2. Overview of Wool Yarn Manufacture

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Learning objectives

On completion of this topic you should be able to:

- Describe the essential features of the worsted, woollen and semiworsted processing routes, using an appropriate flow diagram
- Explain the similarities and differences between these routes with respect to (a) the raw material requirements, (b) complexity of each route, and (c) the properties and uses of the yarn produced by each.
- Outline the functions of the key processing steps involved in converting scoured wool into yarn
- Sketch the layout of a simple, single-swift card and name the key parts.

Key terms and concepts

Worsted, semiworsted, woollen, carding, gilling, drafting, combing, ring spinning, twisting, slubbing, sliver, top, singles yarn, folded yarn, linear density, count, twist, dyeing

Introduction to the topic

To make almost all wool products the wool must first be scoured and impurities such as vegetable matter removed; then the fibres are made parallel and mostly spun into yarn, and finally the yarns are interlaced by weaving or knitting to form the product. The type of processing route and the range of products that can be made depends largely on the properties of the wool. For fine wools which are destined for high quality apparel, the **worsted system** is the preferred route. This is the most complex of the three main routes. To achieve the required yarn quality, there are generally stringent requirements on the raw material. On the other hand, the **woollen system**, which is the most common route for coarser wools, can accept a wide range of wool types. The resulting yarn has quite different properties to a typical worsted yarn, but is well suited for carpets and heavy apparel. Between these two routes is the **semiworsted system**, which is essentially a shortened version of the worsted route and produces a yarn that is intermediate in properties between worsted and woollen yarns.

Australia produces mostly fine and medium Merino wools, so that approximately 85% of Australian wool is directed towards the worsted processing system. The remaining 15% is processed on the woollen system. However, world-wide, woollen processing represents almost 50% of wool processing, and this is the most commonly used route for New Zealand wool and strong wools from other countries.

This topic briefly describes and compares the three yarn manufacturing routes, and the steps involved in each. The specific steps are examined in more detail in subsequent topics.

A brief outline of wool processing is provided by Teasdale (1995). Comprehensive information is provided in two newer texts: Hunter (2002) and Lawrence (2003), and in the review paper by Harrowfield (1987).

A number of web sites cover the basics of yarn manufacture including:

- British Wool Marketing Board
- (http://www.britishwool.org.uk/factsheet3.asp?pageid=96),
- Purdue University
- (http://ag.ansc.purdue.edu/sheep/ansc442/Semprojs/2002/wool/washing_and_processing_wool.htm)
- MWI (NZ)
- (http://www.woolpro.co.nz/sheep_wool/Processing/processing.html).

A wool glossary is also available:
http://www.llamapaedia.com/wool/glossary.html.

2.1 A short history of yarn making

While it is not certain when man first started spinning fibres into yarn, there is archaeological evidence that the skill was practiced at least 8000 years ago. Our cultural history extends back over 10,000 years when some tribes changed from being nomadic forager-hunters to farmers, domesticating animals and cultivating plants. Wool was probably one of the first fibres to be spun, since sheep existed even before Homo sapiens evolved.

It is possible to speculate that early man would have twisted a few fibres from a fleece into short lengths of yarn and then tied them together to make longer lengths. These are called staple fibre yarns, because the fibres used are referred to as staple fibres.

As the various textile skills developed, the impetus for spinning continuous lengths, free of knots, would have led to a stick being used. This tool may have been used for winding up the yarn and then to twist and wind up longer lengths. The method of spinning a yarn using a dangling spindle or whorl was widely practiced for processing both animal and plant fibres. Flax was probably the most common ancient plant made into yarns, although hemp was also used.

The simple spindle continued as the only method of making yarns, until around AD 1300, when the first spinning wheel was invented and developed in Europe into the “great wheel”. The actual mechanisation of spinning took place over the period 1738 to 1825 to meet the major rise in the demand for spun yarn. This demand resulted from the spectacular increase in weaving production with the invention of the flying shuttle by John Kay in 1733.

Here are some significant events:

- Mechanical drafting was invented by Lewis Paul in 1738 when pairs of rollers were first used to convert a fibre mass into a thin ribbon for twisting
- Spindles were grouped together to be operated from a single power source – the water frame of Richard Arkwright in 1769
- The “spinning jenny” of James Hargreaves and the “mule” of Samuel Crompton was followed by Roberts’ self-acting mule in 1825
- In 1830 a new method of inserting twist, known as cap spinning, was invented by Danforth in the USA
- In the early 1960s, cap spinning was superseded by ring spinning, which despite subsequent inventions has remained the main commercial method, and is now an almost fully-automated process.

Today, yarn production involves highly advanced technologies that facilitate the engineering of a different yarn structures having specific properties for particular applications.

More extensive information is available in the reading *The History of Spinning* (Lappage 2004.pdf).

2.2 Mechanical processing of wool

The mechanical processing stage in the wool pipeline commences with clean scoured wool and ends with the yarn ready for the fabric manufacturing stage. The main objectives of mechanical processing are to:

- disentangle the fibres
- remove vegetable matter, mix the fibres
- form a uniform strand of fibres (sliver or slubbing)
- attenuate the strand (i.e. reduce its thickness) and impart cohesion to form a yarn of the required linear density, quality and character.

Other operations that can also take place include:

- removal of short fibre and residual vegetable matter (combing)
- dyeing (as loose stock, sliver, top or yarn)
- folding (plying), winding, clearing, chemical setting, etc.
- shrink-proofing (loose stock or sliver).

All of the above must take place with maximum efficiency and quality, and with the minimum cost, fibre damage and breakage, and fibre loss.

The mechanical processing of wool can be divided into three main steps:

1. **Sliver or slubbing formation:**
   This involves disentangling and mixing the fibres, removing vegetable matter and forming a continuous web, sliver or slubbing. This step is achieved by *carding*.
2. **Preparing the carded sliver for spinning:**
   This involves aligning the fibres (parallelisation), evening (doubling), drafting and the removal of short fibres, neps, vegetable matter and other contaminants. These are achieved by *gilling*, *combing* and *drawing*.
3. **Yarn formation:**
   This involves drafting the fibres into a thin strand, imparting cohesion to the strand (usually by inserting twist). This is the *spinning* step.

Three alternative systems are used for processing scoured wool into yarn: i.e. the *woollen*, *semi-worsted* and *worsted* systems. There are similar and essential features between the three systems, such as the prior application of a special lubricant (as an emulsion with water) to assist processing, and the principles of the carding and spinning steps (see Figure 2.1).

However, the routes have significant differences, in terms of the number of steps required to produce a yarn, the type of machinery used at each step, the types of wools that can be economically processed, and the properties of the yarns produced (see Figure 2.2 and Table 2.1).

Firstly, the carding step, which is common to all three routes, will be considered.

Figure 2.1 General steps in wool processing. Source: Wood, 2006.

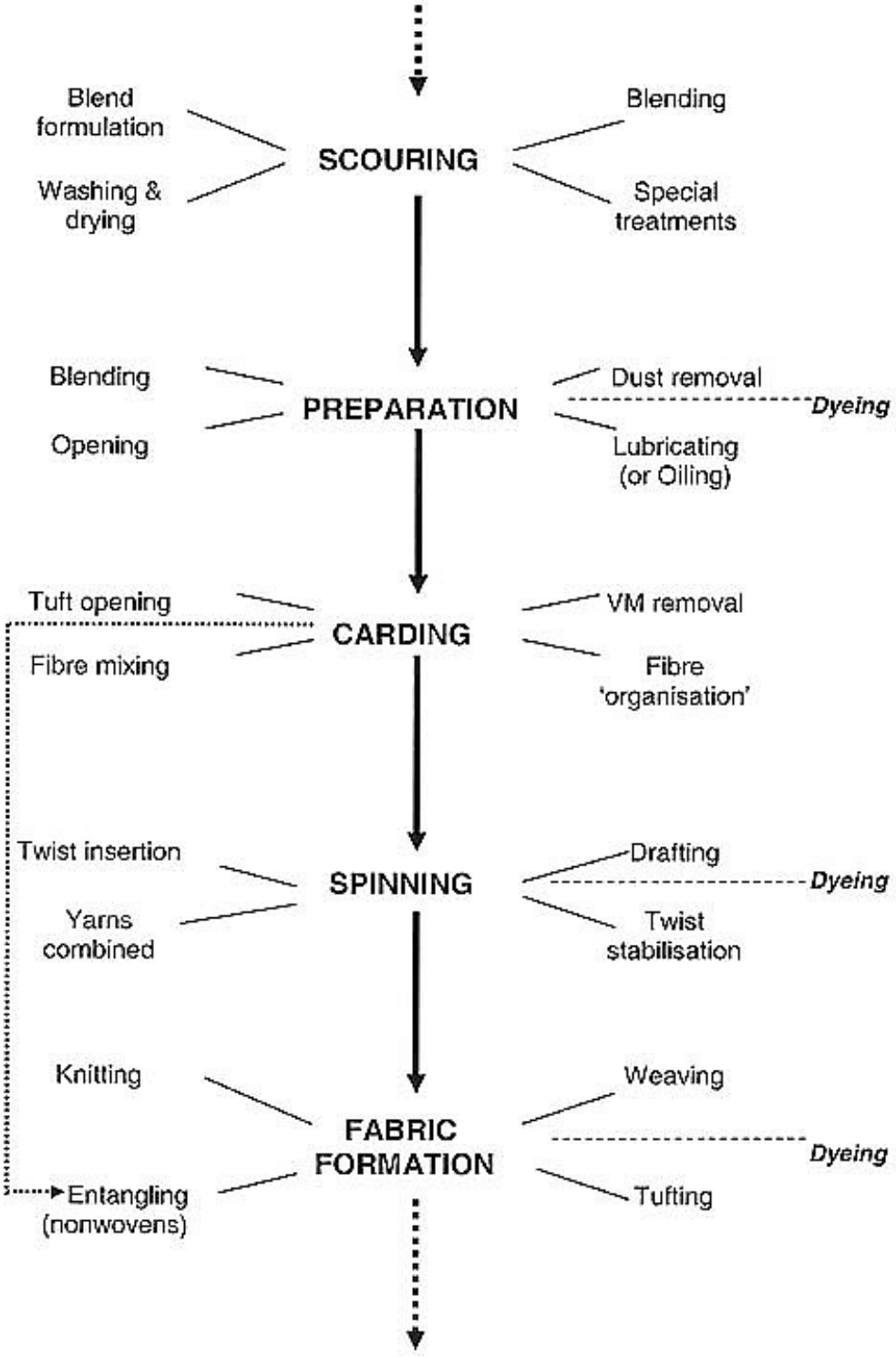


Figure 2.2 The three main processing routes for wool. Source: Wood, 2006.

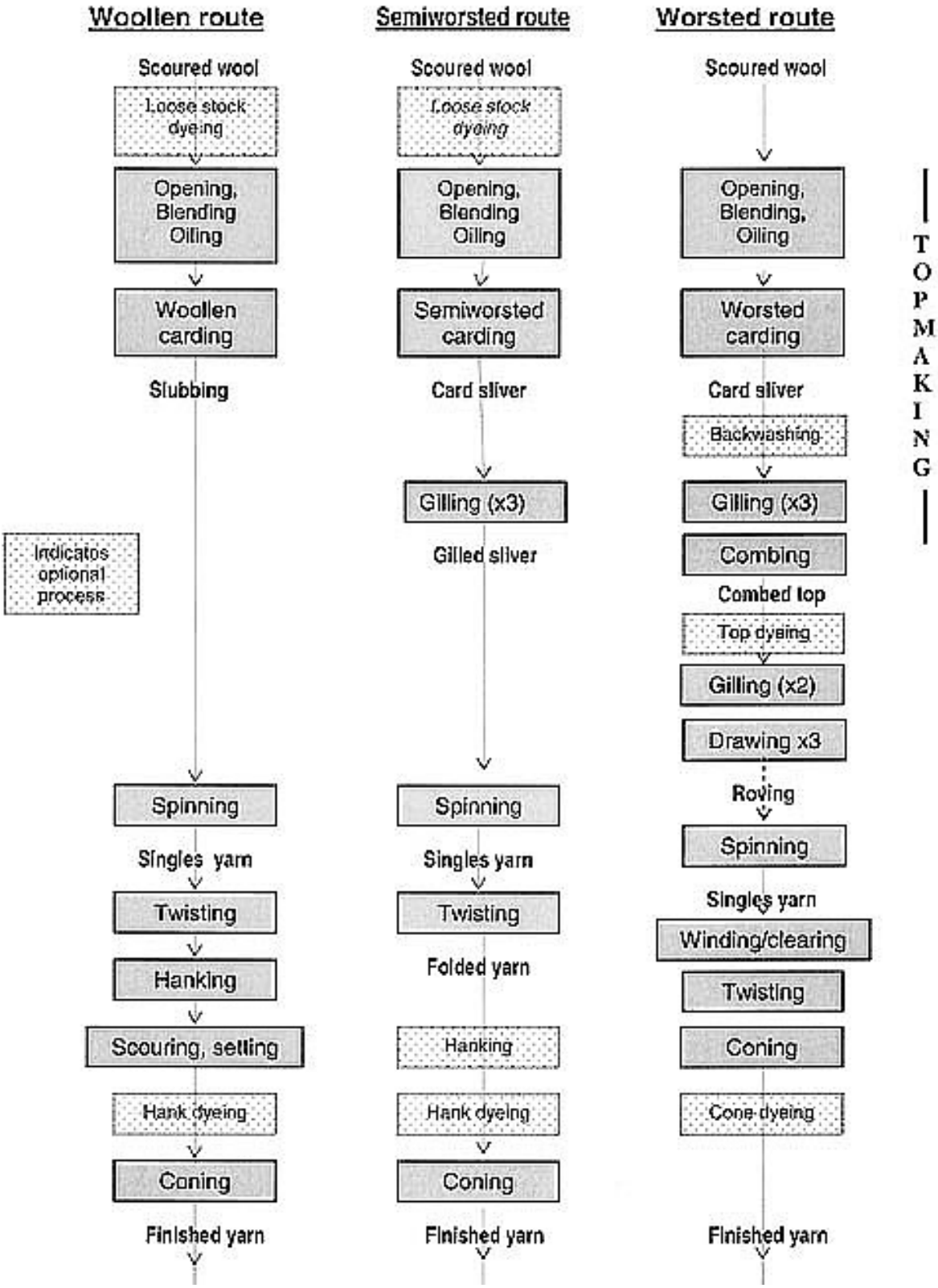


Table 2.1 Comparison of the three processing routes. Source: Wood, 2006.

	Woollen	Semi-worsted	Worsted
Wool requirements:	can handle all wool types, but more suitable for shorter wools rather than very long	wools should be sound, staple length 75-125 mm, and low vegetable matter content	requires wools which for their diameter are longer, better style and sounder
	usually a wide range of blend components	usually a limited range of components in blend	uses similar wools rather than a mixture of types
	all fibre diameters used, from very fine to very coarse	mainly medium fineness wools; 27 - 35 μm	mainly fine wools; less than 30 μm, usually less than 24 μm
	can use reprocessed wools of all types	not suitable for short reprocessed wools	wastes never used
	blend cost generally lowest	blend cost higher than woollen	blend cost highest
Complexity of the processing system	the shortest route with fewest steps, large woollen card has low production rate	a compact, high production system, cheaper to operate than worsted system	the most complex route; largest number of steps; card similar to semi-worsted card
	card removes some VM but cannot tolerate high levels of vegetable matter	limited ability to remove vegetable matter and short fibres	vegetable matter and short fibres removed by combing
	carding is very critical because it sets the yarn count, and is the final opportunity for blending	carding is less critical because of substantial blending and drafting in subsequent steps	carding is less critical because of substantial blending and drafting in subsequent steps
Properties of yarn:	minimal alignment of fibres, many may be hooked	reasonable degree of fibre alignment	fibre alignment very high, giving most even yarn
	yarn is hairy - many fibre ends protrude from surface	less fibre ends and loops protrude from surface	few fibre ends and loops protrude, so least hairy
	yarn is bulky, soft and resilient	medium bulk and resilience	low bulk, and firm handle
	tends to be weakest with breaking strength of 3-5 g/tex	typical breaking strength 5-7 g/tex	tends to be strongest yarn; breaking strength 7-9 g/tex
	require at least around 110 fibres in yarn cross-section	require at least around 90 fibres in yarn cross-section	require at least around 40 fibres in yarn cross-section
End product uses:	suitable for all purposes: apparel, carpets, furnishings.	carpets and knitwear mainly	high quality weaving and knitting yarns for quality apparel
	yarn structure often not apparent in finished product	yarn structure may or may not be clearly visible	yarn structure is usually well-defined in product

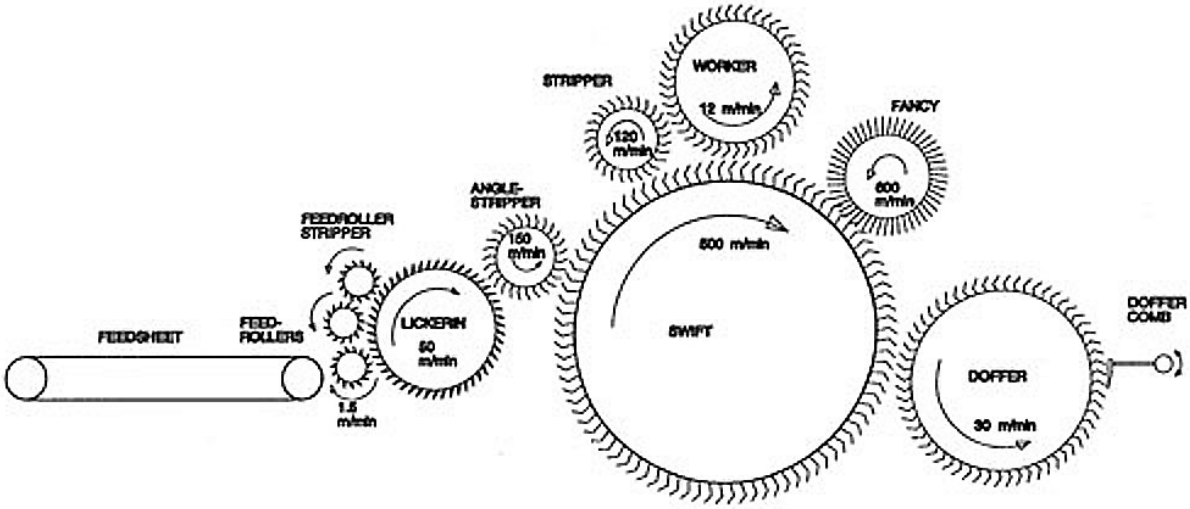
2.3 Carding principles

Irrespective of the processing system, scoured wool is passed through a carding machine (or *card*) to be opened and mixed, and to have vegetable matter and other contaminants removed. A series of rotating, interacting rollers, covered with pointed wire, pins or teeth (the *clothing*), gradually separate the tufts of wool into individual fibres, to be delivered in an appropriate form (slubbing, sliver or web) to the next stage. This function is termed 'fibre organisation' in Figure 2.1.

The carding machine (http://www.osv.org/education/WaterPower/Carding.html) first appeared during the Industrial Revolution, and has not changed significantly in design for over 200 years.

A card is generally composed of two or more of the basic units shown in Figure 2.3, placed in series.

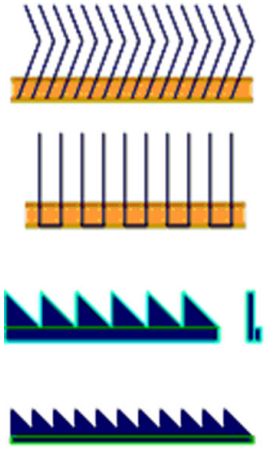
Figure 2.3 A simple carding machine. Source: Wood, 2006.



Each roller (1) has a unique name (e.g. worker, doffer, swift, etc.), (2) a specific rotation speed and direction of rotation, (3) its clothing is appropriate to its function and (4) it is set at a close spacing to the other rollers with which it is required to interact.

The main types of card clothing are shown in Figure 2.4. The upper two diagrams show two views of flexible fillet clothing (http://www.jamesholdsworth.com/flexible.htm), which is the type used for most rollers on woollen carding machines. The lower two diagrams depict rigid metallic clothing (http://www.jamesholdsworth.com/metallic.htm). Coarse metallic clothing is used on the opening rollers of all cards, while the finer metallic clothing is the main type used in worsted and semiworsted carding machines. The ECC document (http://www.ecc-cardclothing.com/pdf/Wolcombing4pg.pdf) shows that clothing with different specifications (tooth angle, height etc.) is required for different card rollers.

Figure 2.4 Types of card clothing. Source: Wood, 2006.

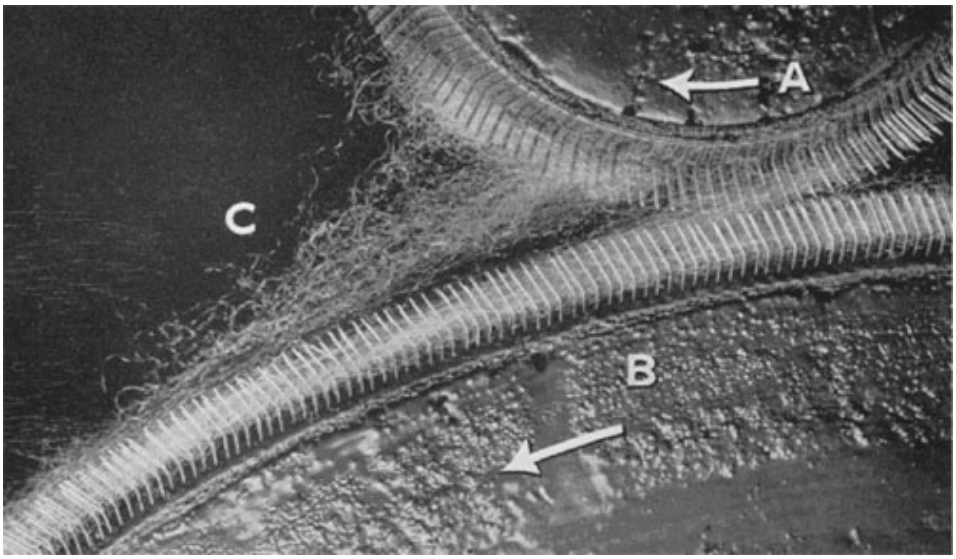


In carding, part of the stream of fibres on the swift is diverted by the worker rollers, and this portion is delayed before it is returned to the main stream. By separating and merging streams of fibres at various points, a very effective blending process is obtained.

The path of the wool through the card is as follows:

- The *feed sheet* delivers the wool to the feed rollers, which slowly presents the clumps of wool to the *lickerin*. The teeth of the lickerin carry out the initial opening by converting clumps into smaller tufts and some fibres are inevitably broken at this stage
- Tufts of fibre are transported from the lickerin to the large cylinder, the *swift*, and cycle around this roller a number of times before (a) being caught by a *worker* roller, or (b) leaving the machine (or going to the next stage) via the *doffer* roller
- The workers (there may be three or four of these rollers around a swift) perform the key opening and mixing functions of the card, as shown in Figure 2.5. This is where the stream of fibres is split, and later recombined on the swift via the *stripper*. The working action involves competition between the worker roller (A) and the swift roller (B) for a tuft of wool (C). Fibres caught by the worker teeth are slowly moved away from the swift and carried around to the accompanying stripper roller. This re-deposits the fibres onto the swift

Figure 2.5 The working action.
Photograph supplied by E. Wood, courtesy Canesis Network Ltd.



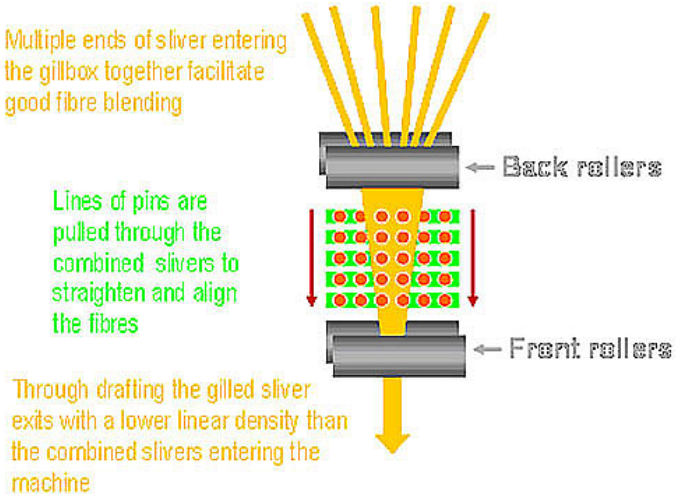
- Fibres may become embedded in the teeth of the swift clothing. The long wire bristles on the *fancy* roller raise these fibres so they are more easily caught and removed by the doffer. The fibres are transported to the next part of the card, or exit the machine.

2.4 Worsted system

The worsted system has the most steps, and better-style, long, sound wools are required to ensure efficient processing and acceptable yarn quality. Fine and medium wools are favoured to produce a fine, lean, flexible yarn, and ultimately a light, soft-handling fabric. The wool is removed from a worsted card as a thick ribbon of fibre, called a *sliver*.

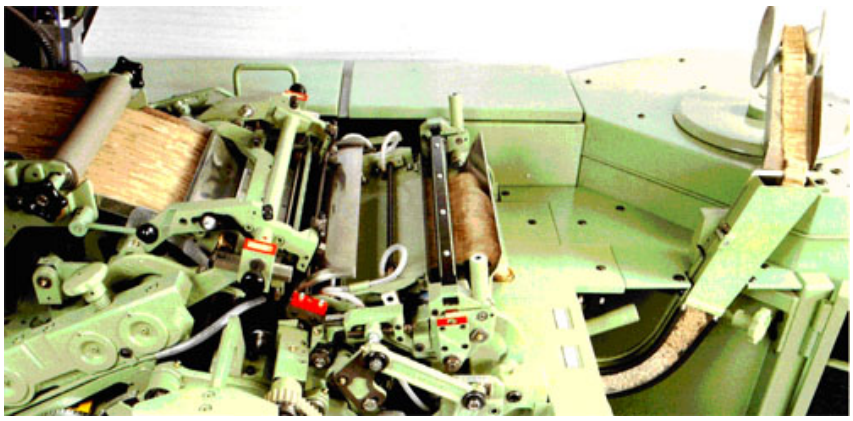
More extensive fibre organisation steps are required in the worsted system, so the card sliver is passed through a series of *gilling* steps (Figure 2.6) to straighten and align fibres in a neat, parallel arrangement. The action of a *gillbox* (http://www.nsc.fr/us/nscfibretoyarn/index2.asp) closely resembles the combing of hair.

Figure 2.6 Principles of gillbox operation. Source: Wood, 2006.



The gilled sliver is *combed* (http://www.nsc.fr/us/nscfibretoyarn/index2.asp http://www.andar.co.nz/Products/Wool/Apparel/default.asp) to remove short fibres (*noils*), *neps* (tiny clumps of fibre) and vegetable matter (Figure 2.7), then gilled again to restore the parallel alignment to form a *top*. An optional *backwashing* (http://www.andar.co.nz/Products/Wool/Apparel/default.asp) treatment may be included at this stage, where the top is scoured to provide a whiter, cleaner product.

Figure 2.7 Combing machine. Source: NSC Schumberger.



The top is drafted (i.e. drawn out to reduce its thickness) to form a thin ribbon of fibres, or *roving* (Figure 2.8), before being twisted and further drafted in spinning to form a yarn (Figure 2.9). In the worsted system the first group of processes, i.e. carding, gilling and combing is called *topmaking.*

Figure 2.8 Roving. Photograph supplied by E. Wood, courtesy Canesis Network Ltd.

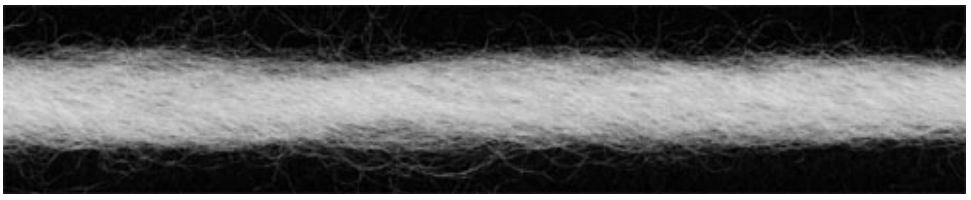
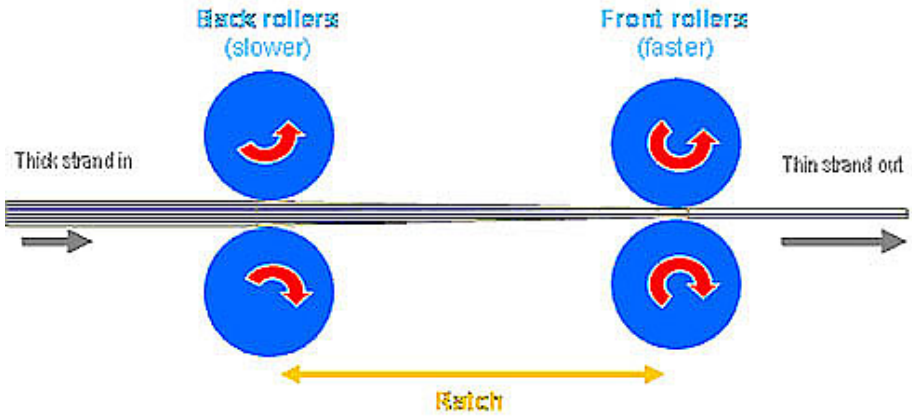


Figure 2.9 Worsted yarn.
Photograph supplied by E. Wood, courtesy Canesis Network Ltd.

In the production of a worsted yarn, the wool goes through a number of intermediate stages. A top may have 25,000 fibres in its cross-section while a worsted yarn may have only 50 fibres or less. To achieve the required yarn fineness, a considerable reduction in the thickness of the structures must occur, through successive *drafting* at each stage (Figure 2.10). The sequence of structures in the worsted system is:

scoured wool – card sliver – gilled sliver – top – roving – singles yarn – folded yarn

Figure 2.10 The principle of roller drafting. Source: Wood, 2006.



Roller drafting (or drawing) is done by passing a sliver or roving between two pairs of driven rollers. The delivery (or front) rollers have a higher surface speed than the feed (or back) rollers. For example, if the surface speed of the front rollers is ten times the surface speed of the back roller (i.e. draft ratio = 10), there will be a ten-fold reduction in the thickness of the sliver.

For example, with a draft ratio of 10, a sliver weighing 20 grams per metre and with a length of 100 metres before drafting will leave the front rollers weighing just 2 grams per metre. In addition, its length will have been extended ten times, i.e. to 1000 metres.

Efficient drafting requires a good fibre length – if too many short fibres are not held by either pair of rollers (i.e. 'floating' fibres) the result is an uneven product. For this reason, minimal drafting is used in the woollen system, and longer, sound fibres are required for worsted and semiworsted spinning. Secondary rollers or a pair of *aprons* in the drafting zone can assist in controlling the passage of the shorter fibres.

Figure 2.11 shows spindles on a worsted ring spinning frame, which is the most commonly used machine for spinning worsted yarns. The rovings (top of picture) pass through the drafting zone (middle) and the yarn is wound onto the bobbins (bottom) which rotate at high speed on spindles.

Figure 2.11 Worsted spinning frame.
Photograph supplied by E. Wood, courtesy Canesis Network Ltd.

As a result of (1) the removal of short fibres in combing, (2) the parallel arrangement of the fibres presented for spinning and (3) the high degree of twist imposed, a worsted yarn is sufficiently strong to permit a minimum of around 40 fibres in the cross-section. Hence fine, even, firm yarns with satisfactory strength can be spun. Figure 2.12 shows the helical path of a fibre, imposed by the twist in a worsted yarn.

Figure 2.12 Helical path of a fibre in an ideal worsted yarn. Source: Wood, 2006.

Worsted-spun yarns are mostly used in high-quality woven suiting fabrics, and hand and machine knitting yarns. In these products it is important that the yarn be free from faults such as *neps*, *slubs* (lumps), vegetable matter and protruding fibres. Short fibres can cause discomfort in wear due to prickliness while long protruding fibres have a propensity to form *pills* (small tangled clusters of fibres on a fabric surface), which are visually unattractive.

2.5 Woollen system

The woollen system is the simplest of the three yarn manufacturing routes, and tends to be used to process blends of wools which vary in length and fibre diameter. The system is capable of handling the poorer-style wools and the short and tender wools. Noils (combing waste) and recycled fibres (e.g. from rags and yarns) may also be included in woollen blends. Crossbred wool blends destined for carpets are mostly processed on the woollen system.

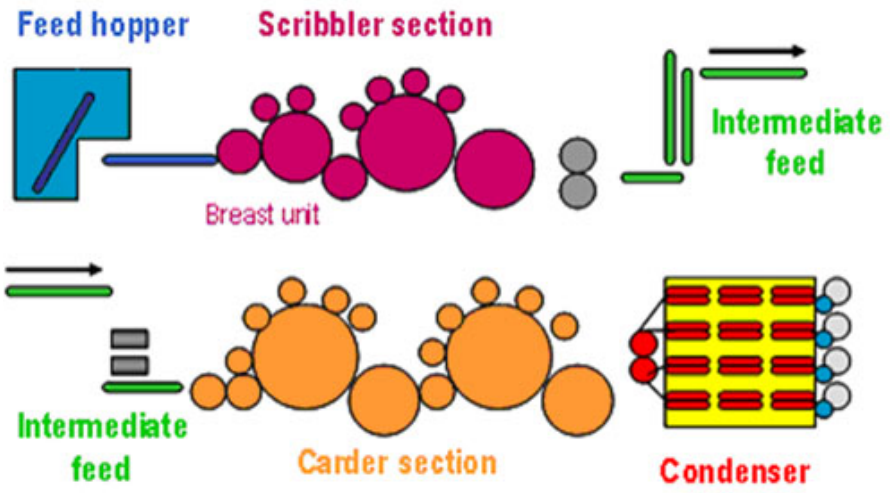
Woollen carding

See http://www.hdb-1823.com/english/2_cardage-carde.html

From the hopper feed the wool generally passes through two carding stages (termed the *scribbler* and *carder* parts respectively) to ensure a thorough opening of the wool tufts and the mixing of fibres, and the removal of contaminants (Figure 2.13). At the tape condenser, the thin web of carded fibres is separated into narrow strips and consolidated by a rubbing action into a thin ribbon of fibres called *slubbing*. (A slubbing is similar to a worsted *roving*, but is less uniform and the fibres are much less well-aligned and straight.) A *web-purifier* (or *Peralta*) is a pair of smooth steel rollers that crushes the vegetable matter into fragments, hence making them more easily removed from the web.

A woollen card (http://www.macart.com/tatham/docs/Equipment/WoolenCarding copy_woollen.htm) is, by necessity, a more complicated machine than a worsted card because it provides the final opportunity for fibre mixing before spinning, and it also determines the count (or thickness) of the yarn. Any variations or irregularities in the slubbing persist through spinning and hence may affect the quality (i.e. evenness) of the finished yarn. A woollen card may be up to 3.5 metres wide and 15 metres or more in length.

Figure 2.13 Layout of a woollen card. Source: Wood, 2006.



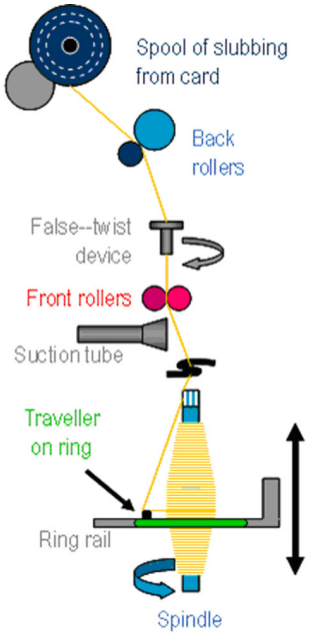
Woollen spinning

The slubbing produced by the card is spun into yarn by applying twist to it. This step is most commonly carried out by a machine called a *ring spinning frame* (http://www.hdb-1823.com/english/2_filatture-carde.html) (Figure 2.14). A ring frame consists of a series of *spindles* which rotate at high speed (around 6000 rpm or higher) onto which the yarns are wound. The yarn is guided onto the tube by a small clip called a *traveller*, which is drawn at high speed around a metal ring by the rotation of the spindle. At the same time, the ring rail oscillates slowly in the vertical direction to enable a tidy, compact package of yarn to be formed on each tube.

Unlike worsted and semi-worsted spinning, the shorter blends mostly used in the woollen system are not suited to roller drafting. Strands of short, poorly-aligned fibres do not draft as well as longer, straighter fibres. Hence, the draft used on a woollen frame is minimal (i.e. a draft ratio ~ 1.3 compared with 20-30 in worsted spinning and up to 50 in semi-worsted spinning).
The sequence of structures in the woollen system is:

scoured wool – slubbing – singles yarn – folded yarn

Figure 2.14 Key parts of a woollen spinning frame. Source: Wood, 2006.



Characteristics of woollen spun yarn

A woollen-spun yarn is characterised by a high proportion of short fibres distributed very much at random throughout the yarn. Longer fibres often undergo reversals in direction and may protrude from the yarn, to contribute to a hairy and quite irregular appearance, as shown in Figures 2.15 and 2.16.

Figure 2.15 Typical fibre path in woollen yarn. Source: Wood, 2006.

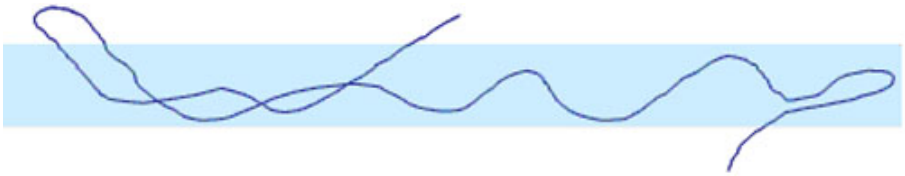


Figure 2.16 Two-fold woollen spun carpet yarn.
Photograph supplied by E. Wood, courtesy Canesis Network Ltd.

The loops and ends of fibres protruding from the surface have an important influence on the tactile and visual properties of a woollen-spun yarn. A fibre with reversals contributes less to the strength of a yarn than if it was fully extended without reversals, as it would be in a worsted yarn. Therefore, woollen yarns tend to have less strength than worsted yarns, and to obtain sufficient strength a minimum of around 120 fibres in the cross-section is required.

The yarns produced by this route tend to be of a coarse count (i.e. thicker), spun to a low twist, and hence are bulky, soft handling, hairy, and less regular than worsted yarns. The reversals and other irregularities in the paths of the fibres within the yarn create air spaces, which also contribute to the soft, bulky handle of woollen-spun yarns (provided the twist level is not high).

Other steps in the woollen system

In conventional woollen spinning, a *processing lubricant*, an emulsion of oil with water, is sprayed as a mist onto the wool before carding. (The rate of application of about 3% on weight of fibre is significantly higher than for worsted and semiworsted spinning where levels around 0.3% are common.) The lubrication treatment has three purposes:

1. the moisture content of the wool fibres is increased, making them more extensible, hence more resistant to the stresses of carding, and also reduces electrostatic effects
2. it reduces the friction between fibres, and between fibre and the card teeth, thereby reducing fibre breakage in carding,
3. web cohesion is improved, so fewer fibres are lost as droppings or fly.

To avoid downstream problems such as excessive soiling of the yarn, the processing lubricant must be removed from the yarn in a process that is similar to wool scouring. At the same time, for yarns destined for cut-pile carpets, one bowl will contain the chemicals required for a *setting* treatment that enables the yarn to resist untwisting when cut. Insect-resist agents can also be applied to the wool during this process.

To provide sufficient strength and improve the uniformity of woollen yarns, and reduce the tendency to untwist, two or more singles yarns produced are usually twisted together to form a *folded* or *plied* yarn. It is usual to ply worsted and semiworsted yarns too.

In the main, woollen spun yarns are used in woven, knitted and tufted products such as carpets, blankets, tweeds and heavier woven and knitted apparel.

2.6 The semi-worsted system

This system was originally developed to produce a yarn with greater strength than in the woollen system, but without the expense of removing short fibres in a combing step. Wool is passed through a high-production card (http://www.hdb-1823.com/english/2_cardage-sp.html), gilled several times to straighten the fibres, and spun directly from a thin sliver (http://www.hdb-1823.com/english/2_filatture-sp.html). In the semiworsted processing route the sequence of structures is:

scoured wool – card sliver – gilled sliver – singles yarn – folded yarn

Because of the need for superior fibre length for the high drafts often employed in spinning, the semi-worsted system requires sound wools of 100-120 mm staple length (with a minimum length of at least 70 mm). There is less opportunity for the removal of contaminants, so wools should be free of vegetable matter.

Semi-worsted yarns are intermediate in properties between those produced on the worsted and woollen systems. In New Zealand they are used mainly for manufacturing carpets and knitwear, but in other countries the semiworsted route is a high production yarn-making process, used mainly synthetic staple fibres. Because of the greater fibre length and the degree of straightening introduced by the gilling step, semi-worsted yarns tend to be less bulky than woollen yarns. Hence bulkier wools are sought as a major component for a semiworsted blend if good fabric cover or a softer handle is required in products.

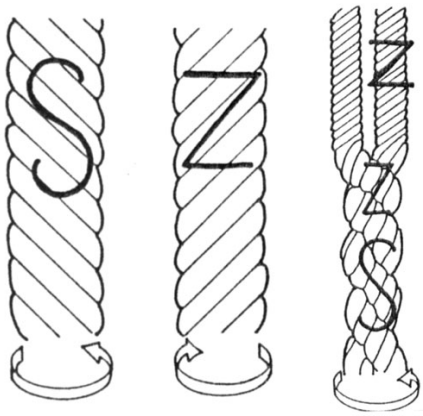
2.7 Yarn specification

A wool yarn is usually specified in terms of (1) its thickness (or more correctly its *linear density* or *count*), and (2) the amount of twist it contains.

Count
The unit, *tex* (= 1 gram per kilometre) is widely used. For example, a 250 tex yarn has a mass of 250g per kilometre or 250 mg per metre.

Twist
The direction of twist is can be either S or Z, depending on the diagonal direction in which the fibres line up when the yarn is held vertically (i.e. \ = S, and / = Z) (Figure 2.17). A folded yarn comprising two singles yarns with S twist will normally have a folding twist in the Z direction (and vice versa) in order to provide stability (i.e. enable the yarn to resist untwisting).

Figure 2.17 Yarn twist: Counter clockwise rotation gives S-twist (left); clockwise rotation gives Z twist (middle); S on Z twofold twisting (right). Source: Wood, 2006.



The amount of twist (either singles twist or folding twist) is measured in turns per metre. In general, the higher the twist, the leaner, stronger and firmer the yarn. To achieve a soft, bulky handle, a low level of twist is necessary.

Other yarn properties of importance:

Strength
The strength of a yarn and its extensibility are important because they influence how easily it will be converted into a fabric or carpet. Some manufacturing processes, such as fabric weaving and carpet tufting require the yarn to have a certain minimum strength otherwise an unacceptable number of yarn breakages will occur.
In addition, the ability of a fabric to resist wear and tear is also influenced by the strength of the yarn.

Evenness
The evenness of a yarn (its regularity or variation in thickness, number of thick and thin places in a given length), also has an influence on processing efficiency and product quality. A thick place or a clump of fibre (*slub*) in a yarn may jam in a tufting needle and necessitate a machine stoppage. A thin place is a likely site where a yarn may stretch and break even under a relatively low stress.

Uneven yarns may also spoil the uniform appearance of woven and knitted fabrics.

2.9 Dyeing

Dyeing (or other coloration methods such as printing) may be carried out at any of several stages in yarn or fabric manufacture.

Loose stock dyeing

Loose wool can be dyed after scouring and before blending and carding. This is usually done when large batches of yarn of the same shade are to be prepared before the early stage processes are usually only economic if large quantities are to be processed at one time.

The scoured wool is packed into a large vessel, and the heated dye liquor is pumped through the mass for a specific time to get the required level of dye uptake by the fibres.

The dyestuffs are not required to dye in such a level way as those used for yarn or piece dyeing because any unlevelness will be completely eliminated in blending and carding.

Loose stock dyeing is more common in the woollen process, especially for yarns destined for plain-shade carpets.

Top dyeing

Worsted tops can be dyed and then processed to produce either solid colours with excellent levelness, or mixtures of colours almost perfectly blended.

Yarn dyeing

Where patterned carpets or fabrics are to be manufactured, yarn dyeing allows the production of larger batches of the most widely used colours and small lots of colours where only small amounts are required.

Yarns can be dyed on large hanks, suspended in dye vats, or wound onto packages (e.g. cones), which are placed on a perforated metal tube to enable a radial flow of dye liquor.

Hank dyeing is expensive in handling costs because the hanks have to specially wound and then re-wound on to packages after dyeing to be in a suitable form for subsequent processing steps.

Although yarn dyeing is more expensive per kilogram than stock dyeing, the extra flexibility and the freedom to hold white yarn supplies until required make it a popular form of dyeing.

Figure 2.18 shows a typical hank dyeing machine.

Figure 2.18 Hank dyeing machine.
Photograph supplied by E. Wood, courtesy Canesis Network Ltd.

Piece dyeing

Colour can be added to a fabric or carpet so that a mill is able to hold an inventory of undyed cloth. This enables a much faster response to an order than, at the other extreme, one that requires loose stock dyeing.

Modern piece dyeing machinery and scientific colour matching means that it is possible to dye the same colour on a series of different pieces of cloth. However, wool is a natural fibre and the components of a blend may vary over time, resulting in minor variations in which the fabric takes the colour. Hence the piece dyer must be as skilled and careful as the loose stock or yarn dyer.

While piece dyeing gives economies of scale in terms of fabric (and carpet) production, it does limit the design to solid colours. It is therefore mostly used for volume production rather than short runs. Piece dyeing of carpets is more common with manufactured fibres, especially polyamide, than wool. The technical requirements for a wool carpet which is to be piece dyed are quite high, especially with respect to the retention of tuft definition.

Printing

It is possible to use the various printing techniques to produce single or multi-colour designs. The design scope is virtually unlimited and the restrictions are generally of an economic nature. Maintaining consistence of colour, and preserving the register of printed designs leads to a higher rate of 'seconds', which adds to the total costs of this colouration route.

A range of other treatments may be carried out in a dyebath, either in conjunction with dyeing or as a separate treatment: e.g.:

Shrinkproofing, mothproofing, flameproofing, anti-soiling, antistatic, softening, bleaching, twist setting, yarn scouring.

Readings

The following readings are available on CD:

1. Wood, E.J. 2004, What makes a good yarn? Canesis Network Ltd., New Zealand
2. Lappage, J. 2004, The history of spinning, Canesis Network Ltd., New Zealand

Activities	Available on WebCT
Multi-Choice Questions	Submit answers via WebCT
Useful Web Links	Available on WebCT
Assignment Questions	Choose ONE question from ONE of the topics as your assignment. Short answer questions appear on WebCT. Submit your answer via WebCT

Summary

To make almost all wool products the wool must first be scoured and impurities such as vegetable matter removed; then the fibres are made parallel and mostly spun into yarn, and finally the yarns are interlaced by weaving or knitting to form the product. The type of processing route and the range of products that can be made depends largely on the properties of the wool. Three alternative yarn manufacturing routes are available for wool – woollen, worsted and semiworsted. This topic briefly describes and compares the three routes, the steps involved and the types of yarn generally produced by each route. The specific processing steps are examined in more detail in subsequent topics.

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Harrowfield, B.V. 1987, 'Early-stage worsted processing – from scoured wool to top', *Wool Science Review,* vol. 64.

Hunter, L. 2002, Mechanical processing for yarn production, in: *Wool: Science and Technology*, W.S. Simpson, and G.N. Crawshaw, (eds.), Textile Institute, ISBN 1 85573 574 1.

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Lawrence, C.A. 2003, *Fundamentals of Spun Yarn Technology*, CRC Press, ISBN 1-56676-821-7.

NSC Schumberger, PB 33 Combing Machine, product marketing brochure,

Teasdale, D.C. 1995, *The Wool Handbook*, *The A to Z of Fibre to Top,* 3rd revised printing, Fast Books, Wild & Woolley Pty. Ltd., Glebe, ISBN: 0 646 24064.

Glossary of terms

Attenuate	To reduce the thickness (linear density) of a sliver, top or roving by roller drafting
Backwashing	The washing of wool sliver before or after gilling and/or combing
Blend	The processing batch, a combination of many grower lots, entering the yarn manufacturing route
Blending	Combining and mixing wools to produce a homogenous batch for processing
Bulk	The ability of a fibrous structure (e.g. yarn) to fill space. A bulky yarn has a softer handle than a lean yarn
Carding	A process carried out by a card (or carding machine). It involves opening clumps of wool, disentangling and mixing the fibres and the removal of vegetable matter as preparation for subsequent steps in yarn manufacture
Clothing	The metallic teeth covering the surface of card rollers
Combing	The straightening and parallelising of fibres and the removal short fibres and impurities
Condenser	The last section of a woollen card. It divides a broad thin web of fibres into narrow strips, which are then consolidated by rubbing into slubbings
Coning	Winding yarn onto a package (cone)
Count (or linear density)	The mass per unit length of a slubbing, yarn, sliver or top – measured in tex or kilotex
Crossbred wool	Coarse (or strong) wool, commonly used in carpets and generally coarser than around 32 microns. Often obtained from Romney sheep and breeds derived from this breed
Doffer	The final roller in a carding section which removes fibres from the swift and delivers them to the next stage
Doublings	The number of slivers or rovings fed into a machine for drafting into a single end
Drafting (or drawing)	Reduce the linear density of a sliver, top or roving, e.g. by the action of two pairs of rollers rotating at different speeds (roller drafting)

Draft ratio	In roller drafting, the ratio of the front roller speed to the back roller speed
Fancy	The card roller with long wire teeth that raises fibre embedded in the clothing of the swift, thus enabling more efficient removal by the doffer
Fillet	Flexible wire clothing comprising wire teeth mounted in a foundation of laminate fabric and rubber
Folding (twisting or plying)	Combining two or more singles yarns using twist, to form a folded or plyed yarn
Gill box	A drafting machine using in worsted and semiworsted processing, in which the motion of the fibres is in part controlled by pins fixed on moving bars (fallers)
Gilling (or pin drafting)	A system of drafting in which the direction of the fibres relative to one another is a sliver is controlled by pins. This action improves the fibre alignment and parallelisation in the sliver
Hank (or skein)	A quantity of yarn in coiled form
Loose stock	Wool without structure, e.g. scoured wool
Lubricating	Applying a processing oil (in a water emulsion) to wool prior to carding
Peralta rollers (or web purifier)	A pair of high pressure, smooth steel rollers on a woollen card. They crush vegetable matter in tiny fragments, making their removal much easier
Ring spinning	A spinning system in which twist is inserted in a yarn by using a revolving traveller (that moves around a ring). The yarn is wound onto a spinning tube because the rotational speed of the tube is greater than that of the traveller
Roving	A fine, well-aligned strand of fibres, the form in which wool is fed to a worsted ring spinning frame
Semiworsted system	A high-speed yarn manufacturing route, involving carding, gilling and ring spinning
Setting	The process of conferring stability on a fibrous structure, e.g. yarn, by physical (steam/heat) or chemical means
Singles yarn	A single twisted strand of fibres
Sliver	A relatively thick strand of fibres in continuous form without twist
Slub	An abnormally thick place in a yarn
Slubbing	The strands of fibre from a woollen card that have been consolidated by the rubbing action of the condenser
Spindle	A rotating shaft that carries a yarn package (tube, bobbin cone, etc.)
Swift	The large, fast rotating roller on a carding section that is the main path for the transportation of fibres through the machine to the next stage
Tex	The unit of linear density (1 tex = 1 gram per kilometre)
Top	Combed sliver, the output from topmaking, characterised by a high level of fibre parallelisation and homogeneity, and an absence of short fibres

Topmaking	The first stage of the worsted yarn manufacturing route, involving carding, gilling and combing
Traveller	The small clip (steel or plastic) that guides the yarn onto the bobbin, in a ring spinning frame. It rotates at high speed around a circular ring
Twist	The number of turns in a yarn, per metre
Vegetable matter	Seeds, twigs, leaves, burrs etc. that contaminate some wools
Woollen system	The route for producing yarn, involving a condenser card and spinning
Worker	The slowly rotating card roller that operates in conjunction with the swift to open the tufts of fibre – the working action
Worsted system	The route for producing yarn, involving carding, gilling, combing and ring spinning
Yarn scouring	Washing of finished yarn to remove processing lubricants and dirt acquired during processing