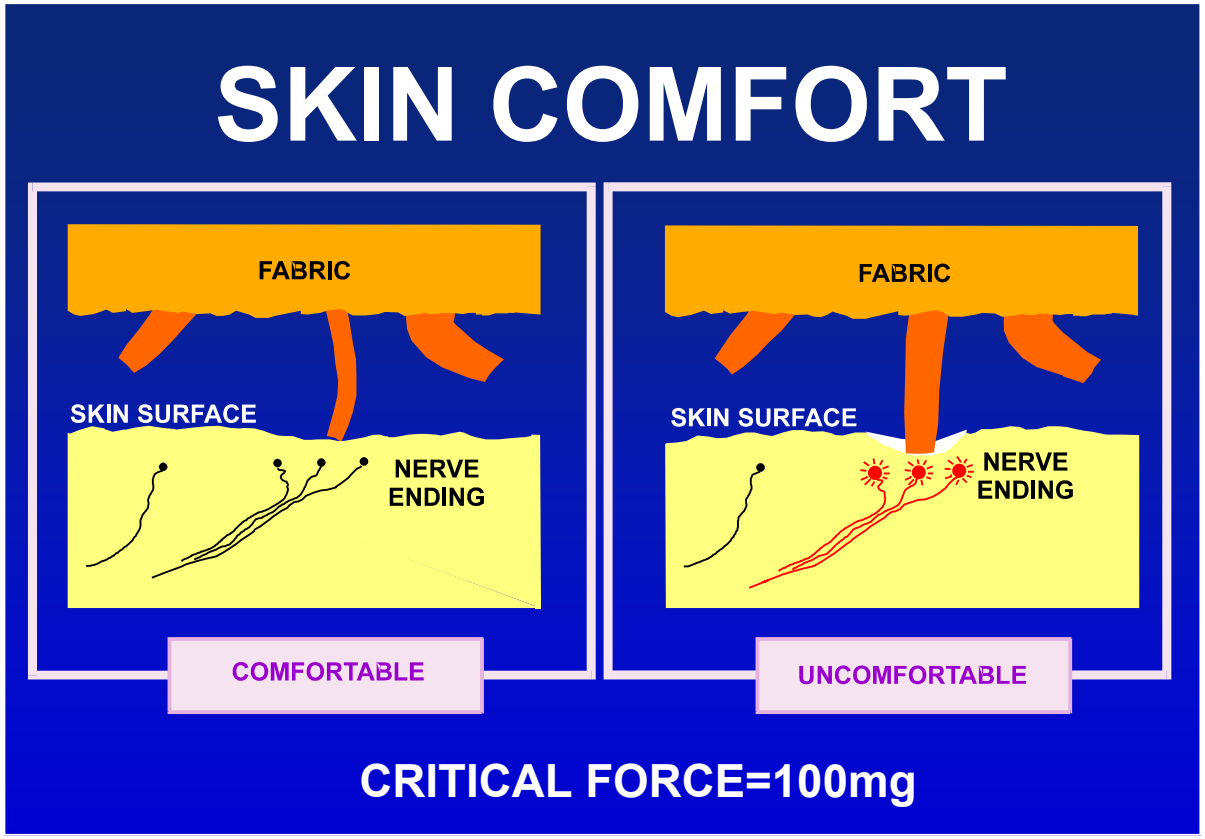


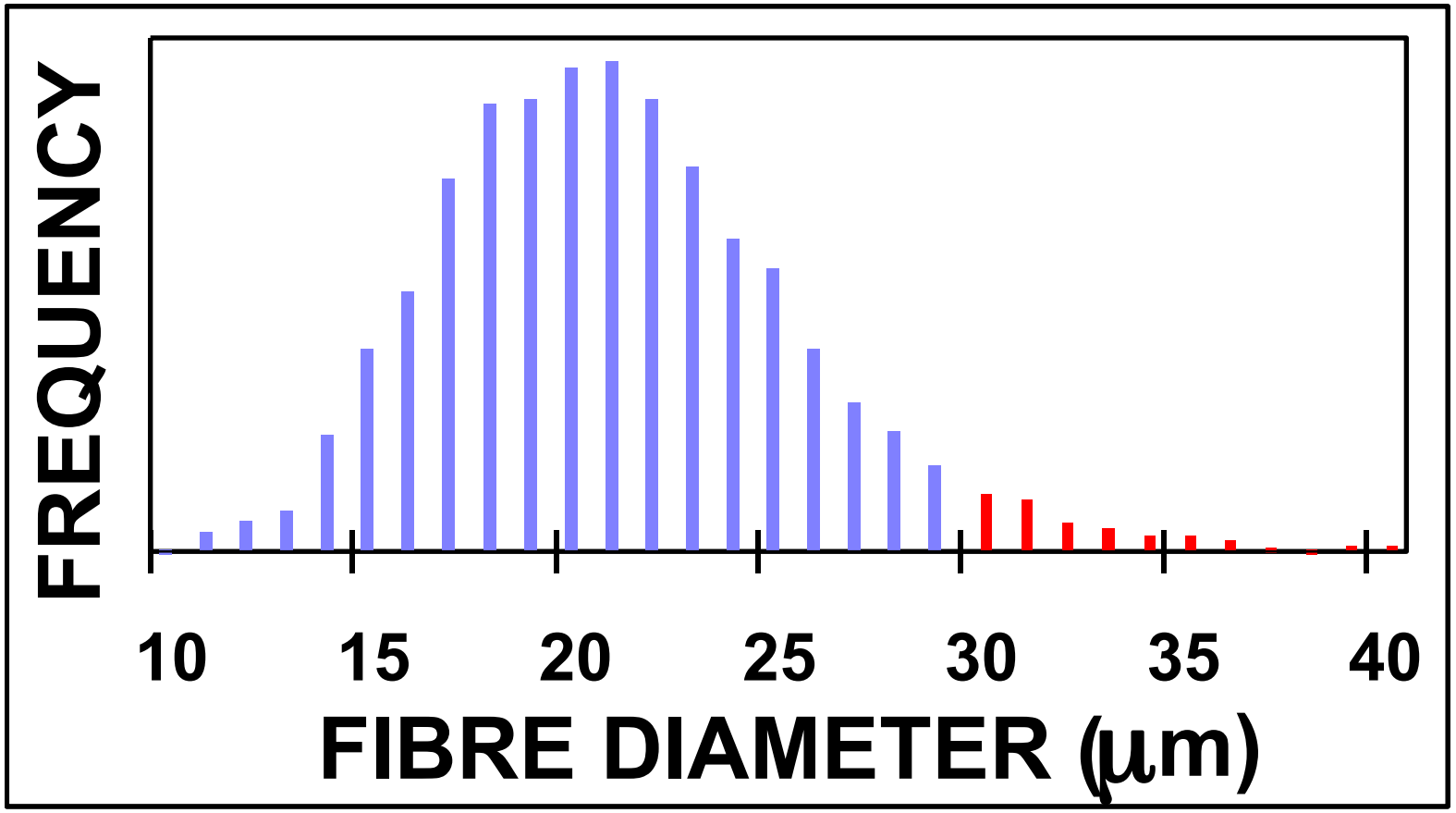
$F \alpha d^4/L^2$

F= force

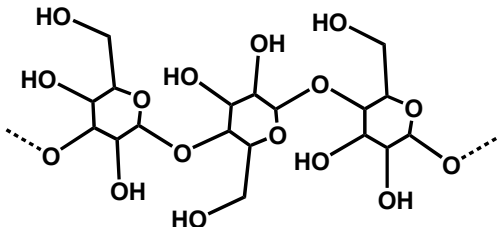
D=diameter

L= bending length

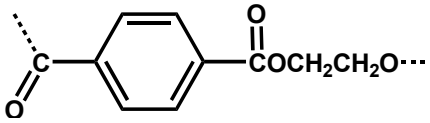



FREQUENCY
10
15
20
25
30
35
40
FIBRE DIAMETER (µm)

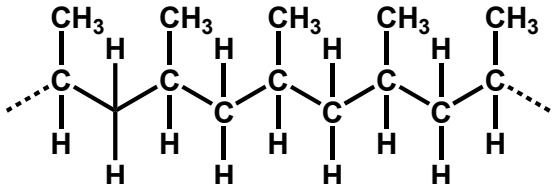
Fibre chemistry



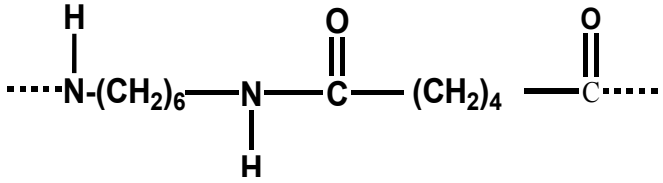
Cellulose, cotton: alkali resistant, damaged by acid



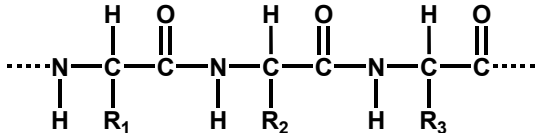
Polyester: alkali and acid resistant



Polypropylene: alkali and acid resistant



Nylon: damaged by strong acid



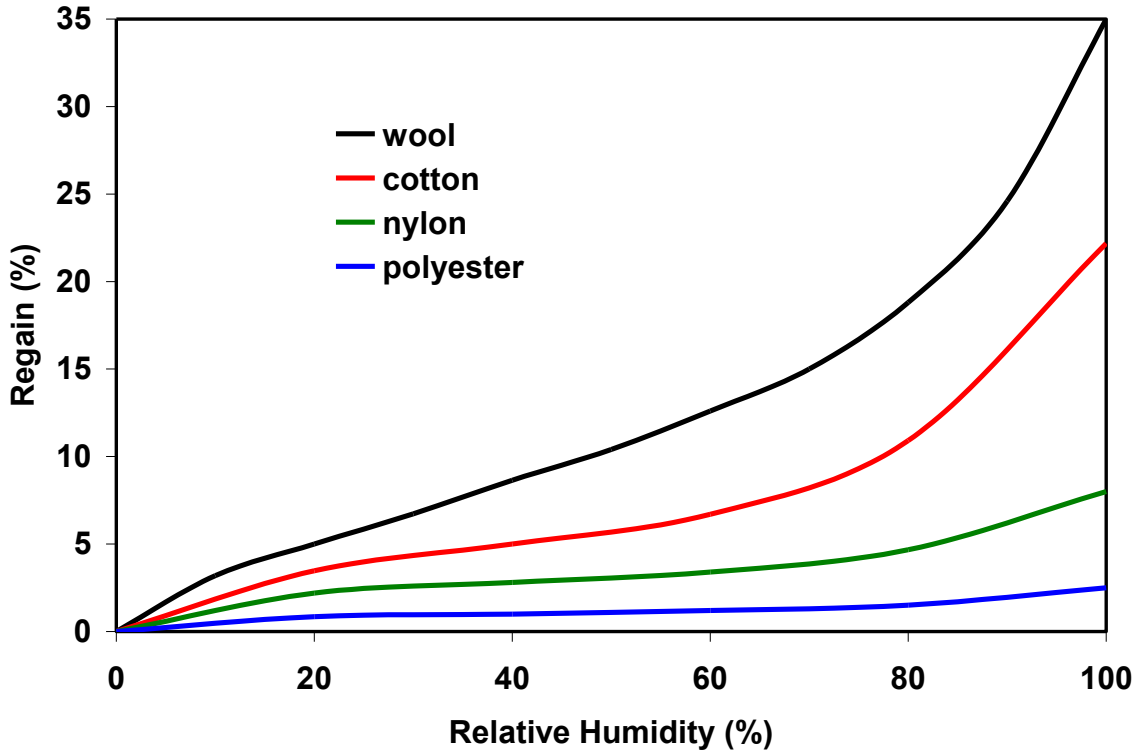
Wool: acid resistant, damaged by alkali

Water sorption

$$\text{Regain (\%)} = \frac{\text{mass water}}{\text{mass dry wool}} \times 100$$

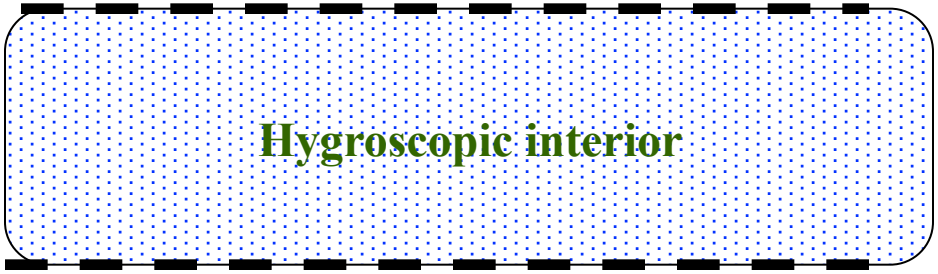
$$\text{Moisture content (\%)} = \frac{\text{mass water}}{\text{initial mass (wool + water)}} \times 100$$

Absorption behaviour of various fibres



Water sorption

- Internal structure absorbs water vapour
- External surface repels liquid water
- Sportwool garments use both these properties



Water repellent waxy surface (hydrophobic)

Properties of wool influenced by water

Property	Regain/%					
	0	5	10	15	25	35
Relative Humidity	0	15	42	68	94	100
Length Swelling/%	0	0.6	0.9	1.1	1.2	1.2
Radial Swelling/%	0	2	4	6	12	16
Youngs Modulus (relative)	1.0	1.0	0.9	0.8	0.6	0.4
Torsional Rigidity /GPa	1.8	1.6	1.3	0.9	0.3	0.1
Electrical Resistivity/$M\Omega$.m		30000	400	8	0.1	

Hygral expansion

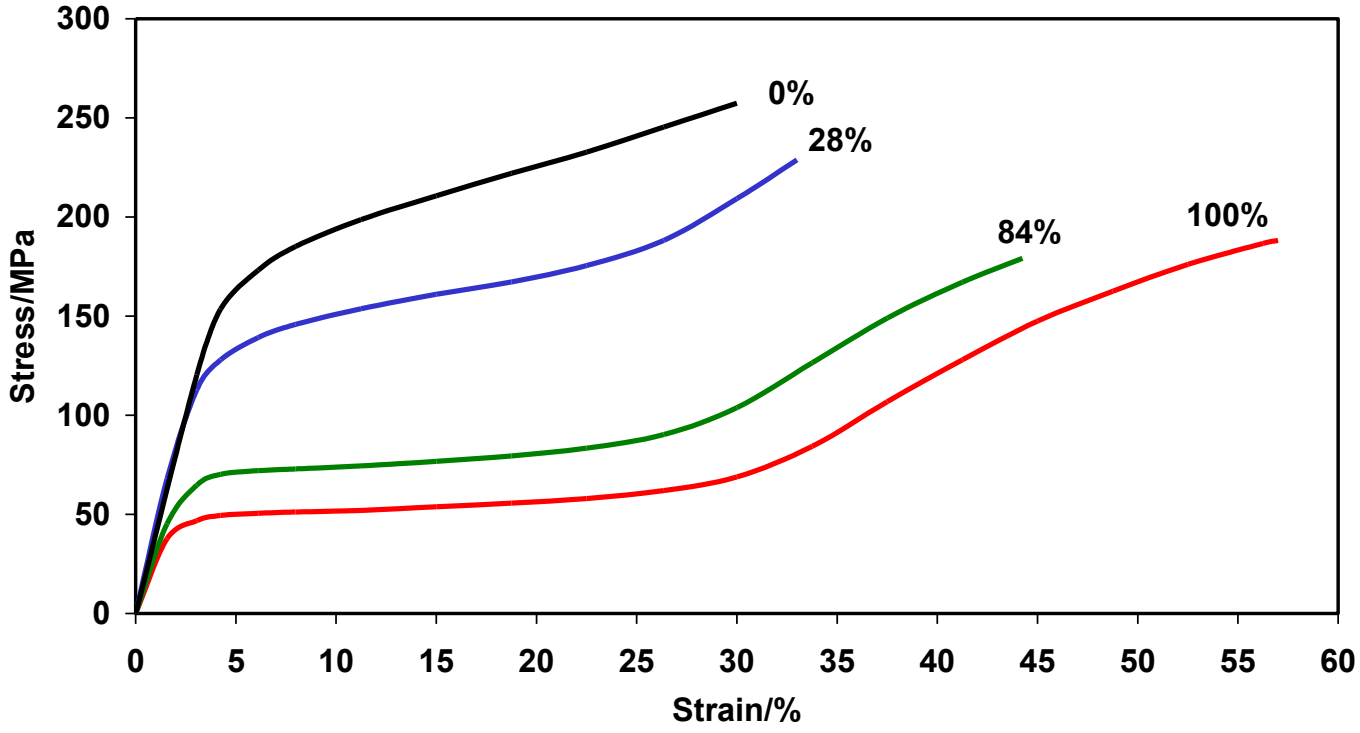
Fabric expands when it absorbs water.

Poor garment appearance if incorrectly made.

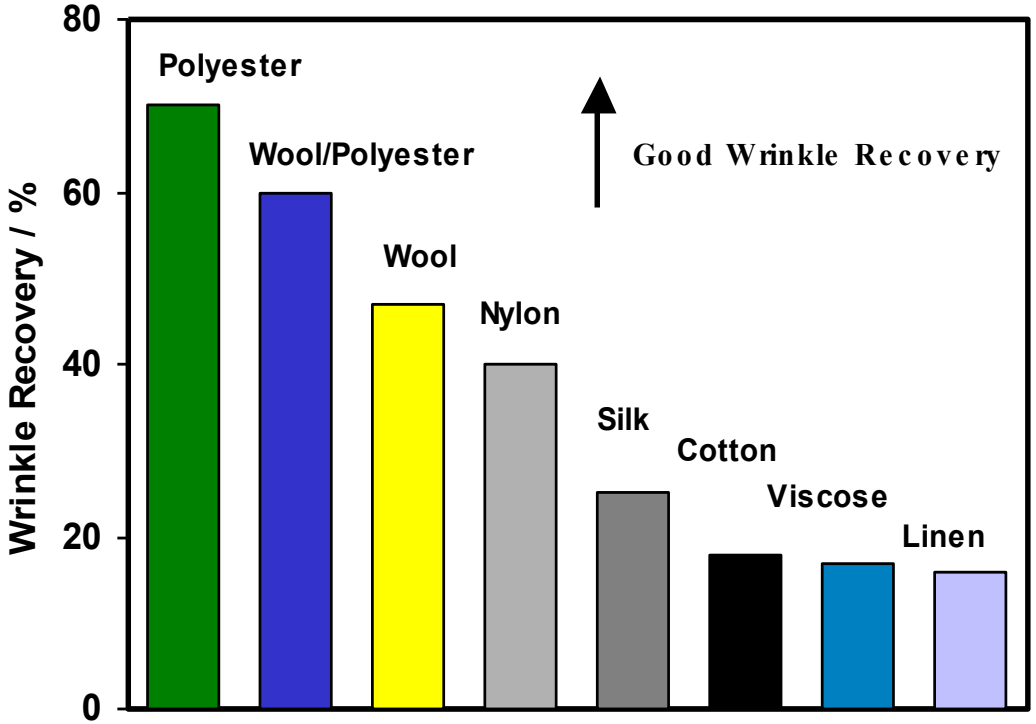
Desirable attributes of wool

- Moisture transport
- Wrinkle recovery
- Tailorability
- Drape
- Handle
- Durability
- Flame resistant
- Water and soil repellence
- Feltability
- Coloration

Stress/strain curve of wool at various relative humidity levels



Wrinkle recovery in a hot and humid environment

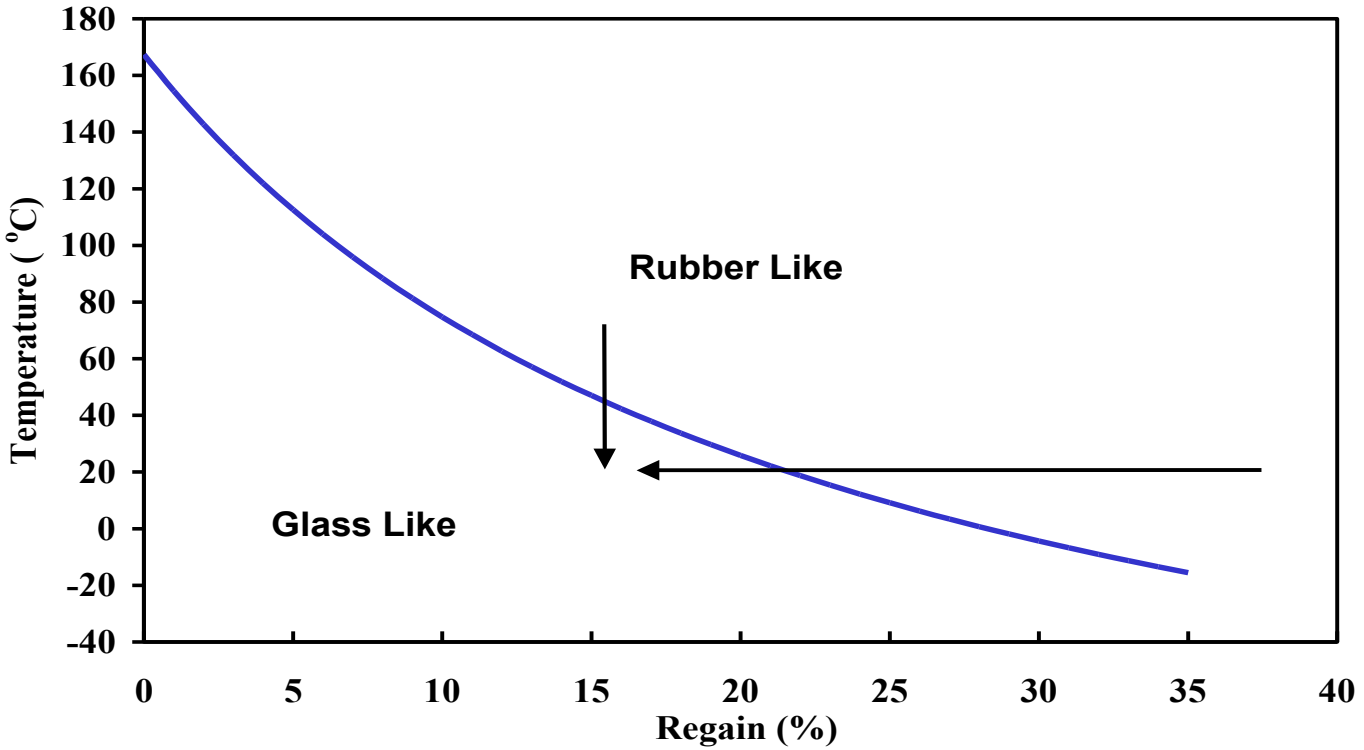


Tailorability

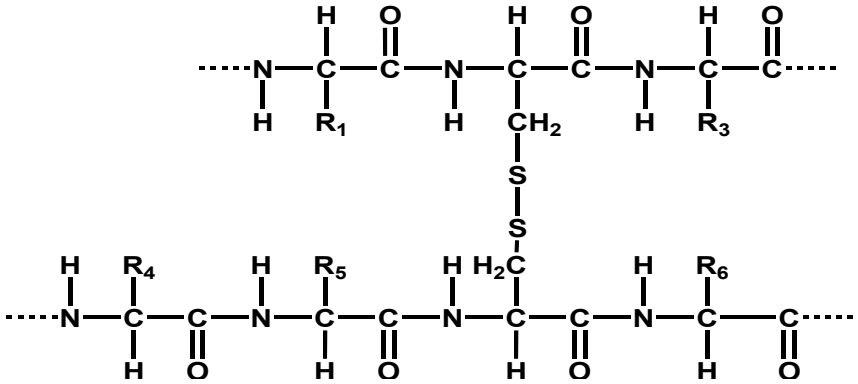
Fabric formed into desired shape.

Shape retained during wear.

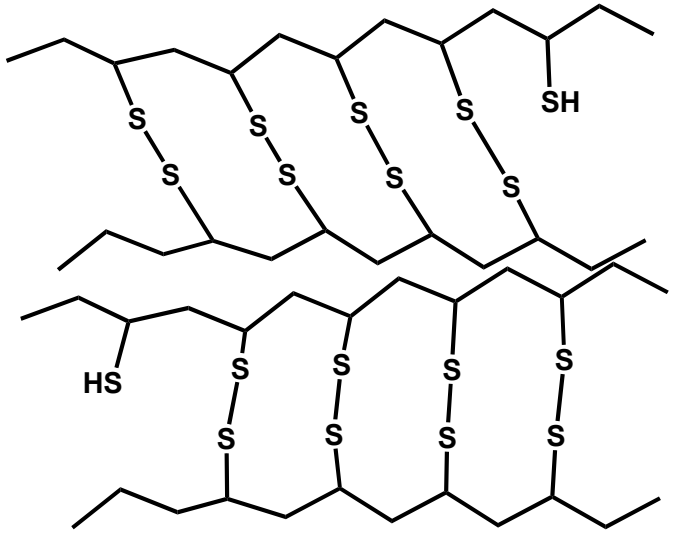
Cohesive/temporary setting of wool



Permanent setting of wool



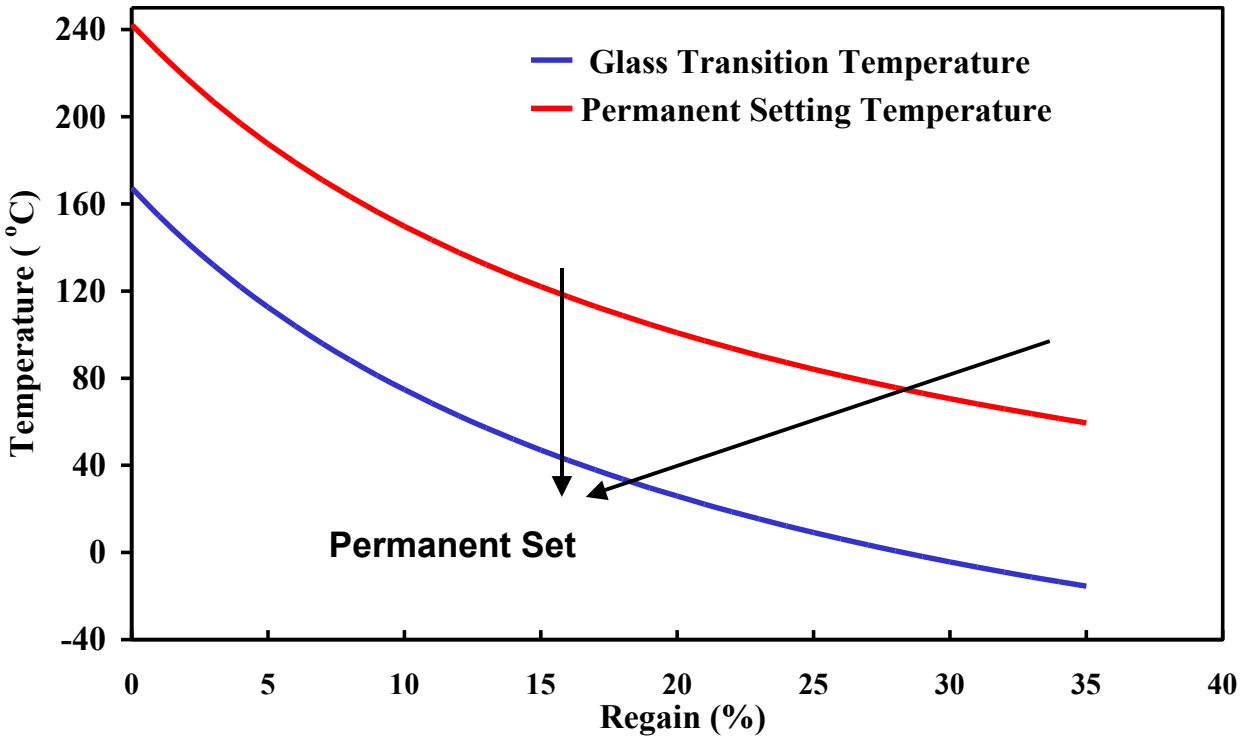
The wool fibre contains a number of disulfide bonds that link the protein chains together.



When the fibre is under stress, the disulfide bonds can rearrange (interchange) with heat and water to permanently set the fibre or shape of the fabric.

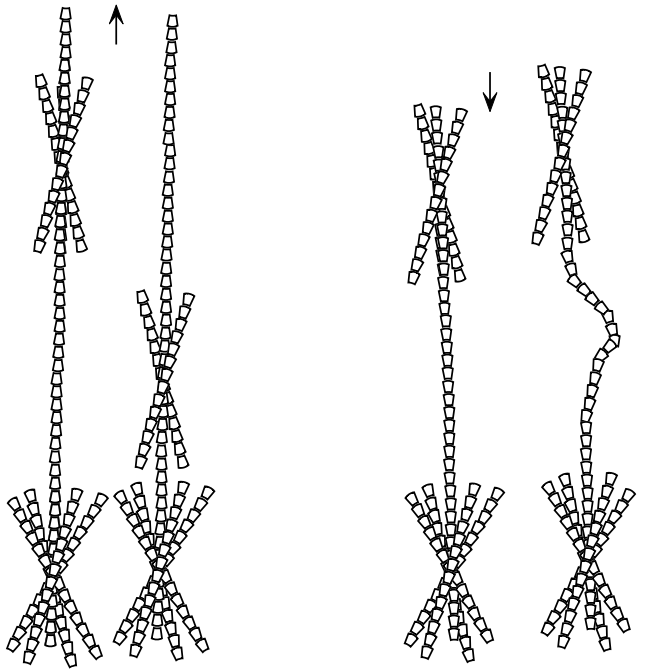
A permanently set fabric will retain its shape and stability even after immersion in warm water.

Permanent setting of wool

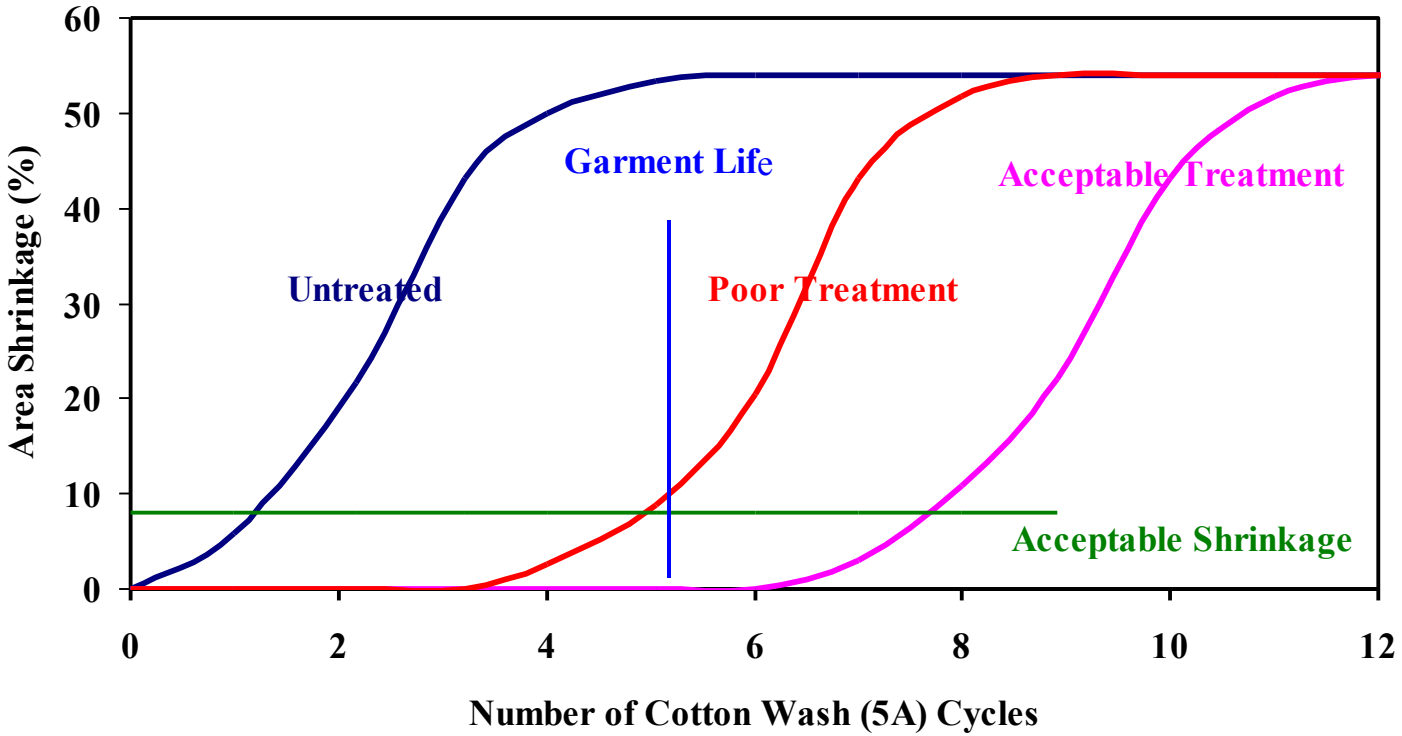


Felting

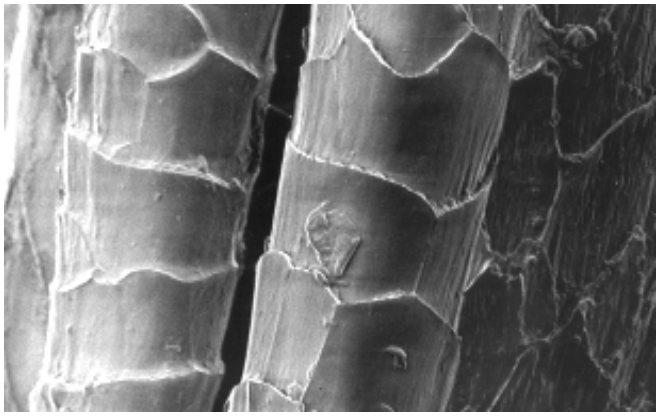
- Scale structure causes a frictional difference (lower when rubbing from root to tip).
- Scales help anchor fibres in the skin.
- Scales help encourage contaminants (burrs, seeds, dirt) to work out.
- Frictional difference results in felting.
- Felt products include:
  - hats
  - polishing pads
  - table covers
  - piano hammers.



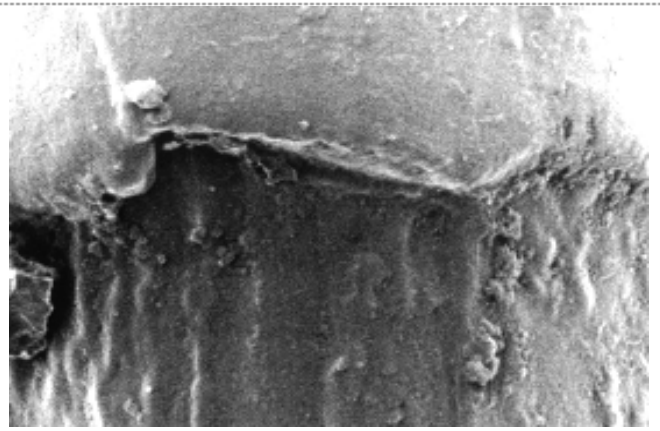
Felting behaviour of fabrics



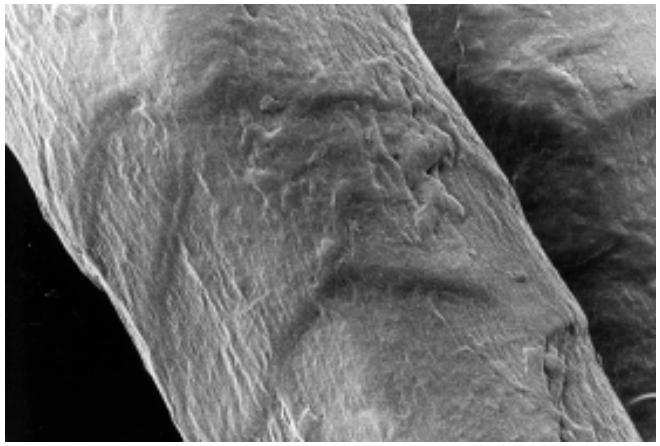
Electron micrographs of treated wool fibres



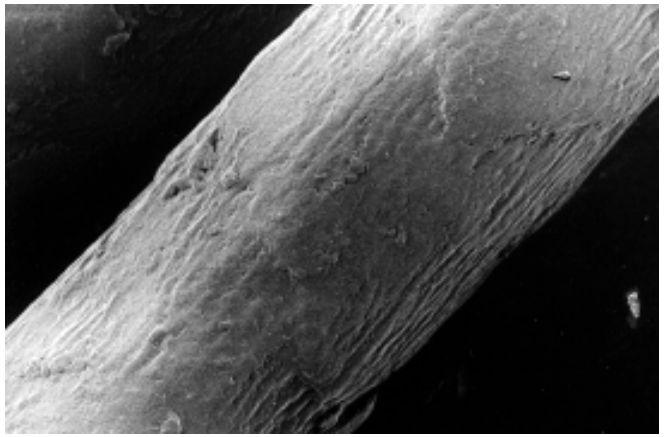
Untreated wool



Chlorinated wool

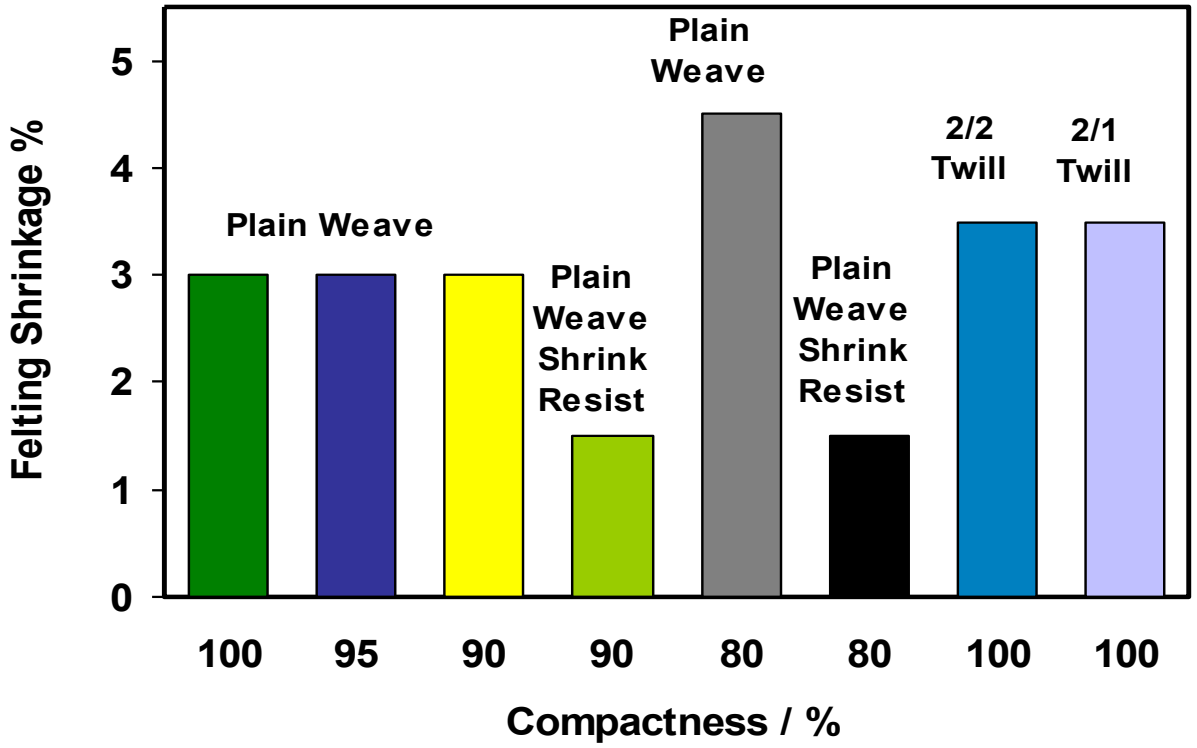


Chlorine/Hercosett



Soft lustre

Felting in 70/30 wool-polyester blend fabrics



Summary

Wool's unique and complex structure makes it a versatile fibre suitable for the production of tailored clothing, active sports wear and non-apparel items.

While other fibres may out-perform wool in one particular area, wool is the only fibre that offers good performance in all areas.