

## 2. Fleece Weight and its Component Traits

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### Learning Objectives

On completion of this topic you should be able to:

- describe and quantify the relationships between fleece weight, washing yield and the non-fibre components of the fleece
- explain the relationship between clean fleece weight and its component traits
- describe the sources of variation and within-fleece gradients in the fibre and non-fibre components of the fleece
- justify the merits of the mid-side region of the fleece for flock testing purposes
- identify non-genetic factors that may introduce bias into selection decisions based on fleece weight and its component traits

### Key terms and concepts

Greasy fleece weight; yield; clean fleece weight; non-fibre components; suint; wax; dust; vegetable matter; within fleece gradients; component traits; body weight; wrinkle score; staple length; fibre diameter; follicle density; non-genetic handicaps; mid-side sample.

### Introduction to the topic

This topic will give you an understanding of the factors that contribute to fleece weight and yield and how the contribution of each differs within and between fleeces as well as discussing how some of the component traits are measured.

### 2.1 Fleece weight, yield and the non-fibre components of the fleece

The mass of greasy wool shorn from the sheep, including the belly wool but prior to skirting, is referred to as the **greasy fleece weight**. This weight represents the combined weight of clean wool fibre, wax, suint, vegetable matter, dirt and dust, and other non-fibre components. This greasy weight is readily obtained if a set of scales is available in the shearing shed. However, from a wool processor's viewpoint, clean fibre is the commodity of interest, such that for trading purposes **yield** estimates are routinely obtained, this being the proportion of clean fibre that can be obtained from the greasy wool sale lots. There are a number of yield estimates reported depending on market requirements, but the common estimate is the **Schlumberger Dry Combed Top and Noil Yield**. This indicates the yield of fibre that can be processed into top, after adjusting for residual contaminants and fibre loss during processing.

For flock testing purposes, a **washing yield** is used to estimate the clean fibre content of the fleece. This involves a sample of the greasy fleece being weighed, then washed and dried, with the resultant clean, dry weight being expressed as a percentage of the greasy sample weight. No adjustments are made for residual contaminants after scouring. The clean fleece weight is then calculated as follows:

$$\text{clean fleece weight (kg)} = \text{greasy fleece weight (kg)} \times \text{washing yield (\%)}$$

Table 2.1 summarises the phenotypic associations between fleece weight, yield and the non-fibre components of the fleece. While those individuals with the heaviest greasy fleece weights may not produce the highest yielding fleeces, there is a strong tendency for them to be among those with the heaviest clean fleece weights. High yielding fleeces also tend to have relatively lower suint, wax and dust contents. Given the definition of washing yield, it is not surprising to find a lack of a strong correlation with vegetable matter content.

**Table 2.1 Phenotypic correlations between greasy (GFW) and clean (CFW) fleece weights, yield at the mid-side and the suint, wax, dirt and vegetable matter (VM) content in the mid-side sample. Source: Compiled from Mortimer and Atkins, (1989; 1993); Thornberry and Atkins (1984).**

	CFW	Yield	Suint	Wax	Dust	VM
GFW	0.87	-0.11	-0.06	0.17	0.03	-0.14
CFW		0.37	-0.23	-0.17	0.10	-0.10
Yield			-0.51	-0.68	-0.74	0.13
Suint				0.01	-0.01	-0.02
Wax					0.34	-0.49
Dust						-0.32

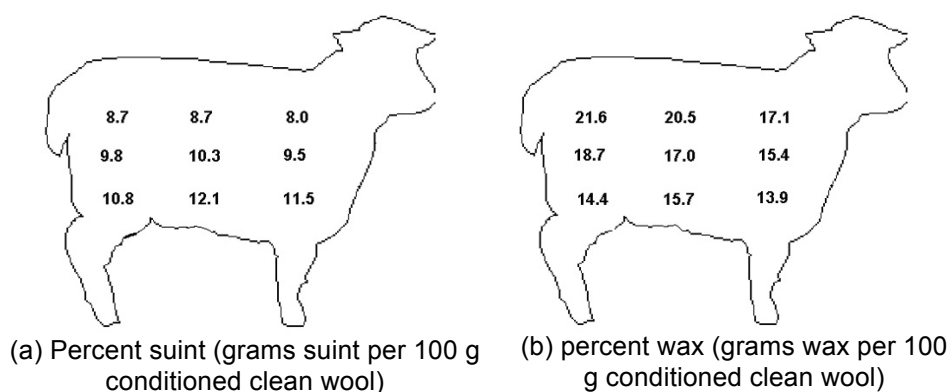
## 2.2 Sources of variation in yield and the non-fibre components of the fleece

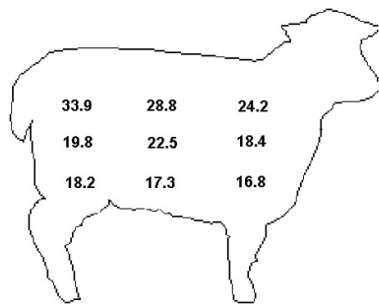
The results summarised in Table 2.2 relate to 4 strains of Merino – one fine, one medium non-Peppin and two medium Peppin strains – maintained as a single flock in one environment. The within-fleece and between-fleece components of variation are expressed as a percentage of the total within-mob variation. Note that these values don't indicate the actual level of variation, such that a source of variation could account for a large percentage of a very small amount of variation within a mob. These results indicate that between-fleece variation in suint and wax content is greater than within-fleece gradients, whereas within-fleece gradients in dust and vegetable matter are large compared to differences between fleeces.

**Table 2.2 Contribution of within- and between- fleece variation to total mob variation for the non-fibre components of the fleece. Source: Thornberry and Atkins (1984).**

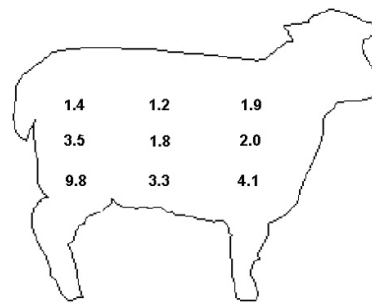
Component	Within-fleece	Between-fleece
Suint (%)	36	64
Wax (%)	42	58
Dust (%)	82	18
VM (%)	89	11

**Figure 2.1 Within-fleece gradients for non-fleece contaminants. Source: Thornberry and Atkins (1984).**





(c) Percent dust (grams dust per 100 g conditioned clean wool)



(d) Percent vegetable matter (grams vegetable matter per 100 g conditioned clean wool)

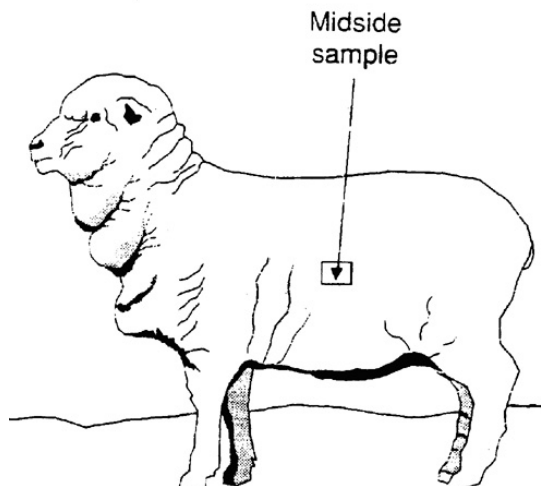
The general fleece gradients (Figure 2.1) can be summarised as follows:

- Suint - shows an increase from back-line to belly. Given its water-soluble nature, this gradient is likely to reflect the tendency for suint to be leached from the back-line in response to fleece wetting, which would be greater at this site than on the side or belly of the sheep
- Wax - shows an increase from mid-side to back-line and from forequarters to hindquarters. This reflects the gradient in follicle density as well as the reduction in the suint content of the mid-side and back-line of the fleece
- Dust - is generally greatest along the back-line, reflecting the more open nature of the fleece at this site. Dust content must be measured directly and not estimated from dust penetration (Ladyman et al. 2003)
- Vegetable matter - increases towards the breech and belly regions of the fleece, reflecting the proximity of these regions to pasture species that contribute to vegetable fault.

For suint and wax, most sample sites provide a reasonably reliable estimate of the fleece average. For vegetable matter and dust, the within-fleece gradients cause all sites to be less reliable in estimating the fleece average, although the mid-side sample is reasonable for dust. However, no single site provides a reliable estimate of vegetable matter content in the overall fleece.

Considering these gradients, the most reliable sample site for estimation of washing yield, which ignores VM, is the mid-side. This is defined as the site centred on the third last rib, halfway between the mid-line of the back and the mid-line of the belly (Figure 2.2). It is also advised that this should be taken from the left hand side of the animal, given then tendency for sheep to rest on their right side while lying down and the implications for VM and dust (Standards Australia 1997).

**Figure 2.2 Location of the mid-side sample site for collection of fleece samples for washing yield. Source: Standards Australia (1997).**



## 2.3 The components of clean fleece weight

Clean fleece weight (CFW) is a composite characteristic in that it is a function of a number of other characteristics comprising:

- those influencing the **total wool-growing surface area** of the animal, these being **body surface area** and **wrinkling factor**, and
- those influencing the **total weight of wool produced per unit area** of wool-growing skin, these being **mean fibre density**, **mean fibre length** and **mean fibre cross-sectional area**.

These individual components of CFW are difficult to measure directly but can be derived for more readily available measurements or scores, as summarised in Table 2.3. In the derivation of mean fibre length, a relationship is assumed between this component, and staple length and fibre diameter coefficient of variation (Schlink et al. 2001) (fibre length (mm) (FL) =  $-42.1 + 1.08 \times \text{staple length} + 3.01 \times \text{fibre diameter coefficient of variation}$ ). In the derivation of mean fibre cross-sectional area, there is a contribution arising from diameter variation (VD), though for most purposes, ignoring this contribution results in minimal error. Wrinkling factor is the only component not derived from a measured parameter, but instead is derived from a wrinkle scoring system developed by Carter (1943).

**Table 2.3 Derivation of CFW components. Source: Compiled from Turner, (1958); Schlink et al. (2001).**

Component trait	Derived from	Derivation
Body surface area	Body weight (B)	B0.67
Smooth surface area	Wrinkle score (F)	F0.20
Mean follicle density	Mean fibre density (N)	N
Mean fibre length	Mean staple length (L)	FL
Mean fibre cross-sectional area	Mean fibre diameter (D)	$\pi (D^2 + VD)/4$
Fibre density	Fibre density (g/cm <sup>3</sup> )	1.304

With the exception of follicle density, all component traits have direct economic value in their own right. Body weight influences the sale value of surplus stock, but this must be balanced with the higher feed intakes associated with larger sheep. Highly wrinkled rams have reduced capacity to thermoregulate the scrotum, such that temporary infertility can occur during hot conditions, with implications for flock fertility in some environments when a late summer joining is practiced.

Fibre diameter and staple length have direct effects on wool value. Clean price increases as average fibre diameter declines, such that premiums are paid for finer wool types. In addition, there is an *increase* in the price differential as fibre diameter *decreases*, ie. the % change in price from 20 $\mu$ m to 19 $\mu$ m is greater than the % change in price from 25 $\mu$ m to 24 $\mu$ m. Thus the relationship between fibre diameter and clean price is curvilinear. There is also a curvilinear trend between staple length and clean price, though different in nature to that for diameter. There appear to be optimum staple lengths such that shorter and longer staple lengths, relative to this optimum length, incur a penalty. The optimum lengths differ for fine, medium and strong wool types and from sale to sale. Also, the penalties tend to be greater for finer wool types.

## 2.4 Phenotypic associations between clean fleece weight and its components

Changes in clean fleece weight must arise from changes in one or more of its component traits. Table 2.4 summarises the phenotypic associations between CFW and the component traits, indicating the extent to which clean fleece weight and its component traits are likely to change together from sheep to sheep. Within any mob of sheep, those individuals producing a heavier weight of clean wool tend also to be those with the longer staples and heavier body weights. To a lesser extent, they may also show a tendency towards higher fibre diameter and wrinkle score. They may not, however, be the individuals with the highest follicle densities.

On this basis, it is expected that factors which increase clean fleece weight will also give rise to an increase in staple length and body weight, and to a lesser extent, fibre diameter and wrinkle, with little effect on follicle density.

**Table 2.4 Phenotypic correlations between clean fleece weight and its component traits in fine, medium and broad wool Merino flocks. Source: Compiled from Swan et al. (1995); Purvis and Swan (1997); Brown and Turner (1968); Gregory (1982).**

Component	Fine	Medium	Broad
Body weight	0.44	0.23	0.36
Wrinkle score	-	0.12	0.20
Follicle density	0.04	0.16	0.09
Staple length	0.36	0.37	0.32
Fibre diameter	0.26	0.14	0.13

This is demonstrated best by way of example. A single mob of young sheep was randomly split into two groups (Morley 1956; Dun 1958). One group (High) was given the best available pastures for grazing and received ad lib cereal hay, oaten grain and meat meal when pasture appeared limiting. The other group (Low) grazed pastures that had been heavily infested with rabbits, with little feed on offer. The groups grazed under these conditions for 12 months. Measurements of clean wool weight, body weight, wrinkle score, follicle density, fibre diameter and staple length were collected at the end of the experiment, when sheep were 18 months of age.

The results are summarised in Table 2.5. Sheep on the high plane of nutrition produced around 40% more clean weight of wool compared to those on the low plane of nutrition. This increase was achieved predominantly through an increase in the weight of clean wool per unit area of skin as well as an increase in the total surface area of wool-bearing skin due solely to an increase in body weight. The increase in clean weight per unit area of skin arose from substantial increases in fibre volume (i.e. diameter and length), offset to some extent by a reduction in fibre density (as the fixed number of follicles were spread over more skin area - thus density declined). There was no significant change in total number of fibres as the increase in smooth surface area was offset by a reduction in fibre density.

**Table 2.5 Mean performance for clean fleece weight and its component traits in groups of sheep maintained on either a high or low plane of nutrition, and the difference between the two groups expressed as a percentage of the low nutrition group performance. Source: Dun (1958).**

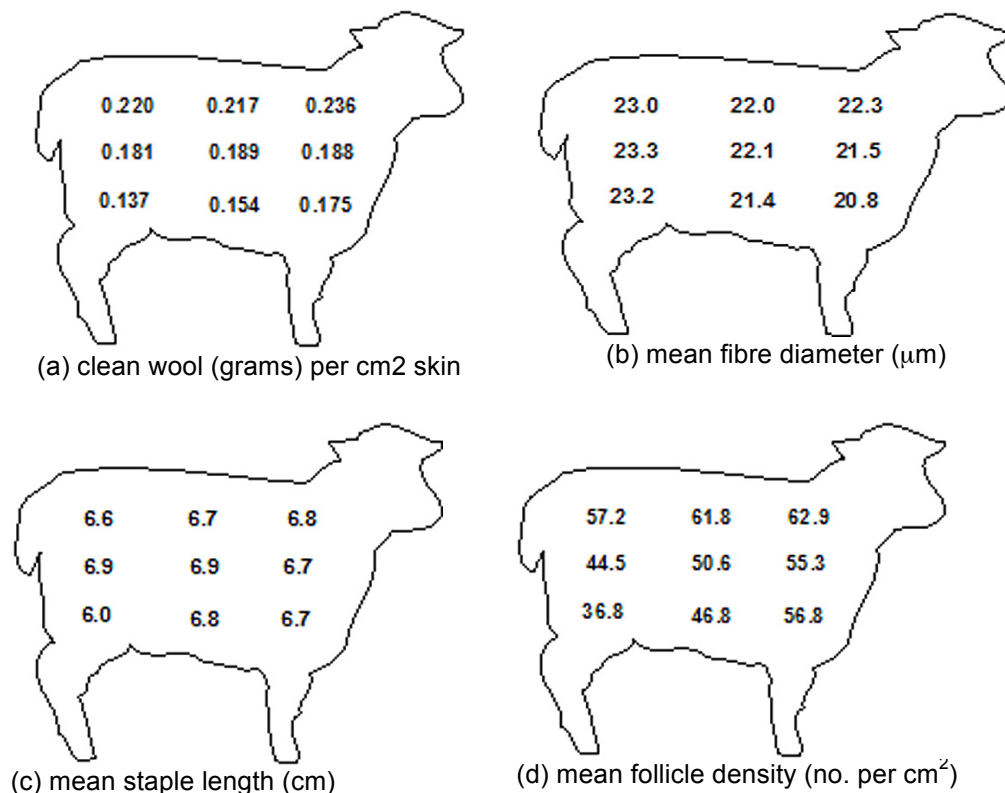
	High	Low	% diff.
Clean fleece weight (kg)	4.1	2.9	41
Body weight (kg)	40.1	30.8	30
Wrinkle score	11.1	11.0	< 1
Follicle density (no. per mm <sup>2</sup> )	33.4	41.3	- 19
Staple length (cm)	10.0	9.1	10
Fibre diameter (µm)	24.2	20.4	19

## 2.5 Within- and between- fleece variation

Figure 2.3 summarises the within-fleece trends evident in Merino sheep for clean wool production per unit area of skin and its component traits, fibre diameter, staple length and follicle density. For the composite trait, there is a significant gradient from the belly to the back-line, and a lesser gradient from hind to forequarters (Figure 2.3a). As to fibre diameter, there is a general antero-posterior gradient, such that the hind section of the fleece is usually the coarsest. Dorso-ventral gradients in diameter are not consistent. Gradients for staple length do not appear to be significant nor consistent. Follicle density, however, shows a large gradient from belly to back-line and from hind to forequarter. Thus differences in wool production per unit area of skin between regions of the body are mainly a reflection of follicle density gradients.

In view of these within-fleece gradients, a choice must be made as to the most appropriate site from which to take a fleece sample for flock testing purposes. As with washing yield, measurements of wool production per unit area of skin, fibre diameter and staple length at the mid-side have the strongest and most consistent correlation with the overall average for the fleece. Other sites can be used for the ranking of animals, provided the sampling site is consistent between animals. For example, some breeders measure diameter at the hip-bones to indicate the "upper limit" of diameter within the fleece, even though it does strongly reflect the fleece average.

**Figure 2.3 Within-fleece gradients for clean wool production per unit area of skin and its component traits. Source: Young and Chapman (1958).**



Given the direct economic importance of fibre diameter and staple (fibre) length, it is worthwhile considering the sources of variation in these two components in greater details. That is, the relative contributions to total mob variation due to variation between fleeces, variation between sites within a fleece, variation between staples within a site and variation between fibres within a staple.

**Table 2.6 Relative contributions to total within-mob variation in fibre diameter, staple length and fibre length. Source: Compiled from Quinnell et al. (1973); Rottenbury and Andrews (1975); Rottenbury et al. (1980); Dunlop and McMahon (1974).**

	Fibre diameter	Staple length	Fibre length
Within fleece	84	66	90
Within staples	80	-	80
Between staples	4	66	10
Between fleece	16	34	10

By referring to Table 2.6, it can be seen that there is more variation in fibre diameter, staple length and fibre length *within* a fleece than there is variation *between* fleeces within a mob. Furthermore, for fibre diameter and fibre length, there is more variation in diameter and length within a single *staple* than there is between sheep within a mob.

## 2.6 Non-genetic handicaps in the clean fleece weight and its components

Non-genetic factors such as age of dam, birth-rearing status and age can significantly affect the performance of young sheep in terms of clean fleece weight and its components. Table 2.7 represents the penalty in hogget performance (12-18 months age) arising from having a maiden dam, being born and raised as a multiple lamb and being born late in the lambing period. For example, sheep born to maiden ewes will have 2% lower clean fleece weight on average at hogget shearing compared to those born to adult ewes. Those born as multiples will have 7% lower fleece weight compared to their single-born contemporaries. Those born at the end of a 5 week lambing period will have 11% lower fleece weight compared to those born at the start of lambing. In general, these handicaps impact on fleece weight and the component traits in much the same way, except possibly for fibre diameter and follicle density.

These handicaps constitute a potential source of bias at selection. In other words, the genetic merit of an individual may be over- or under- estimated due to its performance being (dis)advantaged by one or more of these non-genetic factors. We expect, for instance, that an individual of high genetic merit for wool production would not perform phenotypically as well as unhandicapped individuals of lower merit if it had been born to a maiden dam, was born and raised as a multiple and had been born late in the lambing period. It's performance would be penalised!

**Table 2.7 Possible handicaps in hogget performance for clean fleece weight and its component traits, arising from dam age, birth-rearing status and age. Each handicap is expressed as the difference as a percentage of either maiden, multiple-reared or youngest age. Source: Mortimer and Atkins (1989; 1993).**

	Maiden vs adult dam	Multiple- vs single-reared	Youngest vs oldest (5 week lambing)
Clean fleece weight	-2%	-7%	-11%
Body weight	-2%	-4%	-7%
Wrinkle score	-9%	-29%	-15%
Follicle density	-1%	-3%	-5%
Staple length	0%	-2%	+4%
Fibre diameter	0%	+2%	-2%

Substantial annual variation in flock average performance exists for all components of clean fleece weight. However, annual variation in clean wool per head is largest, reflecting the combined effect of variations in all components. In the example given in Table 2.8, the annual differences are not the result of genetic changes, but a reflection of variation in seasonal conditions. This makes it very difficult to compare individuals across years and to identify genetic gains simply by looking at flock average performance.

**Table 2.8 Highest and lowest average annual performance for clean fleece weight and its component traits in a flock of Merino sheep randomly selected over a 20 year period. The difference between the two is expressed as a percentage of the lowest annual performance. Source: With permission from B. Crook, (Unpubl. data).**

	Highest	Lowest	% diff.
Clean fleece weight (kg)	3.8	1.5	153
Body weight (kg)	42.2	27.4	54
Wrinkle score	4.4	2.0	120
Follicle density (no. per mm <sup>2</sup> )	60.9	43.6	40
Staple length (cm)	10.7	6.9	55
Fibre diameter (µm)	23.7	20.1	18

## Readings

The following readings are available on CD:

1. Dun, R.B. 1958, 'The influence of selection and plane of nutrition on the components of fleece weight in Merino sheep', *Australian Journal of Agricultural Research*, vol. 9, pp. 802-818.
2. Leroy Johnson, C. and Svend-Aage, L. 1978, 'Clean wool determination of individual fleeces', *Journal of Animal Science*, vol. 47(1), pp. 41-45.
3. Mortimer, S.I. and Atkins, K.D. 1993, 'Genetic evaluation of production traits between and within flocks of Merino sheep. II. component traits of the hogget fleece', *Australian Journal of Agricultural Research*, vol. 44, pp. 1523-1539.
4. Thornberry, K.J. and Atkins, K.D. 1984, 'Variation in Non-Wool Components of the Greasy Fleece Over the Body of Merino Sheep', *Australian Journal of Experimental Agriculture: Animal Husbandry*, vol. 24, pp. 72-76.
5. Turner, H.N. 1958, 'Relationships Among Clean Wool Weight and its Components. I. Changes in Clean Wool Weight Related to Changes in the Components', *Australian Journal of Agricultural Research*, vol. 9, pp. 521-552.

### Activities

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Choose ONE question from ONE of the topics as your assignment. Short answer questions appear on WebCT. Submit your answer via WebCT



## Summary

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Clean fleece weight is determined by correction of greasy fleece weight for yield. Yield is the amount of clean wool left after the non wool components of wax, suint, vegetable matter and dust have been removed from the sample. The mid-side sample site has been shown to be the best sample site for the prediction of fleece traits of clean fleece weight, yield, fibre diameter, staple strength, staple length, etc. The amount of wool grown by a sheep is a function of body weight, follicle density, fibre diameter and fibre length. Wool density is assumed to be constant for Merino sheep. Nutrition increased or decreases fleece weight by changes in fibre diameter and length but there are no effects on the total number of fibres on a sheep or wool density. Most of the variation within a flock for fibre diameter, staple length and fibre length is within the fleece and not between fleeces. Time of birth in relation to the rest of the flock, along with birth status of single or twin and whether the lamb was from a maiden or adult ewe must be taken into account when sheep are being phenotypically selected on the basis of clean fleece weight.

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## Glossary of Terms

Birth rearing status	usual refers to lambs rearing status at wean, whether they were born as singles and raised as singles, born as twins and raised as twins, born as twins and raised as singles, etc
Body surface area	function of sheep liveweight calculated using body weight to the power of 0.67
Body weight	liveweight of the sheep
Clean fleece weight	weight of clean wool removed from the sheep by shearing
Dust	dust from the environment deposited in the wool between shearing
Dust penetration	depth of dust movement down the staple expressed as a percentage of staple length or length of dust movement down the staple from the tip
Fibre diameter	the thickness of individual wool fibres
Follicle density	number of wool follicles per unit area of skin
Greasy fleece weight	weight of greasy wool removed from the sheep by shearing
Mean fibre cross-sectional area	assumes the fibre is circular in cross section area and uses the sample mean fibre diameter fibre diameter to calculate cross-sectional area
Mean fibre density	the specific gravity of wool, assumed to be 1.304 with no medullation
Mean fibre length	mean length of the individual fibres in the staple, usually estimated from staple length and final lengths is affected by the degree of fibre crimping in the staple
Mid-side	the site centred on the third last rib, halfway between the mid-line of the back and the mid-line of the belly
Phenotype	the sum of the effects of environment and genotype on the characteristic of interest
Schlumberger Dry Combed Top and Noil Yield	is the most commonly used commercial core test yield and predicts the amount of Top and Noil that can be combed from the greasy wool. It is the main yield basis for wools traded in Western Europe
Staple length	the length of a staple projected along its axis obtained by measuring the staple without stretching or disturbing the crimp of the fibres

Suint	secretions from the sweat glands in the wool
Total weight of wool produced per unit area	equivalent to greasy or clean fleece weight
Total wool-growing surface area	Total area of skin on a sheep that produces wool and is a function of body weight and the amount of wrinkle on the skin
Vegetable matter	burrs (including hard heads), twigs, seeds, leaves and grasses present in wool
Washing yield	Sample of greasy fleece is weighed, washed and dried, with the resultant clean, dry weight being expressed as a percentage of the greasy sample weight
Wax	secretions of the sebaceous gland in the wool
Wrinkle factor	the degree of wrinkle on the skin based on standard scores for skin wrinkling
Yield	total amount of clean fibre, at a standard regain, that is expected to be produced when a delivery of raw wool is processed. This yield may be expressed both as a clean mass in kilograms and as a percentage of the mass of raw wool prior to processing

