WOOL, WORSTED AND WOOLLEN MANUFACTURES. Wool is a modified form of hair, distinguished by its slender, soft and wavy or curly structure, and, as seen under the microscope, by its highly imbricated or serrated surface. At what point an animal fibre ceases to be hair and becomes wool it is impossible to determine, because the one by imperceptible gradations merges into the other, so that a continuous chain can be formed from the finest and softest merino to the rigid bristles of the wild boar. Thus the fine soft wool of the Australian merino merges into the cross-bred of New Zealand; the cross-bred of New Zealand merges into the long English and lustre wool, which in turn merges into alpaca and mohair-materials with clearly marked but undeveloped scale structure. Again, such animals as the camel and the Cashmere goat yield fibres, which it would perhaps be difficult to class rigidly as either wool or hair.

Wool is one of the most important of the textile fibres. Owing to the ease with which it may be spun into thread, and the comfort derived from clothing made of wool, it would naturally be one of the first textiles used by mankind for clothing. Ancient records prove the high antiquity of wool textures and the early importance of the sheep. The different kinds of wool and the cloth made from them in antiquity are described by Pliny and referred to by other writers, and among the arts which the British Isles owe to the Romans not the least important is the spinning and weaving of wool. The sheep certainly was a domestic animal in Britain long before the period of the Roman occupation; and it is probable that some use was made of sheep skins and of wool. But the Romans established a wool factory whence the occupying army was supplied with clothing, and the value of the manufacture was soon recognized by the Britons, of whom Tacitus remarks, "Inde etiam habitus nostri honor et frequens toga" (*Agric.* c. 21). The product of the Winchester looms soon established a reputation abroad, it being remarked that "the wool of Britain is often spun so fine that it is in a manner comparable to the spider's thread." This reputation was maintained throughout the middle ages, and the fibre was in great demand in the Low Countries and other continental centres. There are many allusions to woollen manufactures in England in early times; but the native industry could not rival the products of the continent, although the troubles in various industrial centres, from time to time, caused skilled workers in wool to seek an asylum in England. In the time of William the Conqueror Flemish weavers settled under the protection of the queen at Carlisle, but subsequently they were removed to Pembrokeshire. At various subsequent periods there were further immigrations of skilled Flemish weavers, who were planted at different places throughout the country. The cloth fair in the church yard of the priory of St Bartholomew was instituted by Henry II.; gilds of weavers were established; and the exclusive privilege of exporting woollen cloth was granted to the city of London. Edward III. made special efforts to encourage wool industries. He brought weavers, dyers and fullers from Flanders; he himself wore British cloth; but to stimulate native industry he prohibited, under pain of life and limb, the exportation of English wool. Previous to this time English wool had been in large demand on the continent, where it had a reputation exceeded only by the wool of Spain. The customs duties levied on the export of wool were an important source of the royal revenue. Edward III.'s prohibitory law was, however, found to be unworkable, and the utmost that both he and his successors were able to effect was to hamper the export trade by vexatious restrictions and to encourage much smuggling of wool. Thus while Edward III. limited the right of exporting to merchant strangers, Edward IV. decreed that no alien should export wool and that denizens should export it only to Calais. Legislation of this kind prevailed till the reign of Elizabeth, when the free exportation of English wool was permitted; and Smith, in his *Memoirs of Wool*, points out that it was during this reign that the manufacture made the most rapid progress. In 1660 the absolute prohibition of the export of wool was again decreed, and it was not till 1825 that this law was finally repealed. The results of the prohibitory law were exceedingly detrimental; the production of wool far exceeded the consumption; the price of the raw material fell; wool-"running" or smuggling became an organized traffic; and the whole industry became disorganized. Extraordinary expedients were resorted to for stimulating the demand for woollen manufactures, among which was an act passed in the reign of Charles II. decreeing that all dead bodies should be buried in woollen shrouds—an enactment which remained in the Statute Book, if not in force, for a period of 120 years. On the opening up of the colonies, every effort was made to encourage the use of English cloth, and the manufacture was discouraged and even prohibited in Ireland.

Wool in Britain.

It was not without reason that the attention of monarchs and legislators was so frequently directed to the wool industries. Wool was indeed "the flower and strength and revenue and blood of England," and till the development of the cotton trade, towards the end of the 18th century, the wool industries were, beyond comparison, the most important sources of wealth in the country. Towards the close of the 17th century the wool produced in England was estimated to be worth £2,000,000 yearly, furnishing £8,000,000 worth of manufactured goods, of which there was exported about £2,000,000 in value. In 1700 the official value of woollen goods exported was about £3,000,000, and in the third quarter of the century the exports had increased in value by about £500,000 only. In 1774 Dr Campbell (*Political Survey of Great Britain*) estimated the number of sheep in England at 10,000,000 or 12,000,000, the value of the wool produced yearly at £3,000,000, the manufactured products at £12,000,000, and the exports at £3,000,000 to £4,000,000. He also reckoned that the industry then gave employment to 1,000,000 persons. These figures, in the light of the dimensions of present-day industries, may appear small, but they bore a predominant relationship to the other great sources of employment and trade of the period. In 1800 the native crop of wool was estimated to amount to 96,000,000 lb; and, import duty not being imposed till 1802, the quantity brought from abroad was 8,600,000 lb, 6,000,000 lb of which came from Spain. In 1825 the importation of colonial wool became free, the duty leviable having been for several previous years as high as 6d. per lb, and in 1844 the duty was finally remitted on foreign wool also.

Sheep were introduced at Jamestown in Virginia in 1609, and in 1633 the animals were first brought to Boston. Ten years later a fulling mill was erected at Rowley, Mass., "by Mr Rowley's people, who were the first that set upon making cloth in this western world." The factory woollen industry was, however, not established till the close of the 18th century, and it is recorded that the first carding machine put in operation in the United States was constructed in 1794 under the supervision of John and Arthur Schofield.

Wool in America.

For centuries the finer wools used for cloth-making throughout Europe had been obtained from Spain—the home of the famous merino breed developed from races of sheep originally introduced into the Peninsula by the Moors. Till early in the 19th century the superiority of Spanish merinos remained unchallenged, but the Peninsular War and its attendant evils produced a depreciation of quality concurrently

Merino wool.

with the introduction of Saxon and Silesian wools, which suddenly supplanted the product of Spain. The Spanish merino sheep had been introduced into Saxony by the elector in 1765, and by judicious crossing with the best native race developed the famous electoral breed. Merinos were carried to Hungary in 1775, and to France in 1776, and in 1786 Daubenton brought them to Rambouillet, whence a famous race developed. In 1802 the first merinos known to have left pure descendants were taken to the United States, and in 1809–1810 an importation (4000) of merino sheep was made.

Wool in Australasia.

The introduction of the merino sheep into the United States was an important move, but its results are not to be compared with the results of the introduction of the merino sheep into Australasia about the end of the 18th century and into South America a little later. It is probable that the marked improvement in the appearance of the first sheep taken out by the early colonists suggested the possibilities of Australia as a wool-growing country. As has been noted above, marked endeavours were being made at this time to extend the merino breed of sheep, so that it was but natural that this breed should be given the first chance. That marked success did not attend the first endeavours is shown by the fact that the London Colonial Wool Sales originated in the necessity of selling Australian wools just for what they would bring under the hammer, as distinct from the private treaty method of selling and buying the more highly priced continental merinos. It should here be noted that the Australian fine wools were first shipped from Botany Bay, hence the now universal term " botany " for fine wools. The colonists were not to be repressed however, and eventually, through the endeavours of Captain MacArthur, Sir J. Banks, the Rev. Samuel Marsden and others, the merino breed became established on a firm basis, and in a comparatively short time Australian wools were no longer a drug on the market. The evolution was not to stop, however, with the development of merino flocks and the exporting of merino wool. No doubt early in the 19th century the possibilities of raising larger sheep on the better coastal pasturage was naturally suggested. Until about 1885 this tendency was largely repressed owing to the demand for merino as distinct from cross-bred wool. In other words wool was the dominating factor. But with the possibilities and the development of the frozen meat trade from 1880 to 1890 this condition was changed, and the tendency to breed a large sheep with a valuable carcass and mediocre wool grew apace. New Zealand was specially adapted for this development; thus New Zealand frozen mutton completely dominated New Zealand wool. In this manner it came about that cross-bred wool supplanted merino wool to a very considerable extent throughout Australasia. This change would have been serious for the wool comber and spinner had not the Bradford combers, spinners and manufacturers put their shoulder to the wheel and developed a world-wide renown for their cross-bred tops, yarns and fabrics. Again the change was not altogether for the bad so far as the Australian sheep was concerned. Sheep-breeding developed into a real science, and remarkable results were obtained with such crosses as Merino-Lincoln, Merino-Leicester, Merino-Shropshire; all probably originating in the first place in the desire to produce a large-bodied early-fattening sheep, but later developing into a strenuous endeavour to develop more useful types of wools. Thus the wool produced from the first cross Merino-Lincoln might be very defective judged from a pure merino standpoint, but by breeding back to the merino practically none of the useful merino characteristics were sacrificed, while length of staple was added and the weight of the fleece perhaps doubled.

Wool in Australia.

A somewhat different evolution has taken place in later years with reference to the interior sheep stations. The merino sheep will thrive where a larger sheep would starve, hence its value for the stations where salt-bush dominates all vegetation. But the merino sheep is a " wool " sheep, not a " frozen mutton " sheep, hence all crossing here was carried out with the idea of simply developing the weight of fleece and if possible retaining the merino wool characteristics. The most marked development in this direction was effected by the introduction of the United States merino or Vermont breed. Opinions differ as to the wisdom of this introduction. The weight of fleece carried per sheep has been remarkably increased, and the fact that up to the present weight multiplied by price per lb paid in London or elsewhere has been entirely in favour of first and second cross Vermonts, has undoubtedly influenced breeders in its favour. Against this must be placed the fact that the Australian-Vermont merino cross produces a sheep of unstable physique, naturally unable to withstand drought, and—worst of all so far as London is concerned—producing a fleece very difficult to judge for yield of pure scoured wool. Again, the Australian-Vermont first cross is very liable to produce a very strong botany wool, while what is required is a long but fine wool technically termed a long and shafty 60's to 64's quality.

Wool in South America.

Hardly second in importance to Australia as a wool-growing country comes South America, or more correctly Argentina along with Patagonia, Punta Arenas and the Falkland Islands. In most years Australia has produced the greater bulk, but just occasionally S. America has come out top and is likely to do so more frequently in the future owing to the remarkable developments there taking place. The history of the introduction of the merino sheep into S. America may be briefly summed up as follows. In 1842 Henri Solanet, a Frenchman, began to shear the comparatively few sheep round Buenos Aires. His example was soon followed by Edouardo Olivera and José Planer. The idea almost at once came to these pioneers of importing well-bred rams, and as S. America is essentially a Latin country it was but natural that the French flocks of Rambouillet should be first drawn upon. With the development of the meat trade—just as in the case of Australia and New Zealand—a larger carcass was then sought after. This led to the introduction of the Lincoln ram and the development of cross-bred flocks about the year 1885. Perhaps this cross was favoured owing to the skill of the Bradford spinners, who made excellent use of the cross-bred wool produced. Flocks of sheep were first introduced into the Falkland Islands in 1867. The pasturage here being limited, the flocks have probably attained their limit, but from the Falkland Islands flocks have been passed on to Punta Arenas, where there is practically unlimited pasturage. The chief centres from which wool from S. America comes to Europe are Buenos Aires, which exports chiefly long and cross-bred wools, Montevideo, which exports chiefly merino wools, and the Falkland Islands and Punta Arenas, which export mostly wools of the finer type. The industry is largely in the hands of Englishmen. Unfortunately, however, the British manufacturer early took a dislike to the Buenos Aires, &c., wools, and consequently these wools go largely to the continent of Europe. To-day they by no means merit their previous bad name, and the Bradford comber and spinner are endeavouring to make up for lost opportunities.

Wool in South Africa.

Prior to the introduction of the merino sheep into Australia it had been introduced into S. Africa by the Dutch. There the climate was not so helpful as was that of Australia. The newly acclimatized sheep appears to have cast its wool at about the fifth generation and to have generally deteriorated, necessitating the reintroduction of fresh blood form Europe. In this manner have been developed the Cape flocks and the considerable Cape wool trade—largely centred at Port Elizabeth, East London, Cape Town, Mossel Bay and Port Natal. The country is evidently specially adapted for the rearing of the merino type of sheep, as cross-bred Cape wool is practically unknown. The term snow-white Cape wool, on the other hand, betokens a quality of whiteness no doubt due to the atmospheric and pasturage conditions. Cape wools are also known as non-felting wools, and consequently are largely employed in the manufacture of flannels. In 1907 most marked endeavours were being made to develop the Cape flocks by the introduction of some thousands of Australian merino sheep. The opinion of wool experts was that the Cape had a great future before it as a wool-producing country.

Large quantities of wool also come from the East and from Russia, while even Iceland contributes its quota. It is interesting to note that, notwithstanding all the developments instanced, Europe still maintains its supremacy as the chief wool-producing continent, though, as the wool is largely manufactured locally, one hears little of European wools.

Wool in other countries.

The following statistics give an idea of the development of the colonial and foreign wool trade as gauged by the London wool sales:

	Bales.		Bales.
1814	165	1870	673,314
1824	1,620	1890	1,509,666
1834	16,926	1901	1,602,726
1840	44,502	1903	1,319,365
1850	158,558		

It must not be forgotten, however, that a large quantity of S. American, W. Indian, Russian, &c., wools, along with mohair and alpaca, come through Liverpool, and consequently are not taken into account here.

With reference to wools grown in the United Kingdom the truth seems to be that a fine short wool has never been produced. English wool is known the world over as being of a long and lustrous type, which was doubtless that so much in demand in the middle ages. That it was as long and lustrous as the typical Leicester or Lincoln of to-day is doubtful, as the new Leicester breed of sheep was only fully developed by Mr Bakewell after the year 1747, and the latter day Lincoln was even a later development of a similar character. What the exact type of English wool or wools was prior to the 18th century will probably never be decided, but from the closing years of that century there is no difficulty in being fairly precise. As already remarked, the long and lustrous wools are the typical English, being grown in Lincolnshire, Yorkshire, Nottinghamshire, Devonshire, &c., in fact in all those districts where the pasturage is rich and specially fitted for carrying a heavy sheep. It is claimed that the lustre upon the wool is a direct result of the environment, and that to take a Lincoln sheep into Norfolk means the loss of the lustre. This is partially true, but it is perhaps better to take a larger view and remember that the two influencing factors are race and environment: which is the more potent it is impossible to say. Attempts were made in the 18th century to develop a fine wool breed in England, George IV. importing a number of merino sheep from Spain. The discovery was soon made that it was impossible to maintain a breed of pure merinos in Great Britain, but the final outcome was by no means unsatisfactory. By crossing with the indigenous sheep a race of fairly fine woolled sheep was developed, of which the present day representative is the Southdown—a sheep which feeds naturally on the Downs of Sussex, &c., forming a marked contrast to the artificially turnip-fed Lincoln, Leicester, &c., sheep. Following the short, curly Southdown, but rather longer, come such as the Sussex, Oxford and Hampshire Down sheep; these are followed by such as the Shropshires and Shropshire crosses, Kent and Romney Marsh, until at last the chain from the Southdown to the Lincoln is completed. Of course there are several British wools not included in this chain. Scotch or black-face wool is long and rough, but well adapted for being spun into carpet yarns. Welsh wool has the peculiarity of early attaining its limit of shrinkage when washed, and hence is specially chosen for flannels. Shetland wool is of a soft nature specially suited for knitting yarns, while Cheviot wool—said to be a cross between merino sheep saved from the wreck of the Great Armada and the native Cheviot sheep—has made the reputation of the Scottish manufacturers for tweeds. North wool—wool from an animal of the Border Leicester and Cheviot breed—Ripon, Wensleydale and Teasdale wools are also specially noted as lustre wools, Ripon and Wensleydale wools being, by many judges, considered superior so far as lustre is concerned to Lincoln and Leicester.

British wools.

Such remarkable advances have been made in the weights of fleeces carried by sheep of particular breeds that it is difficult to say if finality has been reached. The following list gives average weights:

Breed.	Weight of Average Fleece.	Breed.	Weight of Average Fleece.
Merino (Australian)	6 lb	Southdown	6 lb
Merino (South American)	6½ lb	Lincoln	12 lb
Merino-Lincoln	8-10 lb	Shetland	4 lb
		Cashmere	4 oz.

In 1885 the average weight of wool per sheep per year was about 5 lb, while 7 to 8 lb is now the average weight. Roughly speaking the weights of Australian fleeces are to-day about double as compared with 1885.

The prevailing colour of sheep's wool is white, but there are races with black, brown, fawn, yellow and grey shades of wool. For manufacturing purposes generally white wool is, of course, most valuable, but for the homespuns, which in earlier times absorbed the bulk of wool, natural colours were in many cases used with good effect. In domestic spinning, knitting, and weaving, natural colours are still largely taken advantage of, as in the cases of rough yarns, Shetland knitted shawls, Highland tweeds, &c.

Physical characteristics of wool.

As has already been indicated, the distinction between wool and hair lies chiefly in the great fineness, softness, and waved delicacy of woollen fibre, combined with a highly serrated surface. These peculiarities are precisely the characters which give wool its distinctive value as a textile fibre, the most distinctive characteristic of all being the serrated structure which specially belongs to wool and markedly aids the important property of felting, upon which many of its applications depend. The serrations of wool and the wavy structure it assumes are closely connected, those wools which have the greatest number of serrations being usually most finely waved in structure. The appearance presented by wool under the microscope is shown in figs. 1–6 (Plate). Under the influence of moisture and pressure, aided by alkalis or acids, masses of wool thoroughly mat together, by the mutual interlocking of the fibres. It is thus that the shrinking and thickening of woollen textures under washing is accounted for, the capacity of wool cloth for felting or fulling being due to this condition of the fibre, possibly along with a certain shrinkage of the true fibre mass. The serrations are most numerous, acute, pointed and distinct in fine merino wools, as many as 2800 per in. being counted in specimens of the finest Saxony wools. In the Leicester wool of England, on the other hand, which is a long bright staple, the serratures are not only much fewer in number, counting about 1800, but they are also less pronounced in character, so that the fibre presents a smoother, less waved character. In some inferior wools the serrations are not so many as 500 per in. A similar difference may be noted in the fineness of the fibres. The finest wool has a diameter of from $\frac{1}{2000}$ to $\frac{1}{3000}$ in., whilst coarse Algerian wools may rise to a maximum diameter of about $\frac{1}{275}$ in.

Other distinguishing qualities of good wool consist in uniformity and strength of fibre with freedom from tender or weak portions in its length, a condition which not unfrequently arises from ill health in the sheep, or is due to violent climatic changes. In ill-bred wool there may also be found intermingled "kemps" or dead hairs—straight, coarse, dull fibres which show conspicuously among the wool, and become even more prominent in the manufactured and dyed goods, as they will not take dye. Wool also possesses a softness of touch and an elasticity both in the raw and manufactured condition which distinguish it from all other fibres. In length of staple it varies very much, attaining in combing wools to a length of as much as 15 to 20 in.

In dealing with wool from a practical point of view it must be recognized that it is by no means a simple body, but has a somewhat complex physical structure. Its composition in the raw state may be said to be threefold. Thus there is the wool-yolk—what may be termed a natural impurity; the wool-fat, which is not only present in the yolk but also permeates the fibre and seems to give it its plastic and soft handle; and the cell structure proper of the fibre. The natural impurity or wool-yolk is truly a skin product and is a protector of the wool-fibre rather than part of the true fibre substance. The wool-fat also may be regarded as

Chemical characteristics of wool.

independent of the true fibrous substance, but it is well to recognize that if the wool-fibre be entirely freed from the wool-fat it loses its plastic and elastic nature and is considerably damaged. In cleansing wool the true fibre mass may be disturbed and partially destroyed not only by dry but also by "wet" heat, and may be entirely disintegrated by means of alkalies, &c., with heat. The wool-fibre will almost free itself from the natural impurities—the yolk—in the presence of tepid water. This is taken advantage of in the various steeping machines placed on the market, which partially scour the wool by means of its own yolk—principally through the potash salts present.

According to Hummel the composition of the average wool-yolk is as follows:—

Moisture	4 to 24 %	Dirt	3 to 24 %
Yolk	12 „ 47 %	Wool-fibre	15 „ 72 %

The potash salts are usually recovered from the wash-water products and a marked economy thereby effected.

The natural wool-fat—popularly known as "lanoline"—may be partially got rid of in the steeping process, but it is almost invariably necessary to free the wool still further from it by actually scouring the wool on either the "emulsion" or "solvent" method, in either case the action being largely physical. As previously pointed out, however, all the wool-fat must not be taken away from the fibre, or the fibre will lose its "nature." According to Dr Bowman, the chemical composition of the cell structure of the average wool-fibre is:—

Carbon	50·8
Hydrogen	7·2
Nitrogen	18·5
Oxygen	21·2
Sulphur	2·3
	100·0

It is said to be a most complex body of which the probable formula is $C_{42}H_{157}N_6SO_{15}$.

If wool is burnt, it largely resolves itself into ammonia gas—whence it derives its characteristic odour—and carbon "beads" or "remains," which serve to distinguish wool from cotton, which, upon being burnt, does not smoulder but burns with a flash and leaves no beads For further particulars on the organic nature of the wool-fibre see FIBRES.

The bulk of the wool of commerce comes into the market in the form of fleece wool, the product of a single year's growth, cut from the body of the living animal. The first and finest clip, called lambs' wool, may be taken from the young sheep at about the age of eight months. When the animal is not shorn till it attains the age of twelve or fourteen months the wool is known as hogg or hogget, and, like lambs' wool, is fine and tapers to a point. All subsequently cut fleeces are known as wether wool, and possess relatively somewhat less value than the first clip. Fleece wool as it comes into the market is "in the grease," that is, unwashed, and with all the dirt which gathers to the surface of the greasy wool present; or it is received as "washed" wool, the washing being done as a preliminary to the sheep-shearing, or, in some few cases, it is scoured and is consequently stated as "scoured." Skin wool is that which is obtained from sheep which either die or are killed. Typical skin wool is that which has been removed by a sweating process. The worst type of skin wool—technically known as "slipe"—is removed from the skins by lime, which naturally affects the handle of the wool and renders it difficult to bring into a workable condition later. Mazamet in France is the great continental centre for skin wools.

Lamb, Hogg and Wether wool.

Where there is abundance of water and other conveniences it is the practice to wash or half-wash sheep previous to shearing, and such wool comes into the market as washed or half-washed fleece. The surface of a fleece has usually a thick coating of dirt, and in the case of merino breeds the fleece surface is firmly caked together into solid masses, from the adhesion of dirt to the wool constantly moist with the exudation from the skin of the greasy yolk or "suint," so that in an unwashed very greasy fleece 30 % of weight may represent dirt, and about 40 % the greasy suint which lubricates the wool, while the pure wool is not more than one-third part of the whole. Where running streams exist, the sheep are penned by the side of the water, and taken one by one and held in the stream while they are washed, one man holding and the other washing. The operation is objectionable in many ways, as it pollutes the stream, and it dissipates no mean amount of potash salts, valuable for manure or for other chemical purposes. Sheep washing appliances are now largely employed, the arrangement consisting of a pen into which the sheep are driven and subjected to a strong spray of water either hot or cold, which soaks the fleece and softens the dirt. This done, they are caused to swim along a tank which narrows towards the exit, and just as they pass out of the pen they are caught and subjected to a strong douche of pure water. They should then be kept on grass land free from straw, sand, &c., so that the wool may be sheared free from vegetable matter, &c. After a few days the wool of a washed sheep is sufficiently dry for shearing or clipping.

Sheep washing.

The relative advantages of shipping wool in the greasy or washed state have been fiercely debated. Although there are naturally exceptions, the superiority of greasy wool is now generally recognized. This is not only because the wool more fully retains its nature, but because it is more readily judged for "yield" and its spinning qualities are, perhaps, more readily estimated.

The following list gives an idea of the yield in clean wool of the chief commercial varieties, from which it will be noted that roughly merino greasy wool yields about 50 % clean wool and English about 75 % clean wool.

Type of Wool.	Yield per cent of Clean Wool.
Australian Merino	50 %
Cape „	48 %
South American Merino	45 %
New Zealand Cross-bred	75 %
South American Cross-bred	75 %
English Southdown	80 %
„ Shropshire	80 %
„ Lincoln	75 %
Mohair	85 %
Alpaca	85 %

A skilful shearer will clip the fleece from a sheep in one unbroken continuous sheet, retaining the form and relative positions of the mass almost as if the creature had been skinned. In this unbroken condition each fleece is rolled up by itself and tied with its own wool, which greatly facilitates the sorting or stapling which all wool undergoes for the separation of the several qualities which make up the fleece. Mechanical shears have almost revolutionized the shearing industry, a good shearer shearing from 100 to 200 sheep per day.

Sheep shearing.

On the great Australian sheep stations wool classing is one of the most important operations, largely taking the place of sorting in the English wool trade. This is no doubt due to the wonderful success which has attended the efforts of the Australian sheep breeders to breed a sheep of uniform staple throughout. Thus the fleeces as taken from the sheep are skirted and trimmed on one table and then passed on to the classer, who places them in the 56's, 60's, 64's, 70's, 80's or 90's class according to their fineness, these numbers approximately indicating the worsted counts to which it is supposed they will spin. The shorter Australian wools not coming under any of these heads are classed as super-clothing, ordinary clothing, &c., being more suitable for the woollen industry.

Wool classing.

The art of sheep shearing, skirting, classing, packing and transporting has been brought up to a wonderful state of perfection in Australia, and the "get up" of the wool is usually much superior to the "get up" of the "home-clip." Of late there has been an outcry against the prevalence of vegetable matter in colonial wools, but it seems probable that with the adoption of a suitable woolpack, and the exercising of a little more care in sorting at the home end, this difficulty will be satisfactorily surmounted.

Sorting or stapling was formerly a distinct industry, and to some extent it is so still, though frequently the work is done on the premises of the comber or spinner. Carding wools are separated and classed differently from combing wools, and in dealing with fleeces from different breeds, the classification of the sorter varies. In the woollen trade short-staple wool is separated into qualities, known, in descending series from the finest to the most worthless, as picklock, prime, choice, super, head, seconds, abb and breech, and the proportions in which the higher and lower qualities are present are determined by the "class" of the fleece. In the worsted trade the classification goes, also in descending series, from fine, blue, neat, brown, breech, downright, seconds, to abb for English wools. The last three are short and not commonly used in the worsted trade. The greater proportion of good English long wool will be classified as blue, neat and brown; it is only in exceptional cases that more than from 5 to 8 % is "fine" on the one hand, or of lower quality than breech on the other. Generally speaking, the best portion of a fleece is from the shoulders and side of the animal. The quality decreases towards the tail end of the sheep, the "britch" being frequently long, strong and irregular. The belly wool is short, worn and dirty, as is also the front of the throat, while on the head and shins the product is short, stiff and straight, more like hair than wool and is liable to contain grey hairs. The colonial wools come "classed," and consequently are only as a rule sorted into three or four qualities. Thus a 60's fleece may be sorted into 56's, ordinary 60's, super 60's and skirtings.

Wool sorting.

The sorter works at a table or frame covered with wire netting through which dust and dirt fall as he handles the wool. Fleeces which have been hard packed in bales, especially if unwashed, go into dense hard masses, which may be heated till the softening of the yolk and the swelling of the fibres make them pliable and easily opened up. When the fleece is spread out the stapler first divides it into two equal sides; then he picks away all straws, large burrs, and tarry fragments which are visible; and then with marvellous precision and certainty he picks out his separate qualities, throwing each lot into

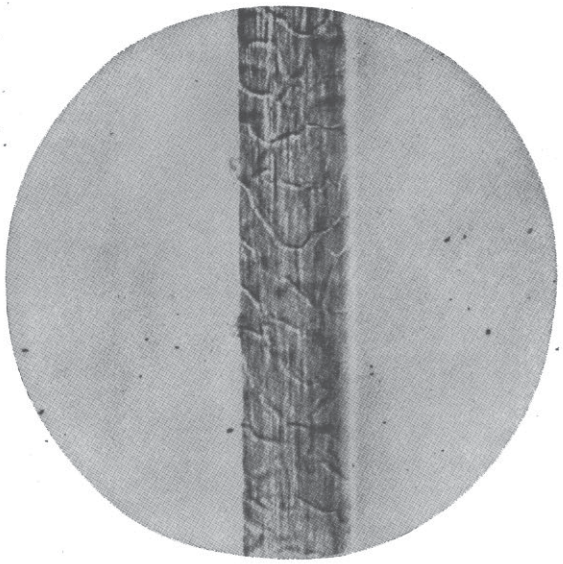

FIG. 1.—MOHAIR (×320).

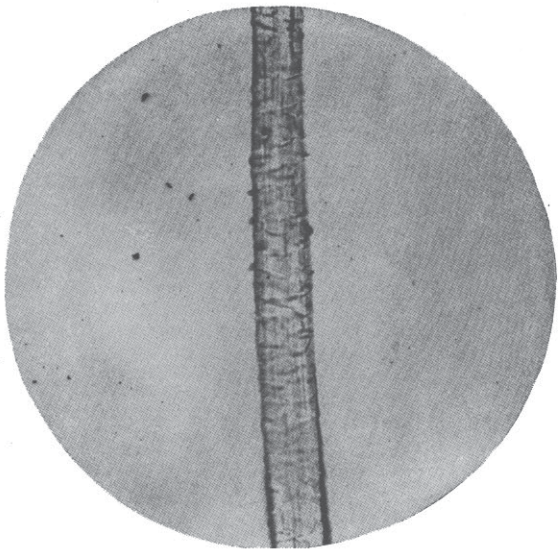

FIG. 4.—ALPACA WOOL HAIR (×320).

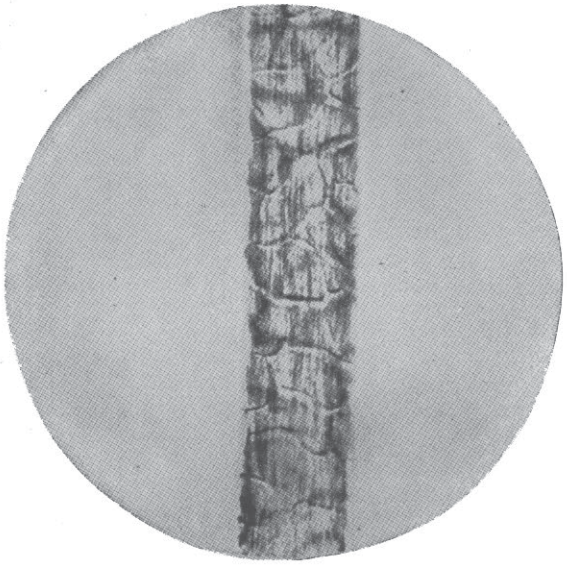

FIG. 2.—LEICESTER WOOL (×320).

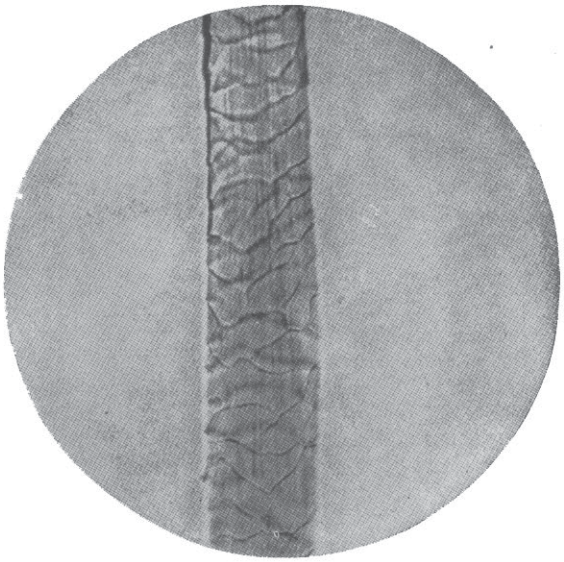

FIG. 5.—DOWN WOOL (×320).

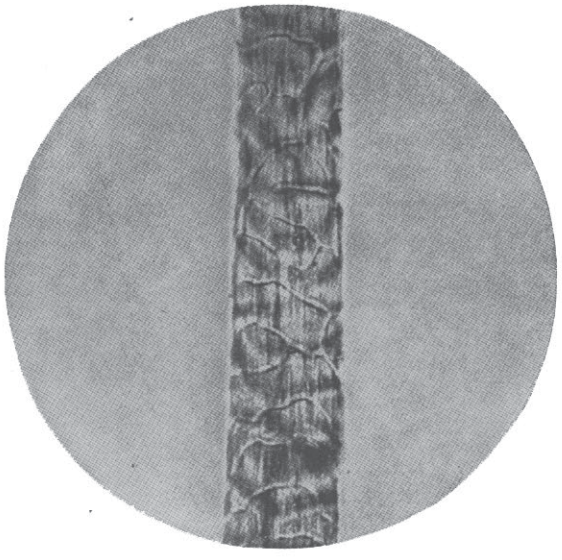

FIG. 3.—NEW ZEALAND CROSS-BRED WOOL (×320).

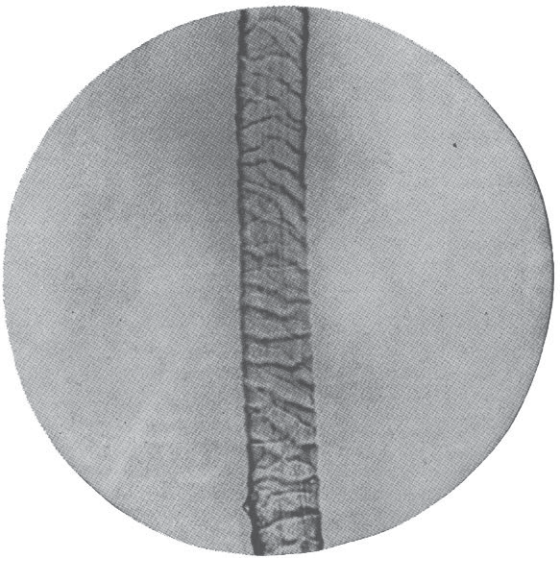

FIG. 6.—AUSTRALIAN MERINO WOOL (×320).

Photomicrographs of the most representative hairs and wools used in the textile industries.

its allotted receptacle. Sorting is very far removed from being a mere mechanical process of selecting and separating the wool from certain parts of the fleece, because in each individual fleece qualities and proportions differ, and it is only by long experience that a stapler is enabled, almost as it were by instinct, rightly to divide up his lots, so as to produce even qualities of raw material. Cleanliness is most essential if the wool sorter is to keep his health and not succumb to the dread disease known as "anthrax" or "wool-sorters' disease." Certain wools such as Persian, Van mohair, &c., are known to be very liable to carry the anthrax bacilli, and must be sorted under the conditions imposed by government for "dangerous wools." Ordinary or non-dangerous wools are perfectly harmless from this point of view.

The washing which a fleece may have received on the live sheep is not sufficient for the ordinary purposes of the manufacturer.

Scouring. On the careful and complete manner in which scouring is effected much depends. The qualities of the fibre may be seriously injured by injudicious treatment, while, if the wool is imperfectly cleansed, it will dye unevenly, and the manufacturing operations will be more or less unsatisfactory. The water used for scouring should be soft and pure, both to save soap and still more because the insoluble lime soap formed in dissolving soap in hard water is deposited on the wool fibres and becomes so fixed that its removal is a matter of extreme difficulty. In former times stale urine was a favourite medium in which to scour wool; but that is now a thing of the past, and a specially prepared potash soap is the detergent principally relied on. Excess of alkali has to be guarded against, since uncombined caustic acts energetically on the wool fibre—especially in the presence of heat—and is indeed a solvent of it. A soap solution of too great strength leaves the wool harsh and brittle, and the same detrimental result arises when the soapy solution is applied too hot.

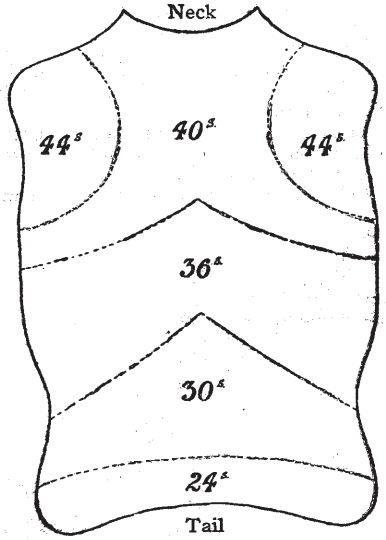

FIG. 7.—Qualities of Wool in a Lincoln Fleece.

The numbers indicate the quality of wool taken from the respective sections of the fleece. Thus the finest quality —44's—is found on the shoulders, while the coarsest "britch" is found on the hind-quarters of the sheep.

In former days, when the method of hand-scouring prevailed, the wool to be washed was placed with hot soap-sud in a large scouring "bowl" or vat, and two men with long poles kept stirring it gently about till the detergent loosened and separated the dirt and dissociated the grease. The wool was then lifted out and drained, after which it was rinsed in a current of clean water to remove the "scour" and then dried. These operations are now performed in scouring machines. Many firms now steep the wool previous to the true scouring operation, the object being to scour the wool with its own potash salts, to obtain wash-waters so fully charged with the potash salts that these salts, &c., may be readily extracted and put to some good use, and lastly to save the artificial scouring agent employed in the true scouring operation. The scouring of wool has passed through many vicissitudes during the past fifty years, but to-day the principle upon which all scouring machines are based is that wool naturally opens out in water. The mechanical arrangements of the machines are such as to ensure the passage of the wool without undue lifting and "stringing," to obviate the mixing of wool grease, sand, dirt, &c., once taken out of the wool with that wool again, to give time for the thorough action of the scouring agents, so that neither too strong a solution nor too great a heat be employed, and to allow of the ready cleansing of the machines so that there is no unnecessary waste of time. In England the recognized type of merino wool-washing machine is the fork-frame bowl. Three to five of these machines are employed. The "scour" is strongest and hottest in the first bowl (unless this is used as a "steeper") as the wool at first is protected from the caustic by the wool-fat, &c., present. The last bowl is simply a rinsing bowl. With modern "nip rollers" botany wool is sufficiently dry to be passed on directly—say by pneumatic conveyers —to the carding. This the worsted spinner does, thereby saving time and money. The woollen spinner, however, may require the wool for blending, and so may require it dry and in a fit state for oiling. He, therefore, will employ one or other of the drying processes to be immediately described. For English and cross-bred wools more agitation in the scouring bath may be desirable. If so, the eccentric fork action machine is employed, in which the agitation of the bath is satisfactorily controlled by the setting of the forks which propel the wool forward. An average wool will be in the scouring liquor about eight minutes, the temperature will vary from 120° F. to 110° F., and the length of bath through which it will have passed will be from 48 to 60 ft.

It is interesting to note that the "emulsion" method of wool scouring as described above is practically universal in England. In the United States of America the "solvent" method is largely in use, for the two points aimed at are quantity of production and cheapness. Quality is sacrificed to quantity and cheapness results from the ease with which the agent employed—say carbon disulphide —is recovered by volatilizing and condensing, thus being used over and over again.

Botany wools should leave the wool-washing machine in a fit condition to be fed immediately on to the carder, provided that the first cylinders are clothed with galvanized wire. Cross-bred and English wool, however, require artificially drying.

Wool drying. The more gently and uniformly the drying can be effected the better is the result attained; over-drying of wool has to be specially guarded against. By some manufacturers the wool from the squeezing rollers is whizzed in a hydro-extractor, which drives out so much of the moisture that the further drying is easily effected. The commonest way, however, of drying is to spread the wool as uniformly as possible over a framework of wire netting, under or over which is a range of steam-heated pipes. A fan blast blows air over these hot pipes, and the heated air passes up and is forced upwards through the layer of wool which rests on the netting or downwards, as the case may be. In this case, unless the wool is spread with great evenness, it gets unequally dried, and at points where the hot air escapes freely it may be much over-dried. A more rapid and uniform result may be obtained by the use of the mechanical wool drier, a close chamber divided into horizontal compartments, the floors of which have alternate fixed and movable bars. Under the chamber is a tubular heating apparatus, and a fan by which a powerful current of heated air is blown up the side of the chamber, and through all the shelves or compartments successively, either following or opposing the wool in its passage through the machine. The wool is introduced by a continuous feed at one side of the chamber; the strength of the blast carries it up and deposits it on the upper shelf, and by the action of the movable bars, which are worked by cranks, it is carried forward to the opposite end, whence it drops to the next lower shelf, and so on it travels till at the extremity of the lower shelf it passes out by the delivery lattice well and equally dried. Another drying machine in extensive use is what is known as the "Jumbo Dryer." This consists of a large revolving cylinder or churn which turns over the wool—as a churn turns butter—and owing to its inclination passes it from one end to the other. A hot air blast follows the wool through the machine. In this and in all drying machines it is more important to get the moisture laden air away from the wool than to develop a great heat.

The dried wool may be in a partially matted condition. If so, it must be opened out and the whole material brought into a uniformly free and loose condition. This is effected in the Willey, ***Teasing.*** which consists of a large drum and three small cylinders mounted in an enclosed frame. The drum is armed with ranges of powerful hooked teeth or spikes, and is geared to rotate with great rapidity, making about 500 revolutions per minute. The smaller cylinders, called workers, are also provided with strong spikes; they are mounted over the drum and revolve more slowly in a direction contrary to the drum, the spikes of which just clear those of the workers. The wool is fed into the drum, which carries it round with great velocity; but, as it passes on, the locks are caught by the spikes of the workers, and in the contest for possessing the wool the matted locks are torn asunder till the whole wool is delivered in a light, free and disentangled condition. It is a debatable point as to whether willowing should precede scouring. Some scourers always willow prior to scouring, while others never subject the wool to this operation, which is advantageous in some cases and not in others.

Burring. For certain classes of wool, notably Buenos Aires, still another preparing operation is essential at this stage—that is, the removal of burrs or small persistently adherent seeds and other fragments of vegetable matter which remain in the wool. Two methods of effecting this—one chemical, the other mechanical—may be pursued. The chemical treatment consists in steeping the wool in a dilute solution of sulphuric acid (or other carbonizing agent), draining off the dilute acid by means of the hydro extractor, and then heat-drying in a temperature of about 250° F. The acid leaves the wool practically uninjured, but is concentrated on the more absorbent vegetable matter, and the high heat causes it to act so that the vegetable matter becomes completely carbonized. The burrs are then crushed and the wool washed in water rendered sufficiently alkaline to neutralize any free acid which may remain, and dried. The same burr-removing effect is obtained by the use of a solution of chloride of aluminium, a method said to be safer for the wool and less hurtful to the attendant workmen than is the sulphuric acid process. For mechanical removing of burrs, a machine something like the Willey in appearance is employed. The main feature of this apparatus is a large drum or swift armed with fine short spikes curved slightly in the direction in which it rotates. By a series of beaters and circular brushes the wool is carried to and fed on these short spikes, and in its rotation the burrs, owing to their weight, hang out from the swift. The swift as it travels round is met by a

series of three burring rollers rotating in an opposite direction, the projecting rails of which knock the burrs off the wool. The burrs fall on a grating and are ejected, with a certain amount of wool adhering to them, by another rotating cylinder. With wools not too burry the worsted spinner largely depends upon burring rollers placed upon the first cylinder of the "carder," and possibly to one or other of the patent pulverizing processes applied further on in the card. In the latter process a complete pulverizing of the burrs is aimed at, this being effected by the introduction of specially constructed pulverizing rollers between the first doffer and the last swift of the carding engine.

The processes hitherto described are common to merino, cross-bred or botany wools be they intended for woollen or worsted yarns. From this point, however, differentiation starts. Wool may now be manipulated with the idea of converting it into felt (*q.v.*), woollen or worsted fabrics. In a general way it may be said that woollen yarns are those made from short wools possessed of high felting qualities, which are prepared by the process of carding; whereby the fibres are as far as possible crossed and interlaced with each other, and that the carded-slivers, though perhaps hard spun on the mule frame, form a light fluffy yarn, which suits the conditions when woven into cloth for being brought into the semi-felted condition by milling which is the distinguishing characteristic of woollen cloth. On the other hand, worsted yarns are generally made from the long lustrous varieties of wool; the fibres are so combed as to bring them as far as possible parallel to each other; the spinning is usually effected on the frame, and the yarn is spun into a compact, smooth and level thread, which, when woven into cloth, is not necessarily milled or felted. At all points, however, woollen and worsted yarns as thus defined overlap each other, some woollens being made from longer wool than certain worsteds, and some worsteds made from short staple wool, carded as well as combed. Worsted yarn is now largely spun on the mule frame, while milling or felting is a process done in all degrees—woollen being sometimes not at all milled, while to some worsteds a certain milled finish is given. The fundamental distinction between the two rests in the crossing and interlacing of the fibres in preparing woollen yarn—an operation confined to this alone among all textiles, while for worsted yarn the fibres are treated, as in the case of all other textile materials, by processes designed to bring them into a smooth parallel relationship to each other.

Woollens and worsteds.

To obtain a sliver which can be satisfactorily spun into a typical woollen thread the following operations are necessary: willowing, oiling and blending, teasing, carding (two or three operations), condensing and roving. Spinning upon the woollen mule completes the series of operations all of which are designed to lead up to the desired result. Of the foregoing operations the carding is perhaps the most important as it is certainly one of the most interesting. At the same time it must be fully realized that deficiencies in any one of these operations will result in bad work at every subsequent process. For example, let an unsatisfactory combination of materials be blended together and there will be trouble in both carding and spinning. The roving operation included above is not always necessary. In the old days, if a really fine thread were required, roving was absolutely necessary, as the carder could not turn off a sliver fine enough to be spun at one operation. To-day, however, with the "tape" condensers, such fine slivers can be turned off the condenser that there is no difficulty in spinning directly to the required count. In some few cases, however, it may be cheaper to rove than to condense fine; again, certain physical characteristics appertain to the roved thread, as distinct from the condensed thread, which may occasionally be of use to the cloth constructor.

Woollen yarn manufacture.

At the beginning of the 19th century woollen cloths were made of wool—some of them of the very finest wool obtainable. To-day woollen cloths are made from any and every kind of material, of which the following are the most important: noils (botany, cross-bred, English, alpaca and mohair), mungo, shoddy, extract, flocks, fud (short mill waste), cotton sweeping, silk waste, &c., &c.; in fact it is said that anything which has two ends to it can be incorporated into a woollen thread and cloth. It does not follow, however, that all woollen cloth is cheap and nasty. On the contrary the west of England still produces the finest woollen fabrics of really marvellous texture and beauty, and Batley, Dewsbury, &c., produce many fabrics which are certainly cheap and yet anything but nasty. The first essential for blending is that the materials to be blended should be fairly finely divided. This is effected by passing each material, if necessary, through the willow or through the "fearnaught"—a machine coming between the willow and card—prior to beginning the "blend-stack." Sometimes it may be that a blending of different colours of wools to obtain a definite "colour mixture" is necessary, more often it will be a blending of various materials, such as noils, mungo, cotton, &c., to obtain a cheap blend which may be spun into a satisfactory warp or weft yarn. The blender proceeds as follows: first a layer of No. 1 material—say wool—is spread over the required area on the floor; it is then lightly oiled. A layer of No. 2 material—say noils—is now added to the first layer; then another layer of wool with rather more oiling; then No. 2, then No. 1 with still more oil until all the material is built up into layers in the stack. The stack is now beaten down sideways with sticks, and then the more or less mixed mass is passed through the willow and fearnaught still further to mix it prior to carding, where the true and really fine mixing takes place. After passing through the fearnaught the material is sheeted and left to "mellow," this no doubt consisting in the oil applied distributing itself throughout the material. If wool and cotton are blended together the wool must be oiled first, or the blend will not work to the greatest advantage. The oil may be best Gallipoli olive oil—which should not turn rancid—but there are many good oils—and unfortunately many bad oils—placed on the market at a reasonable rate which the really skilled judge may use to advantage. The percentage of oil varies from 2 % to 10 %—this remark applies both to the woollen and worsted trades—and there is no guide as to the amount required, saving and excepting experience, observation and common sense. Automatic oiling arrangements have been applied in the woollen trade with only a moderate amount of success, the sprinkling of the oil by means of a watering-can on the stack, made as described above, still being most in favour. The oil serves to lubricate the fibres, and to render them more plastic and consequently more workable, and to bind the fibrous mass together and thus prevent "fly" during the passage through the cards.

Blending and oiling.

Carding was originally effected by hand, two flat boards with convenient handles, covered with teeth or card clothing, serving as a means of teasing out lock by lock, fibre by fibre, reversing root to tip and tip to root, so that a perfect mixing of the fibres resulted. It was but natural that, when an attempt was made to render the carding operation more mechanical, the operation should be converted into a continuous one through the adoption of rollers in place of flats. Flats combined with rollers still maintain their position in cotton carding, but in wool carding the pure roller card is employed. The factors of carding are size of rollers, speeds of rollers, inclination of teeth and density of card clothing. Probably no operation in the textile industries is so little understood as carding. Thus the long wool carder would think a man an idiot who suggested the running of the teeth of the various cylinders actually into one another, while the short mungo carder regularly carries out this idea, and so on. The underlying principle of carding, however, is shown in fig. 8, in which a sectional drawing of part of a card is given. The wool is carried into the machine on a travelling lattice and delivered to the feed rollers A, A′, A″ of which A and A″ in turn are stripped by the licker-in B working at a greater speed point to smooth side. This in turn is stripped by the angle stripper C again working at a greater speed point to smooth side, which in its turn is stripped by the swift D—the "carrying-forward" and swiftest carding cylinder in the machine. The swift carries the wool forward past the stripper E—which as a matter of fact is stripped by the swift still working point to smooth side—into the slowly retreating teeth of the first worker F, which, being set a fair distance from the swift, just allows well laid-down wool to pass, but catches any projecting and uncarded staples. The worker in its turn is stripped by the stripper E′, which in turn is stripped by the swift as already described. The passage of the wool forward through the machine depends upon its being carried past each worker in turn. Thus from beginning to end of a machine the workers are set closer and closer to the swift, so that the last worker only allows completely carded wool to pass it. Immediately on passing the last worker F′ the wool is brushed up on the surface of the swift by the "fancy" G—as a rule the only cylinder whose teeth actually work into the teeth of the swift and the only cylinder with a greater surface speed than the swift. The swift then throws its brushed-up

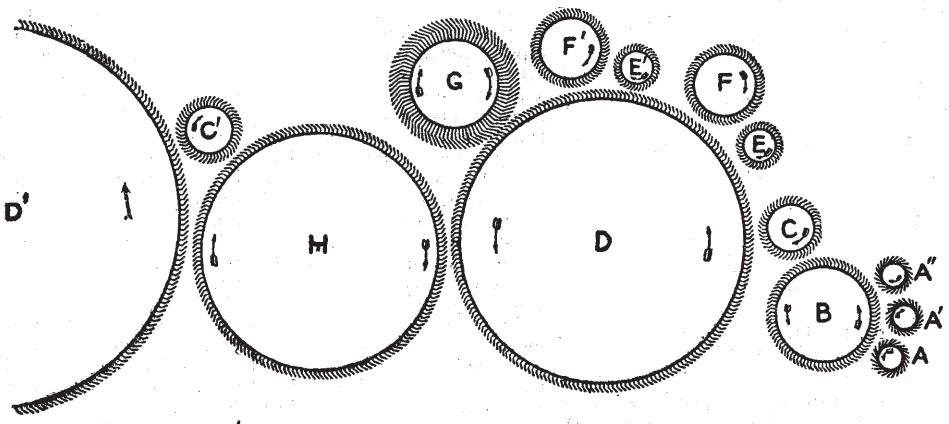

FIG. 8.—Sectional View of Carder; illustrating the principles of carding.

Carding.

coating of wool into the slowly retreating teeth of the doffer H, which carries it forward until angle stripper C′ strips the doffer, to be in its turn stripped by swift D′ and so on. The speeds of the cylinders are in the first place obviously dependent upon the principle of carding adopted, the greater speed always stripping (save in the case of the fancy). As to whether the speed shall be obtained by actual revolutions or by a larger diameter of cylinder depends upon the nature of the wool to be carded (long or short), the part which each cylinder has to play in the card, and upon the question of wear of clothing and power consumed. As a rule the strippers are all driven from a smaller circumference of the swift to obtain conveniently the necessary reduction in speed, and the slowly revolving workers are chain driven from the doffer, which indirectly receives its motion from the swift. The principles involved in the relative inclinations of teeth are very apparent, but the principles involved in the relative densities of teeth on the respective cylinders are again much involved and little understood.

A complete scribbler or first card engine consists of a breast, or small swift, and two swifts with the accompanying workers, strippers, fancies, doffers, &c. The wool is stripped from this card as a thin film by means of the doffing comb. This is usually weighed on to the next machine—whether intermediate or condenser—a given weight giving a definite count of condensed sliver. Should an intermediate be employed, there must be an automatic feed, taking the wool, as stripped from the last doffer of the intermediate, and feeding it perfectly evenly on to the feed sheet of the condenser. The condenser is usually a one-swifted card, the only difference in principle being that, whereas the sliver comes out of the scribbler or intermediate in one broad film, it is broken up into a number of small continuous slivers or films, each one of which will ultimately be drafted or drawn out and twisted into a more or less perfect thread. These slivers—which are delicate and pith-like in substance—are wound on to light bobbins, and these bobbins are placed on the mule for the final roving and spinning operations. There are many forms of condensing mechanisms such as the single-doffer, the double-doffer and the tape-condensers, but their construction is too complex to be described here. Whatever the type may be, the result is that noted above, but it should be noted that the tape enables a much finer sliver to be taken from the card than is possible with either the single- or double-doffer condenser.

The principles involved in mule spinning are comparatively simple, but the necessary machinery is very complex; indeed it is questionable if a more ingenious machine than the mule exists. The pith-like slivers received from the card-loom must be attenuated until the correct count of yarn is obtained; they must be twisted while this attenuation or drafting is in process, otherwise they would at once break; and after being attenuated to the required fineness the requisite number of turns must be inserted. Great stress must be laid on the effects of what is termed the "drafting-twist" noted above; it is probably this simultaneous drafting and twisting which develops the most pronounced characteristics of the woollen yarn and cloth, and differentiates it entirely from the worsted yarn and cloth. The mule (see fig. 9) consists of the delivery cylinders A, upon which the sliver bobbins B from the condenser are placed, which deliver the slivers as required to the front delivery rollers C (these rollers controlling perfectly the delivery of sliver for each stretch of the carriage), and the carriage EE carrying the spindles which may be run close up to the front delivery rollers and about two yards away from them to effect the "spin," which is of an intermittent character. The spindles D are turned by bands passing round a tin drum K in the carriage, but this motion, and every other motion in the mule, is controlled perfectly from the headstock. In brief, the operation of spinning is as follows: as the carriage begins to recede from the delivery rollers these rollers deliver condensed sliver at about the same rate as the carriage moves out, the spindles putting in a little twist. When the carriage has perhaps completed half its traverse (say 36″) away from the front rollers these suddenly stop delivering the condensed sliver, the carriage goes more and more slowly outwards until it completes its traverse, drafting the sliver out to perhaps double the length. This drafting could not be effected but for the "drafting-twist," which, running into the thin parts of the yarn during drafting, strengthens them and thus from beginning to end equalizes the thread. Upon the completion of drafting the spindles are thrown on to "double speed" to complete the twisting of the 72″ of yarn just spun as rapidly as possible, the carriage being allowed to run inwards for a few inches, to allow for the take-up due to twisting. The mule now stops dead, backs-off the turns of yarn from the bottom of the spindle to the top, the faller H wire falls into position to guide the thread on to the spindle to form the required cop G, and the counter-faller I wire rises to maintain a nice tension on the yarn. The carriage now runs in, the spindles being revolved to wind up the yarn, and, in conjunction with the guiding on of the faller wire, builds up a firm cop or spool, as the case may be.

Mule spinning.

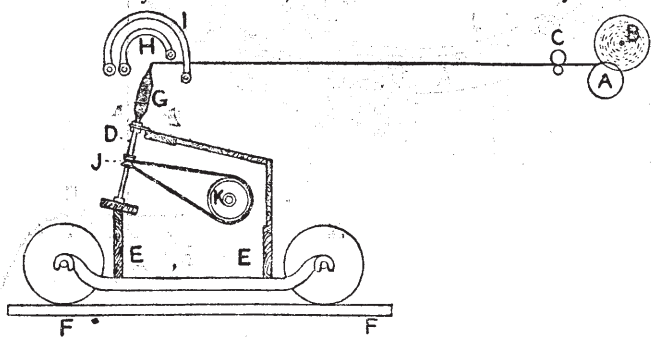

FIG. 9.—Sectional View of the Woollen Mule.

Woollen mules are made with several hundred spindles and of varying pitch to suit particular requirements. Thus if the mules are to follow a set of say three carders with a tape condenser, and are required to spin fine counts, the pitch of the spindles may be much finer than ordinary, but a greater number will be required to work up the sliver delivered by the set of machines. There are many other details which require careful consideration; the inclination of the spindles, for example, must be suited to the material to be spun. And when all the mechanical arrangements are perfect there is still the necessity of correct judgment as to the qualities of the blend in hand, for in this case perhaps more than in any other the machine must be adjusted to the material and not the material to the machine.

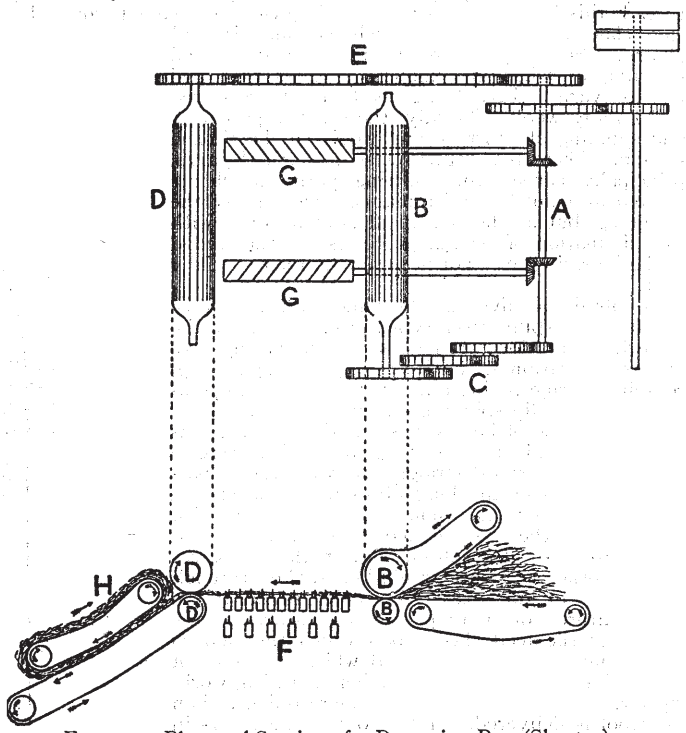

FIG. 10.—Plan and Section of a Preparing Box (Sheeter).

A is the back-shaft receiving its motion from the driving shaft upon which are the pulleys. This back-shaft A drives the back-rollers B at a slow speed by the reducing train of wheels C; also the front rollers D at a much quicker speed through the train of wheels E, and the fallers F at an intermediary speed by means of the levels and screws G. G. The wool is "made up" on the feed sheet and on emerging from the front rollers is built up layer by layer into the lap H, which is finally broken across and feeds up at the next machine.

The yarn as delivered by the mule is "single" and will serve as warp or weft for the great bulk of woollen cloths, warp being as a rule twisted harder than weft. Sometimes for strength, sometimes for colour, however, it will be necessary to twist two or more of these single strands together. This is best effected on a twisting frame of the ring type, which consists of delivery rollers, to deliver a specified length of yarn in relationship to the turns of the spindles, and the spindles, which serve to put in twist and to wind the yarn upon the bobbin or tube, which they carry by reason of the retarding action of the traveller. Fancy twists such as knops, loops, slubs, &c., may also be produced if the frame is fitted up with two pairs of delivery rollers and two or three special but simple appliances.

Worsted yarn manufacture.

The essential feature of a worsted yarn is straightness of fibre. Prior to the introduction of automatic machinery there was little difficulty in attaining this characteristic, as long wool was invariably employed and the sliver was made up by hand and then twisted. With the introduction of Arkwright's "water frame" or "throstle" the necessity for prepared slivers became apparent, and with the later introduction of cap and mule spinning the necessity for perfectly prepared slivers has been so accentuated that the preparatory machinery has quite

exceeded the actual spinning machine in extent and complexity. To-day there are three distinct methods of producing worsted yarn.

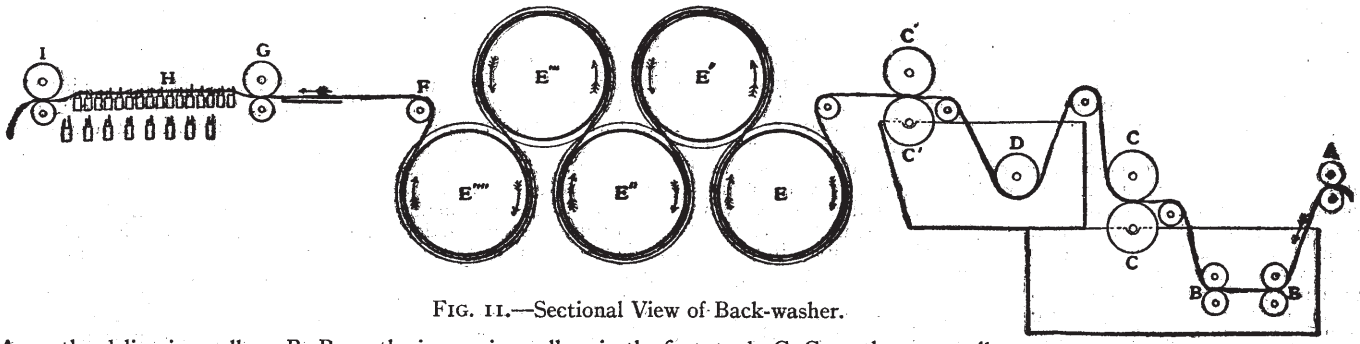

FIG. 11.—Sectional View of Back-washer.

A are the delivering rollers, B, B are the immersing rollers in the first tank, C, C are the press rollers to squeeze out superfluous liquors, D is the immersing roller in the second tank, and C′, C′ are the press rollers for the second tank. Drying cylinders E to E‴ may be arranged as "live-heat" cylinders, as secondary heated cylinders or as air drying cylinders. The roller F directs the slivers into the back rollers G of the gill-box, which in turn delivers up the slivers to the fallers H, which in turn delivers the wool to the front rollers I.

Firstly, there is the preparing and spinning of the true worsted thread, this being made from long English and colonial wool. In this class should also be included mohair and alpaca. Secondly, there is the preparing and spinning of what are known as cross-bred and botany yarns, these being made from cross-bred and botany wools. Thirdly, there is the preparing and spinning of short botany wools on the French system. There is a fourth class of worsted yarns, principally carpet and knitting yarns, which are treated in a much readier manner than any of the foregoing, but as the treatment is analogous—with the elimination of certain processes—to the second of the foregoing, it is not necessary to refer specially to it.

To obtain a sliver or "roving" which can be satisfactorily spun into a typical worsted thread the following operations are necessary:—preparing (five or six operations), back-washing, straightening, combing, straightening and drawing (say six operations), and finally spinning on the flyer frame.

After long wool has been scoured and dried it is necessarily considerably entangled, and if it were to be combed straight away a large proportion of the long fibres would be broken and combed out as "noil" or short fibre. To obviate this the wool is fed as straight as possible into a sheeter gill-box; after this it passes through other two sheeter gill-boxes, then through say three can gill-boxes. As shown in fig. 10 the main features of a preparing or gill-box are the following: the feed sheet upon which the wool is "made up," the back rollers B which take hold of the wool and deliver it to the fallers F which, working away from the back rollers more quickly than the wool is delivered, comb it out. The fallers in turn deliver the wool to the front rollers D, which, taking in the wool more quickly than the fallers delivering it, again draft and comb it, but with a reversing of the former combing operation. The wool emerges from the front rollers as thin attenuated continuous fibre about 12 in. wide, which is wound upon an endless leather sheet H from which the box takes its name. When a sliver of sufficient thickness has been wound upon the sheet, it is broken across and fed up at the next gill-box. The fourth gill-box delivers into cans instead of on to a sheet. A number of cans are then placed behind the fifth box and the slivers from these fed up into the back rollers, and similarly with the sixth. The primary object of "preparing" or gilling is to straighten and parallelize the fibres in the sliver. This is effected by means of the combining or doubling and drafting to which the slivers are subjected. In addition to this, however, a level sliver suitable for combing is formed by the combined action of the drafting and doubling which has taken place at each box.

Preparing.

Oil will have been added to the wool at the first preparing-box to cause the fibres to work well. Were this all, there would perhaps not be the necessity for back-washing. But the slivers during their passage through the preparing-boxes become sullied naturally, and in addition, owing to the opening out of the locks of wool, dirt which was not "got at" in the scouring now works out and further sullies the slivers. It is consequently necessary to scour the slivers again, this being effected in what is termed a back-washing machine. This machine as shown in fig. 11 usually consists of two scouring tanks with immersing rollers, drying cylinders, a gill-box and oiling motion. The slivers on emerging from this machine should be clean, fairly straight and in good condition for combing. Their condition may be further improved by passing them through

Back-washing.

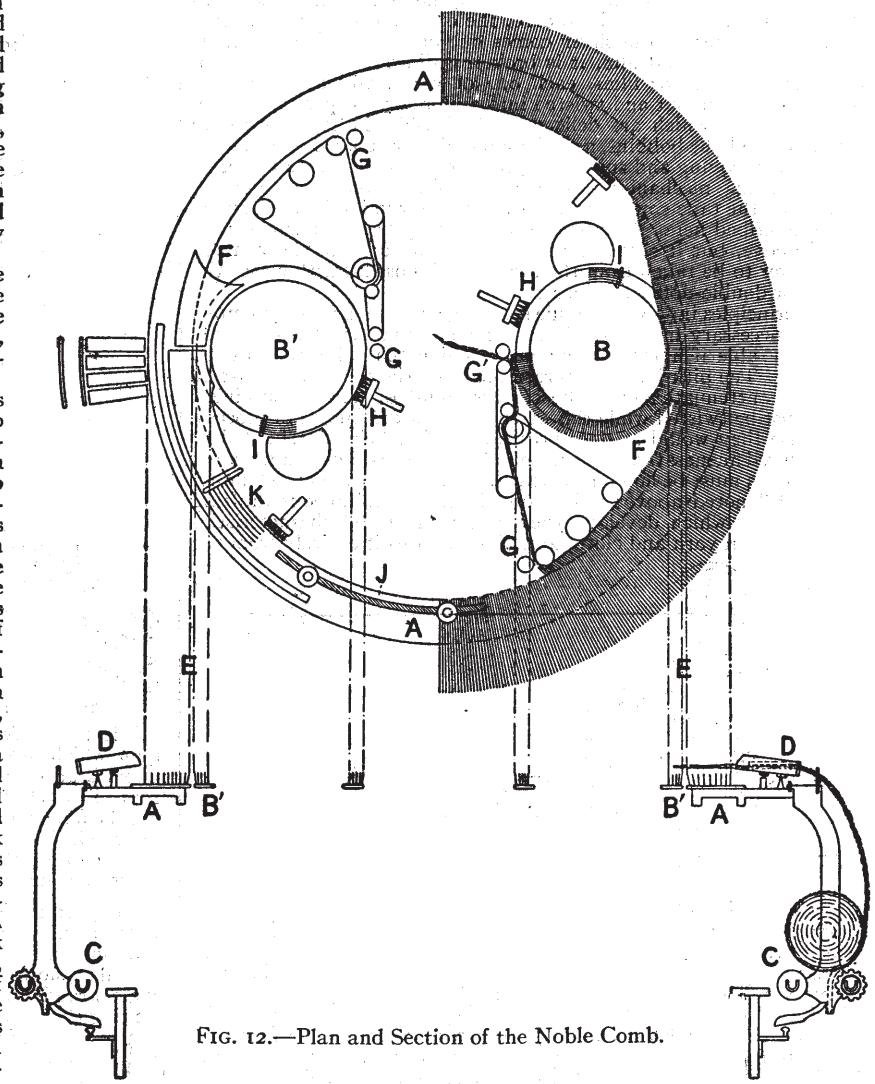

FIG. 12.—Plan and Section of the Noble Comb.

A, A is the large comb circle and B, B′ the two small comb circles. The slivers are delivered by the mechanism C to the feed boxes D, being thrown across the pins of the large and small circles at position E. A stroke at F suitably directs the fringes of fibre as the circles separate and the combed fibres are taken hold of by drawing-off rollers G and G′ and combined to form the "top." The brushes H, H and the noil knives I clear the small circles of the "noil." The feed knife J in conjunction with the inclined planes at K are instrumental in feeding a previously directed length of sliver over the two circles as they practically touch one another at the point E, and so the process is continued.

one or two more gill-boxes, prior to combing, to ensure straightness of fibre and even distribution of the lubricant.

Combing. Prior to the mechanical era wool was combed immediately after scouring; there was no preparatory process. As a matter of fact the first combing process took the place of the processes just described and was termed "straightening," the "combing proper" following. Prior to the invention of a really satisfactory mechanical comb, between 1850 and 1860, the combing operation was the limitation of the worsted trade. English wools could be satisfactorily combed by hand, and perhaps the results of combing botany or fine wools by hand were satisfactory so far as quality of result was concerned, but the cost was largely prohibitive. The history of the colonial wool trade is inextricably bound up with the combing industry. How eventually botany wools were combed by machinery and how the wool industry was thereby revolutionized can only be briefly referred to here. About 1779 Dr Edmund Cartwright invented two distinct types of combs, the vertical and the horizontal circular. The former type was developed on the continent by Heilmann and others, and has only within the last five years taken its rightful place as a successful short wool comb in this country. The latter type was worked upon by Donisthorpe, Noble, Lister, the Holdens and others, and largely through the "driving" force of Lister (later Lord Masham) was made a truly practical success about the year 1850. Latter-day combs of this type may be readily grouped under three heads. The Lister or "nip" comb is specially suitable for long wools and mohair and alpaca. The Holden or square-motion comb is specially suited for short and very good quality wools. The last type, the Noble, is the most popular of all and, by a change of large and small circles, may be adapted to the combing of long, medium or short wools. As the great bulk of cross-bred and a considerable proportion of botany wool is combed upon the Noble comb a brief description is here called for. The object of all wool combing is to straighten the long fibres and to comb out from the slivers treated all the fibres under a certain length, leaving the long fibres or "top" to form the sliver which is eventually spun into the worsted yarn. The Noble comb, which so effectually accomplishes this, consists in the main of a large revolving circle A inside which revolve two smaller circles B, B′ as shown in fig. 12, each of which touches the larger comb circle at one point only. At this point the slivers of wool to be carded are firmly dabbed into the pins of both the large and small circles. As the circles continue to revolve

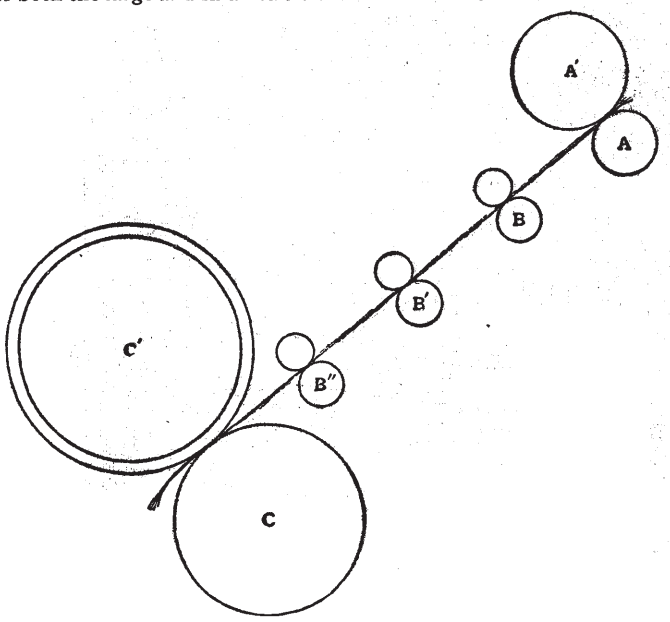

FIG. 13.—Section of Wool Drawing Rollers.

A, A′ are the back-rollers in a drawing box of which A is positively driven and A′ driven by friction which may be varied at will. Carriers B, B′, B″ simply control the fibres of which the sliver is composed during drafting. The front rollers C, C′—of which C is positively driven and C′ driven by friction—running at a greater speed than A, A′ draft or elongate the slivers as required. The carriers B, B′, B″ should be speeded to run at a suitable rate to assist the drafting operation, more by support than by direct aid. Rollers A, A′ must hold the sliver, hence they are fluted. Rollers C, C′ must pull the sliver somewhat severely, hence roller C′ is covered with leather. The yarn delivered by the front rollers is slightly twisted and wound into a double-headed bobbin of convenient size on the "flyer-system."

they naturally begin to separate, combing the wool fibres between them, the short fibres or "noil" being retained in the teeth of both small and large circles, the long fibres hanging on the inside of the large circle and on the outside of the small circle. A stroker or air blast at F now directs these long fibres into the vertical rollers, G and G′, shown here in plan, which draw them out, thus separating them from the short fibres. There are at least four pairs of drawing-off rollers in a comb, and the fibres drawn off by each—be it noted continuously—are united to form a sliver which is passed through a

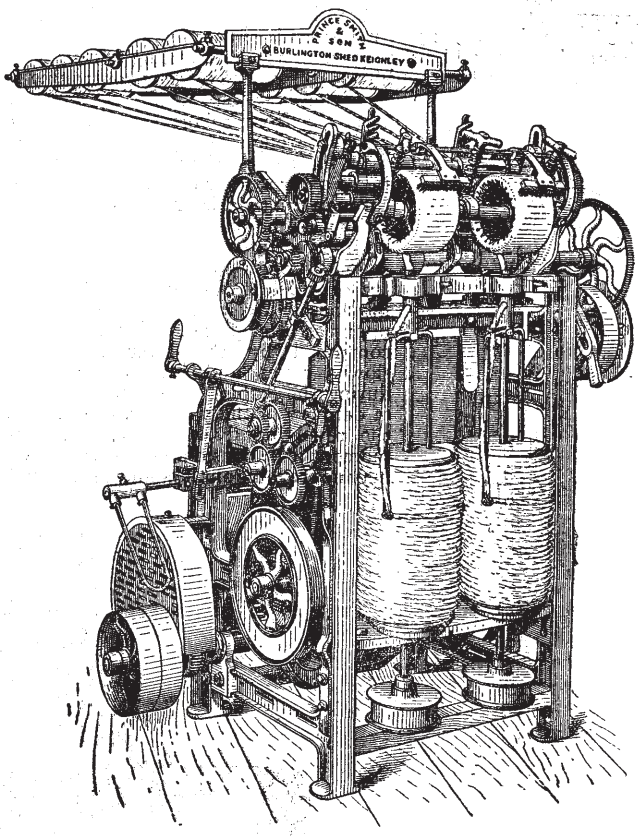

FIG. 14.—Two-Spindle Drawing-Box.

revolving funnel into a can. The short fibres, or "noil," are lifted out of the pins of the small circle by "noil knives." The continuous slivers, the ends of which remain in the pins of the large circle after the drawing-off rollers have been passed, are now lifted up until these ends are above the pins, at the same time an additional length of sliver being drawn into the comb, so that, as they reach the second small circle, they are ready to be again dabbed into the pins of both circles and the combing operation repeated. Thus the combing on a Noble comb is absolutely continuous. All the movements of this machine—with the exception of the dabbing-brush motion—are circular, so that mechanically it is an almost perfect machine. As illustrating the extent of the combing industry, it is interesting to note that even the making of dabbing-brushes is a separate and by no means unimportant trade.

After combing it is usual to pass the "top" through two gill-boxes termed "finishers." The last of these boxes, and often the first, delivers the "top" in the form of a ball, thus it is often spoken of as a "balling gill-box." This stage marks one of the great divisions of the worsted trade, the comber taking the wool up to this point, but now handing it forward in the shape of top to the "worsted spinner," who draws and spins the slivers into the most desirable worsted yarns.

Drawing. English tops are usually prepared for spinning by seven or eight operations. Three of these operations are effected in gill-boxes of a somewhat similar type to the preparing-box, only lighter in build. The remaining four are drawing-boxes, *i.e.* as shown in figs. 13 and 14, they consist of back and front rollers with small carrying-rollers—not gills—to support the wool in between. Thus an English set of drawing usually consists of a single-can gill-box, a double-can gill-box, a two-spindle gill-box, a four-spindle drawing-box, a four-spindle weigh-box, a six-spindle drawing-box, two six-spindle finishers and three thirty-spindle rovers. About fifteen flyer frames of 160 spindles each will be required to follow this set, although the balance varies partly in accordance with the counts spun to, in this case 1/32's English being the standard.

The object of drawing is to obtain firstly a level sliver from which an even thread may be spun, and secondly to reduce the comparatively thick top down to a relatively thin roving from which the required count of yarn may be spun. Of course parallelism of fibres must be retained throughout, so far as possible. To accomplish these objects doubling and drafting is resorted to. Thus the ends put up at the back of the above boxes will be 6, 6, 4, 4, 3, 3, 2 respectively, while the drafts may be 5, 6, 8, 8, 6, 9, 9 approximately.

As the drafts markedly preponderate over the doublings, so in exactly this proportion will the sliver be reduced in thickness.

Spinning.

The flyer spinning frame is very similar to the drawing frame, consisting of back rollers, carriers and front rollers, with the necessary spindle and flyer to put twist into the yarn and to wind it upon the bobbin. From the two-spindle gill-box to the spinning frame the spindle, bobbin and flyer combination is employed with the object just mentioned. From fig. 15 the action of this combination will be clearly understood. Drafting takes place as usual between the back and front rollers, the carriers controlling the yarn between the two. On emerging from the front rollers the yarn usually passes through an eyelet, to centre it over the centre of the spindle; it then takes a turn or two round the flyer leg, through the twizzle or eyelet on the flyer and on to the bobbin F. The flyer may be freely rotated by means of the wharl J and through the spindle G upon the top of which it is screwed. The bobbin fits loosely over the spindle and rests upon the lifter plate I; this latter, being controlled by the lifter mechanism, slowly raises and lowers the bobbin during the "spin" past the fixed plane of delivery of the yarn, *i.e.* the eyelet of the revolving flyer. Now, if for one moment it be considered that the bobbin may not revolve on the spindle but may be slid up and down by the lifter motion, then, if the front rollers deliver the necessary yarn, the flyer will wrap it in successive layers upon the bobbin—but no twist will be inserted. On the other hand, if the bobbin is perfectly free upon the spindle and the front rollers cease delivering yarn, then the flyer, by means of the yarn, will pull the bobbin round at the same speed as it goes itself, and the yarn will be twisted but not wound upon the bobbin. By obtaining an action in between these two extremes both twisting and winding on to the bobbin is effected. The speed of the bobbin is suitably retarded by washers placed between it and the lifter plate, so that it just drags sufficiently to wind up the yarn "paid out" by the front rollers. The turns per inch are in proportion to the yarn delivered and the revolutions of the flyer. Thus if, while 1 in. of yarn is delivered, the flyer revolves twelve times the turns per inch will be approximately twelve. This in brief is the theory of the spindle, flyer and bobbin action.

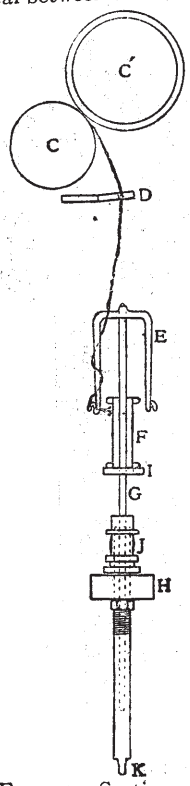

FIG. 15.—Section of Flyer Spindle.

C, C' are the front rollers of a drawing or spinning frame, delivering the sliver to a centring board D, containing an eye for each sliver, from which the sliver passes to the flyer E and finally to the bobbin F, which rests on the lifter-plate I and is traversed up and down by this plate according to the length of bobbin employed. The flyer E is screwed on to the spindle G which is suitably held by the sheath, bolster, &c., shown at H, and in the footstep at K. The spindle is turned by a tape passing round the wharl J and thence to an ordinary tin-drum.

Wools not more than 7 in. long are usually prepared for combing by the operation of carding. On first thought it might be imagined that carding would result in broken fibres and a poor yield of top. That this is not so is evident from the fact that there is a tendency to card wools from 7 to 10 in. long, this tendency being due to the relative cheapness of carding as compared with preparing. If long wools were fed directly on to a swift, no doubt serious breakage of fibre would occur, but it is customary to place before the first swift of a worsted card a series of four opening rollers and dividers—with their accompanying "burring rollers"—to open out the wool gradually, so that when it eventually reaches the first swift it is so opened out that further opening out instead of breakage occurs. Some carders use a breast or small swift in place of those opening rollers—mostly on account of economy. The swift is usually surmounted with four workers and strippers and is very similar to the woollen carder, save that the workers and doffer are larger, thereby effecting more of a combing action and working economically by reason of the greater wearing surface brought into play. As botany wool is usually brought directly from the wash bowl to the feed sheet of the card, it is usual to clothe the first cylinders with galvanized wire clothing.

Carding of medium and short wools for worsted yarns.

After the carding the wool is back-washed and gilled—on similar lines to English wool—and then is ready for combing. The largest combers of botany wools, Messrs Isaac Holden & Co., employ the square-motion comb, in fact this comb is known in the trade as the Holden comb. Other combers, however, almost without exception employ the Noble comb with a fine "set over," *i.e.* fine spinning of the comb circles. After combing, the tops are "finished" by being passed through two finisher-boxes, the last of which "balls" the tops ready for marketing.

Combing medium and fine wools.

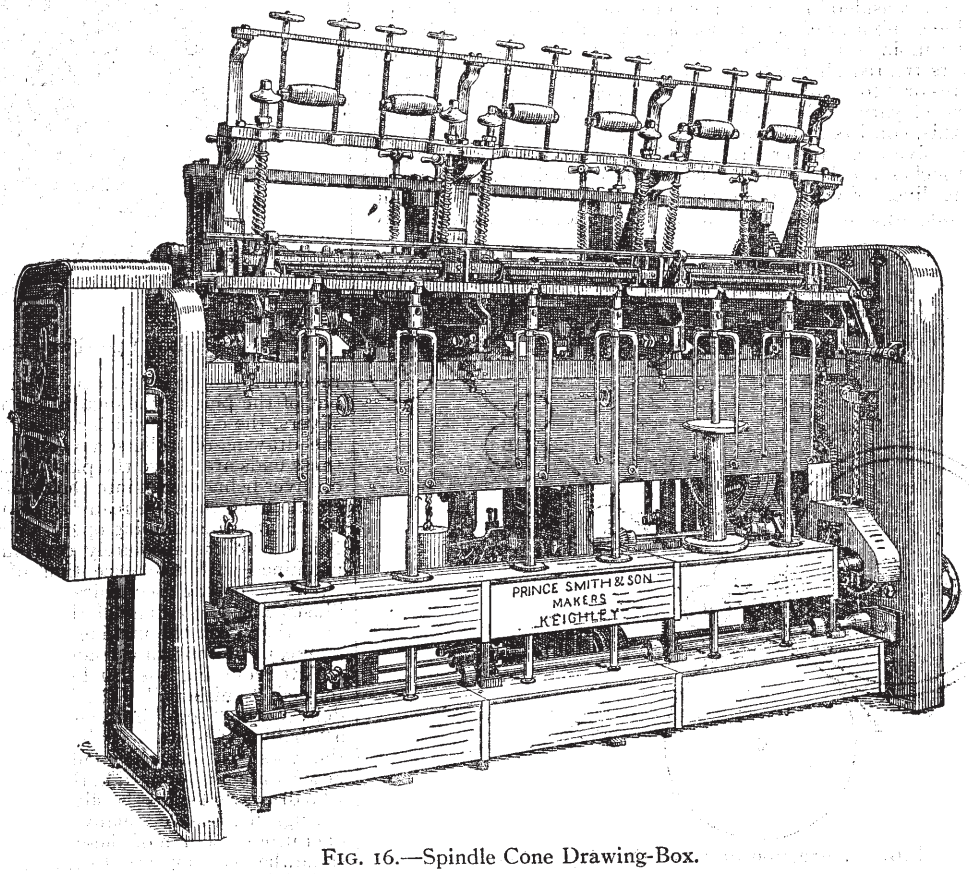

FIG. 16.—Spindle Cone Drawing-Box.

Short wools are drawn and spun on very similar lines to the longer wools, save that the boxes are more in number and are in some cases lighter in build. The boxes usually employed in a botany set are as follows: two double-head can gill-boxes, two two-spindle gill-boxes, a four-spindle drawing-box, a six-spindle weigh-box, an eight-spindle drawing-box, two eight-spindle finishing-boxes, two twenty-four-spindle second finishers, three thirty-two-spindle dandy reducers, ten thirty-two-spindle dandy rovers, with ten two-hundred-spindle cap spinners to follow.

Drawing and spinning.

The doublings as a rule are about 7, 6, 6, 6, 5, 5, 5, 4, 4, 2 and the drafts 5, 6, 6, 7, 7, 7, 8, 8, 8 at the respective boxes, an endeavour as a rule being made to obtain a roving of which 40 yds. = 2 drams, as this is the most convenient size for being spun into fine botany count of yarn.

Following the lead of the cotton trade endeavours have been made

to positively control the driving and speed of both flyer and bobbin in all the drawing frames of such sets as that described above. Such control is usually effected by a pair of cones, from which this system has taken its name, viz. "cone" drawing. In fig. 16 a usual type of cone drawing-box is illustrated. The chief advantages of this system seem to be the possibilities of employing larger bobbins, and thus obtaining greater production, the consumption of relatively less power, and more particularly the production of a softer sliver with less twist, partaking more of the character of a French roving.

Spinning is usually effected upon the cap frame (see fig. 17)—a frame in which the bobbin, resting upon a fixed spindle, is itself driven at say 5000 revolutions per minute to put in the twist, while the friction of the yarn on the cap which covers the bobbin enables the bobbin to wind up upon itself the yarn as delivered by the front rollers. The weakness and the strength of the cap frame is that to make reasonably hard bobbins the bobbins must be driven at a high speed.

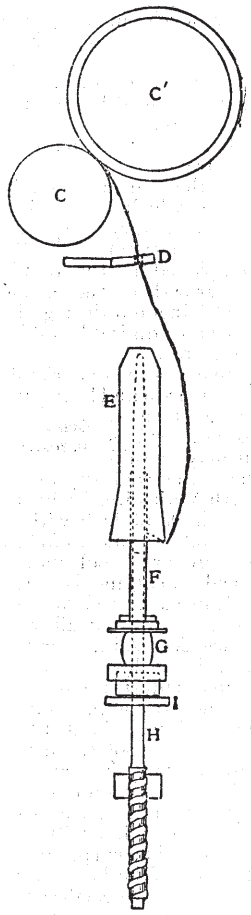

FIG. 17.—Section of Cap Spindle.

C, C' are the front rollers of a cap spinning frame delivering the yarn through the centring board D under the edge of the cap E to the bobbin F, which rests upon the tube and wharl G, which in turn rest upon the lifter-rail I, which effects the necessary traversing. The spindle H is simply screwed into the framework, and does not revolve, but simply acts as a support for the cap and as a centre of motion for the tube and bobbin.

French drawing and spinning. The French are noted for a special system of worsted spinning, which, producing soft botany yarns of a marked type, is worthy of more than passing comment. The preparation is very similar to the preparation of botany yarns for the English system save that as a rule the order of the operations are carding, gilling, combing, back-washing and finishing. The characteristic features of the method lie in the subsequent drawing and spinning. The drawing-box as shown in fig. 18 consists of back rollers, porcupine or revolving gill, front rollers, rubbers and winding-up arrangement. Thus there is no twist inserted, the slivers being treated softly and openly right away through the processes. A set of this type usually consists of two gill-boxes preparing for combing, comb, back-washing machine and two finishing gill-boxes, first drawing frame, second drawing frame, the slubbing frame, the roving frame and the self-acting mule. After leaving the last box as a fine soft pith-like sliver, spinning is effected upon the worsted mule. The main differences between the worsted and the woollen mule are firstly, the worsted mule is fitted with preliminary drafting rollers, and secondly, there is little or no spindle draft. As the mule is an intermittent worker it is natural to contrast it with the cap frame, which runs continuously. What the real advantage is it is difficult to say, but the mule-spun worsted yarn trade is becoming yearly of more importance, and it is pleasing to note that English spinners are at last doing a fair share of this business.

Doubling, twisting, etc. Upon whichever system the yarns have been spun it will frequently be necessary to twofold them and sometimes to three- and fourfold them. Again the fashion sometimes runs upon fancy twists, and then it is necessary to be able to produce the various styles of cloud, loop, curl, knop, &c., yarns. Twofolding is done upon the flyer, cap and ring frames. The main difference between the cap and the ring frame is that in the latter a small bent piece of wire, termed a traveller, revolved round a ring by the pull of the spindle through the yarn, serves as the retarder to enable the bobbin to wind the yarn, delivered by the front rollers on to itself (see fig. 19). Fancy twisters are almost universally on the ring system.

Yarns. Yarns are placed on the market in eight forms, viz. in hank, on spools, on paper tubes, on bobbins, on cops, in cheeses, in the warp ball form and dressed upon the loom beam. Thus the manufacturer can order the yarn which he requires in the form best suited to his purpose.

Weaving. Although in some few cases special means must be employed for the weaving of woollens, worsteds and stuff goods, still the main principles are the same for all classes of goods (see WEAVING). Attention may here be concentrated on the characteristic principles of woollen and worsted manufacture.

Finishing processes. The characteristic feature of wool and of wool yarns and cloths is the quality of "felting." This quality has always been made use of in woollen cloths, but in worsted cloths, until comparatively recently, it has been largely ignored. To-day, however, cloths are made, ranging from the truest woollen to the typical worsted, of which it would be impossible to indicate the type of yarn employed without very careful analysis. As it is obviously impossible to give here every variety of finish employed, the two typical styles for woollen and worsted cloths are dealt with in detail, and further to elucidate the matter the finishing of a Bradford "stuff" or "lustre" piece is also given in outline.

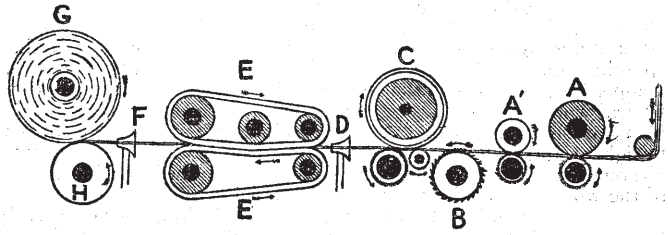

FIG. 18.—Section of French Drawing-Box.

A, A', delivery rollers which control the slivers during the drafting operation. B is the porcupine (or circular gill) and C are the front drafting rollers. D is the funnel through which the slivers pass to the consolidating rubbers E, E, F is a second funnel and G is the condensed sliver wound up at a uniform rate on the roller H.

Woollen cloth finishing. The fabric on leaving the loom is first mended and then scoured. The operation of scouring is effected in a "dolly," and must thoroughly clear the piece so that it is free to take the desired finish. The piece is now soaped and "milled," *i.e.* felted. Milling may be effected either in the stocks or in the milling machine. The stocks, the main features of which are huge hammers which are caused to fall or are driven positively into the cloth, exert a bursting action eliminating the thread structure. The milling machine acts more by compression, arrangements being made to compress the cloth in length or breadth at will. After milling scouring follows to clear the cloth thoroughly of the milling agents previous to the finishing proper. The cloth is now taken in a damp state to the tentering machine and, being hooked upon a frame running into a heated chamber, is stretched in width and dried in this condition. Raising follows, this being effected by subjecting the surface of the fabric to the action of "teazles" fixed on a large revolving cylinder, the whole machine being termed a "gig." After raising the fabric is "cropped" by being passed over a blade near which revolving knives work, on the principle of a lawn-mower, shearing and levelling the piece. Sometimes fabrics are raised wet, especially if a velvet finish is required. Brushing follows to clear the piece of all stray fibres. The fabric is now ready for "crabbing," which consists in winding it tightly on to a perforated roller through which steam may be blown or upon which the piece may be boiled. The pieces are then rewound and the operation repeated at least once, to obtain even distribution of finish. Being now ready for pressing, the fabric is cuttled, usually with press papers between each cuttle, and placed in the hydraulic

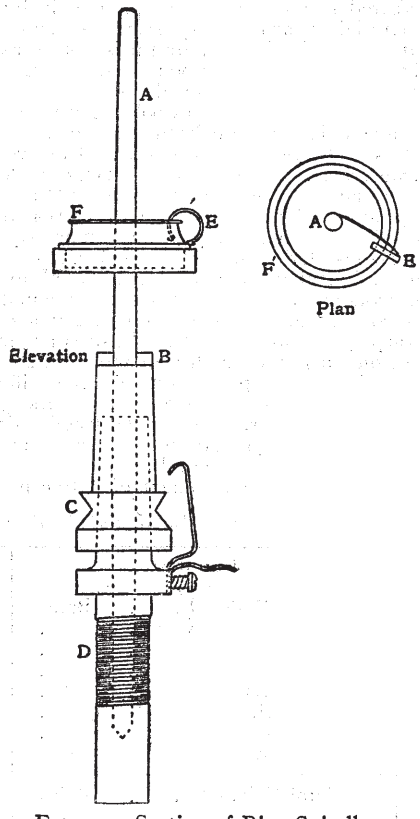

FIG. 19.—Section of Ring Spindle.

A is the spindle suitably shaped to receive the bobbin at B, with a wharl for turning at C, running in the specially designed receptacle D, which may be screwed firmly into the spindle rail. The traveller E is drawn round the ring F by the spindle acting through the yarn as shown in the plan. The spindle is a fixture and the ring-rail is traversed to distribute the yarn on the bobbin.

press either hot or cold. After pressing dry steaming is frequently necessary to take away cakiness and a certain false lustre which sometimes develops. Final cuttling completes the finishing operations.

Worsted cloth finishing.

Worsted cloth finishing is very similar to woollen cloth finishing save that some of the operations are less severe. Mending, scouring, milling and tentering are similar. The raising as a rule is effected by brushing, although it is by no means uncommon to raise worsteds on the gig. Cropping, crabbing, pressing and steaming are the same as for woollen fabrics. Of course the real difference between the woollen and the worsted cloth is due to the selection of the right material, to correct roving, spinning and fabric structure: finishing simply comes as a "developer" in the case of the woollen fabric, while in the case of the typical worsted fabric it simply serves as a "clearer," the cloth really being made in the loom. A woollen cloth as it leaves the loom is unsightly and in a sense may be said to be made in the finishing, although it is truer to say "developed" in the finishing: in the case of the worsted cloth it is altogether otherwise.

Lustre finishing.

A cotton warp, lustre weft style, is treated altogether differently from either of the foregoing. It is first crabbed, then steamed, then scoured and dried, then singed by being passed over a red-hot copper plate or through gas jets, then scoured again, and if necessary dyed. It is then washed, dried, then tentered and finally pressed. Of course these operations are applied with discrimination to the varied styles of goods made in the Bradford district. Thus, for instance, the finishing of an "Italian" may be considerably varied from the foregoing, being more complex, while other styles, such as plain all-wool goods, are treated very simply.

Varieties of woollens and worsteds.

It will be gathered from the foregoing remarks that the varieties of wool textures are many and very different in character. This is perhaps realized best by contrasting a heavy melton cloth weighing say 24–30 oz. per yard with a fine mohair texture weighing say 2–3 oz. per yard. None the less remarkable is the difference in appearance of varieties of wool textures. A rough Harris tweed, for example, contrasts strangely with a smooth fine wool Italian. Of course these differences are not created in any one process or merely by the selection of the raw material or yarn. Every process of manufacture must be directed to attain the desired end, and it is well to realize that huge businesses have been built up upon what, by the outsider, would only be regarded as unimportant details.

The principal styles of woollen cloth are tweeds, meltons, Venetians, beavers, doeskins, buckskins, cassimeres and diagonals. The largest class is the tweed, as this ranges from very expensive coatings and trouserings to the cheap styles made of the re-manufactured materials. Tweeds for ladies' wear also form a large class.

The principal styles of worsted cloths are coatings and trouserings, delaines, voiles, merinos, cashmeres, lastings, crêpe-de-chines, amazons, Orleans, lustres of various types (plain and figured), alpacas, Italians, moreens, &c., &c. Many of these are made entirely of worsted yarns, but others are compound so far as material or yarn is concerned. Thus amazons are made from mule-spun worsted warp and a woollen weft. Lustres are made from fine hard spun cotton warp and English or mohair weft, and so on. Perhaps the most interesting point to note is the skill developed by English designers during recent years. Fifty years ago the continental designer ruled the market. To-day the English designer can at least claim an equality with and in some respects is already considered as superior to his continental rival.

Wool tops, yarns and fabrics.

Prior to the development of native ingenuity and skill England was remarkable as a wool-growing country, most of the wool being shipped to the continent, so that it may be said that the wool of England met the skill of southern Europe in Flanders, which thus became the great textile centre so far as wool was concerned. With the development of native skill under the fostering care of several of the English monarchs—notably Edward III. and James I.—it was but natural to expect that endeavours would be made to manufacture English wool at home and export the woven cloth. With the remarkable colonial developments of the 17th, 18th and 19th centuries, in conjunction with the invention of the spinning frame and power-loom, this expectation was most fully realized, at least so far as ordinary wearing fabrics were concerned. Latterly, however, with the development of skill in newly developed countries, the tendency has been to partially revert to the old conditions. Thus in 1850 Bradford's chief export was cloth, in 1875 the yarn trade had markedly developed, in 1900 the top trade was well established, and to-day Bradford has a large wool export trade. Fabrics are made for the home and general export trade; yarns are exported mostly to the continent; tops and wool mostly to the United States of America.

Statistics.

The following tables give a useful idea of (*a*) the sources of supply of the raw material, wool, also of the changes which have taken place in the trade since 1800; (*b*) the changes in monetary value of the chief sorts of wool during recent years; (*c*) the number of factories and of persons employed in the textile industries during the past half-century; (*d*) growth of the export trade in woollens and worsteds of the United Kingdom during the past century. For further details see Hooper's admirable tables now issued by the Bradford Chamber of Commerce.

Centres of industry.

Prior to the development of the factory system and the remarkable development in textile appliances at the end of the 18th and beginning of the 19th centuries, the textile industries were scattered all over the country, only in some few cases more or less accidental centralizing occurring. To-day it may be said that the wool industry is centralized where the coal supply of south Yorkshire meets the wool supply of north Yorkshire, *i.e.* in the Bradford and Leeds districts, though much of the wool dealt with in this district is imported and consequently can only be said to follow the trend already established. Of course there are wool manufacturing districts other than those mentioned. Scotland is noted for its Scotch tweeds manufactured in the Hawick and Galashiels district, the West of England still makes some magnificent all-wool cloths; Norwich guards a remnant of its once flourishing worsted industry and Leicester has developed a remarkable hosiery trade. Again, firms whose existence is due to individual enterprise are still studded up and down the country, and manage to compete fairly well with the main manufacturing districts. Since about 1856, however, there can be no doubt that the English wool trade has been centring more and more round Bradford, while the remanufactured materials and the blanket trade is centred round Batley and Dewsbury. Wales retains only a fragment of its once large flannel trade, this trade now being located in Yorkshire, with the exception of one or two individual firms elsewhere. The carpet trade is centred in Halifax, Kidderminster and Glasgow. Whether further centralization may be looked for is questionable. Specialization undoubtedly favours Bradford, as there the wool, top, yarn and fabric branches of the industry are individually developed to great advantage; but the development of means of communication and some such factor as electric or water power may radically disturb the present balance of the industry. (A. F. B.)

Imports of Wool into the United Kingdom from the Principal Countries, Foreign and Colonial.

Country.	1800.	1820.	1840.	1860.	1880.	1900.	1905.	1907.
New South Wales } Bales	..	..	..	..	..	248,408	240,922	308,628
Queensland }	658	213	25,820	46,092	224,777	124,401	148,959	130,128
Victorian	..	..	..	78,186	306,817	255,131	261,724	330,326
Tasmanian	..	180	11,721	16,731	23,653	18,225	13,770	22,147
South Australian	..	..	3,484	23,554	109,917	50,720	76,469	89,637
West Australian	..	..	..	1,992	9,211	26,317	44,623	41,467
New Zealand	..	..	..	17,870	189,441	395,693	394,390	442,973
Cape and Natal	..	29	3,477	55,711	190,614	102,268	192,210	259,691
Total Colonial . . Bales	658	422	44,502	240,136	1,054,430	1,221,163	1,327,167	1,624,997
East Indian and Persian	..	..	7,611	62,226	112,716	142,518	153,841	159,818
Chinese	..	..	..	119	1,672	4,151	7,284	15,060
German	1,170	14,609	63,278	19,681	28,119	9,126	6,636	11,533
Spanish	30,318	17,681	5,273	4,199	14,603	896	1,732	4,077
Portuguese	9,622	475	1,569	24,503	14,356	5,242	11,018	10,214
Russian	25	150	11,776	22,150	45,417	28,018	7,404	15,889
Turkish, Egyptian and North African	76	380	5,492	17,545	49,853	39,108	43,104	51,725
Peruvian and Chilean	..	25	40,004	69,068	52,876	70,423	55,163	53,493
Buenos Aires and Montevidean	..	..	..	5,058	9,852	22,077	52,839	70,348
Falkland Islands and Punta Arenas	..	..	..	..	4,700	28,784	34,903	53,249
Italian and Trieste	84	334	4,055	719	2,565	2,768	3,889	2,761
Sundry	487	1,479	2,519	15,172	35,973	37,150	46,485	43,176
Goat's Wool	..	..	..	11,915	57,449	69,445	101,712	109,077
Total Bales	42,440	35,555	186,079	492,491	1,484,581	1,680,869	1,853,177	2,225,417

Prices per lb *in each Year of some Colonial, Foreign and English Wools, also of Alpaca and Mohair.*

Material.	1874.[1]	1880.	1885.	1890.	1895.	1900.	1901.[2]	1902.[2]	1905.
	d.	d.	d.	d.	d.	d.	d.	d.	d.
Port Philip—Greasy	14 5/8	13 1/2	10	10 3/4	8 3/8	11 1/2	9 1/2	13	13 1/2
Adelaide—Greasy	11 1/2	10 5/8	6 3/4	7 1/2	5 5/8	7 7/8	6 3/8	8 1/2	9
Cape—Greasy	16 1/8	12 5/8	9	9 1/2	7	9 3/4	7	9 1/4	10 1/4
Buenos Aires—Greasy	7 1/2	7 1/2	4 1/2	5 3/4	4 3/8	4 1/4	4 5/8	5 3/4	6 3/8
British Wool	22	16 1/2	9 1/2	10	9 1/2	7 1/2	6 1/10	6	11 4/5
Alpaca	33-35	13-15 1/2	12 1/2-14 1/2	22-14 1/2	14 1/2-27	16-13	12 1/2-16	15 1/2-19 1/2	15 1/2-17 3/4
Mohair	35-45	27-35-21	14-19	18-13 1/2	14-30	20 1/2-17	19-17	15	13 3/4-16

[1] Year of the highest values of wools ever reached within recent times.
[2] Years of the lowest values of wools ever reached within recent times.

Summary of Woollen and Worsted Factories and of Persons employed in the same in the United Kingdom.

	1867.	1874.	1885.	1889.	1901.	1904.
Factories	2,649	2,617	2,751	2,517	..	2,382
Rag grinding machines	..	..	..	..	..	900
Woollen carding sets	..	..	..	..	..	6,700
Worsted combing machines	1,038	1,276	..	..	..	2,924
Spinning spindles	6,455,879	5,449,495	5,375,102	5,604,535	..	5,625,477
Doubling spindles	519,629	558,914	769,492	969,812	..	1,059,049
Power looms	118,875	140,274	139,902	131,506	..	104,514
Children (half timers)	33,054	38,416	24,636	22,940	7,475	..
Persons working full time—						
Males	94,838	106,005	112,935	120,441	102,876	..
Females	134,368	135,712	145,684	158,175	149,558	..

Summary of Exports of Wool, Wool Waste, Noils, Tops, Yarns and Fabrics from the United Kingdom.

	1840.	1882.	1890.	1900.	1907.
	lb	lb	lb	lb	lb
British Wool	5,000,000	13,800,000	19,500,000	24,900,000	34,500,000
Foreign and Colonial	2,000,000	264,100,000	342,200,000	197,500,000	314,200,000
Waste	..	..	2,397,600	1,593,100	8,937,100
Noils	..	..	10,234,700	7,897,400	12,689,700
Tops	..	..	9,016,000	28,031,200	35,580,000
Worsted Yarn	..	29,840,300	39,510,100	56,075,900	55,521,700
Mohair, &c., Yarn	..	8,752,200	12,959,600	10,397,700	17,782,800
Woollen Yarn	..	1,992,400	1,572,700	1,088,300	2,576,100
Cloths	..	£18,768,634	£20,418,482	£15,682,154	£22,153,680
Apparel	..	£1,380,000	£1,700,000	£1,700,000	£2,550,546