

Wool and Woollen Manufactures [*wool* is O. Eng. *wull* : Ger. *wulle* : Goth. *wulla* ; cf. Lat. *lana*, Gr. *λίπος*, Lith. *vilna*, O. Bulg. *vilna*] : strictly, the covering or fleece of the sheep, and the processes by which it is converted into textile and other fabrics. The term wool, however, has been extended to include the hair of the angora, cashmere, and other goats, the hairy fleece of the alpaca, vicuña, and other species of the llama, the soft down from the belly of the camel, several kinds of fur which are spun and woven, and even cow's hair, which is made up into a cheap quality of woollen goods. Wool proper may be distinguished from all these varieties of hair, as well as from all vegetable fibers, by the corrugated character of its fibers and by its property of felting, which is due to the epithelial scales which overlap each other along the course of its fibers, and which, under certain conditions, from their corrugation, interlock with

each other and form a felted fabric. (See FELT.) The average number of these epithelial scales or serrations per linear inch varies greatly in different breeds of wool. The larger numbers improve the elasticity and the felting property in like proportion. East India wool has 1,000 scales per inch; common domestic, 1,400; Leicester, 1,400; merino, 2,000; Saxony, 2,200. The average size of the fiber varies, and almost inversely to the above proportion. East India measures $\frac{7}{1000}$ th of an inch; common domestic, $\frac{11}{1000}$ th; merino, $\frac{13}{1000}$ th; Saxony, $\frac{20}{1000}$ th. Hair possesses very little of this felting property, but by long beating and rubbing develops it to some extent. The primitive sheep was covered with long hair, the rudiments of the present fleece being an undercovering or down. This hair was bred out, and the wool was left. If sheep are neglected now, or become very old, they will revert to this habit by growing hairs among their wool. Sheep formed a large part of the wealth of the Oriental nations, particularly of those which were more or less nomadic in their habits; and as these were kept very largely for food, though shorn every year, it is remarkable that in the absence of any special efforts to improve the character of their wool it should have retained its good qualities to such an extent as to enable those nations with their rude processes to have produced fabrics of such delicate and exquisitely fine texture as issued from their looms.

The first attempts to improve the breeds of sheep with special reference to the production of a finer quality of wool were made by the Romans about the second century B. C. Their Tarrentine sheep produced a long and finely stapled wool, and their fleeces were very heavy, but the color was either brown or black, and the sheep was so delicate in constitution that they were reared with difficulty, and were kept covered even in the mild climate of Italy. Columella relates in his *De re rustica* that his uncle, Marcus Columella, who was a wealthy agriculturist in Spain, transported some white African rams of great size and beauty to his estate in Batica, and by continually crossing them with his Tarrentine ewes and their progeny succeeded in producing a breed of white fine-wooled sheep of vigorous and hardy constitution and yielding a heavy fleece. This cross is supposed by many to have been the original of the Spanish merino sheep, which, with its various modifications and crossings, has been the parent of most of the fine-wooled sheep of Europe and America. It was renewed by Pedro IV. of Castile in the middle of the fourteenth century, and probably from Africa, and again with Barbary rams in the sixteenth century by Cardinal Ximenez. Its transportation to France and careful improvement there have led to the production of the French merino, one of the finest of the long-wool breeds. Its introduction into Germany, and modification by crossing and by climatic influences, have produced the fine Saxon wools, adapted to the making of the best broadcloths; and the French sheep of Naz, which yields a more silky wool of great luster, though now a distinct breed, bears traces of its early merino origin. In the U. S. the Spanish merino, introduced by Delessert, Livingston, Col. Humphreys, and William Jarvis between 1801 and 1812, has exerted a wide influence, and, together with the Saxony sheep, the sheep of Naz, and the French merino, constitutes to this day the largest proportion of those flocks which are bred mainly for their wool. The Australian and Cape Colony wools are also largely indebted to the merino sheep for their good qualities. The greatly increased demand for mutton has led to the breeding of sheep which have larger food-producing value, and with which the wool is an incidental rather than the principal product. The Leicester, Cotswold, South Down, Hampshire Down, and Oxford Down among the English sheep are the best of this class, while the undistinguished breeds of South America have some of the same characteristics. The large flocks of the Western States and the Pacific coast are American merinos. These all yield a portion of medium and coarse wools, and while the best grades are valuable for the worsted manufacture, the coarser are equally in demand for carpets, friezes, and the lower grades of goods for men's wear.

Wool is divided primarily into pulled and clipped or fleece wools, the former being pulled by the roots from the pelt or skin of the dead animal, and the latter clipped or shorn from the living one. The clipped or fleece wools form the greater part of the wool in market, and these are again divided into long and short staple, or combing and clothing wools. The clothing wools are used mainly for broadcloths and the thicker woolen cloths; the finer combing wools for soft and thin fabrics for women's wear; the medium for

worsted goods, delaines, alpacas, mohairs, etc.; and the coarser for carpets, blankets, and coarse goods generally. The quantity of wool grown has increased very rapidly during the nineteenth century, especially in Europe, America, Australia, and Southern Africa. The increase in quantity in Europe and America has been largely due to improved methods of breeding and feeding the sheep, which caused them to mature earlier and to yield larger and more uniform fleeces. Horned Dorsets are the most prized for the production of hot-house or winter lambs. The increase in the consumption of wool in Great Britain has been enormous, and the production has increased. In 1801 the wool-clip of the United Kingdom amounted to 94,000,000 lb., and the imports of unmanufactured wool to 8,000,000 lb. more. In 1828 the production was about 112,000,000 lb., and the imports in round numbers 30,000,000. In 1873 the production was 165,000,000 lb., and the imports 324,000,000, of which 123,000,000 was re-exported. In 1883 the production was 128,000,000 lb., and the imports 508,000,000, of which 277,000,000 was re-exported. In 1892 the production was 153,000,000 lb., and the imports 762,000,000, of which 332,000,000 was re-exported. Large quantities of shoddy, wool extract, and mungo were also consumed. The wool production of France has increased almost as rapidly as that of Great Britain, though mainly in the finer descriptions of wool; but it is now decreasing. France imports also considerable quantities of fine wools from other countries. The Australian colony of New South Wales alone exported in 1893 344,982,876 lb. of wool. Australasia produces the best wool in the world for fine combing purposes. In the U. S. the demands for wool for home manufactures have immensely increased the production, while the amount imported was nearly 55,000,000 lb. in 1875, 67,768,778 lb. in 1885, and 172,435,838 lb. for the year ending June 30, 1893. Importation consists of the merino wools of Australia, the Leicester and other combing wools of high luster for worsted goods, from Canada and Great Britain, and the coarse long-stapled wools from Asia, Russia, and South America for carpets, etc. In 1810 the wool produced in the U. S. was estimated at 13,000,000 lb.; 1886, 264,000,000 lb.; 1890, 309,474,856 lb.; 1891, 307,101,507 lb. These figures are those of James Lynch, continued by Mr. Truitt. In 1840 the average weight of the fleece, as estimated by the Department of Agriculture, was 1.9 lb.; 1850, 2.4 lb.; 1860, 2.7 lb.; 1870, 3.5 lb.; 1880, 4.8 lb.; 1891, 5.5 lb. The scoured wool produced by the growth of 1891 was rated at 139,326,703 lb. The Department of Agriculture estimated the growth for 1891 at 285,000,000 lb.; the imports at 129,303,648 lb.; total consumption after deducting exports, 411,373,603 lb. The percentage of imports was 30.2 per cent., and in 1890 it was 27.6 per cent. The percentage has varied from 21.7 per cent. in 1840 to 44.9 per cent. in 1872, the highest point ever reached. It dropped to 15.6 per cent. in 1879, the lowest point. It was 29.9 per cent. in 1886. The consumption of wool *per capita* in the U. S. was 4.49 lb. in 1840. It increased steadily, and was 8.52 lb. in 1880 and 9.07 lb. in 1890. The world's supply was 955,000,000 lb. in 1860 and 2,456,773,600 lb. in 1890. The latter quantity was distributed as follows:

United Kingdom.....	147,475,000 lb.
Continent of Europe.....	639,917,000 "
North America.....	319,100,000 "
Australasia.....	550,000,000 "
Southern Africa.....	128,681,600 "
River Plate country.....	376,700,000 "
Other countries.....	294,900,000 "
	2,456,773,600 lb.

The principal European markets for wool are at London and Antwerp. At London periodical auction sales of British colonial wools are held, and are attended by buyers from all manufacturing countries. At Antwerp the bulk of the wools from the important River Plate country is disposed of.

Woolen Manufactures.—The manufacture of wool into fabrics for clothing is one of the oldest industries. At a very early date the primitive man, or rather the primitive woman, discovered that the coarse wool of the sheep, the first of domesticated animals, could be spun into long threads, woven, and then, by rubbing with clay and beating in water, thickened or fullled till it furnished a satisfactory substitute for the pelts of the sheep, which had till then formed the clothing of man. From these rude garments the transition to those of finer and more skillful workmanship, such, for instance, as are shown on ancient Egyptian monuments, was gradual, and must have required long periods of development. The production of dyed garments, of shawls, and

of carpets, often of elaborate patterns and requiring protracted labor, was attempted at a very early period, and the manufacture of tent and curtain cloths, of tapestry hangings embroidered with needlework, and of those vestments of lamb's wool and the rich imperial robes of Tyrian purple came somewhat later. Some of the Persian, Greek, and Roman cloths, robes, and shawls must have been very beautiful; but in the ages which followed the downfall of the Western Roman empire the art of manufacturing them, like most of the fine arts, was nearly lost; the says and serges of the Middle Ages were made from coarse and harsh wools. The rough friezes, made of still coarser wool in Friesland, were still more objectionable, and the manufacture, such as it was, existed mainly in Florence, in Flanders, in England, and in France. After the thirteenth or fourteenth century silks, satins, and velvets became the favorite and distinguishing clothing of the wealthy. Until after the period of the Reformation the manufacture of woolen goods was almost entirely domestic; the large spinning-wheel and the reel had indeed taken the place of the distaff; and the hand-loom, gradually improved, of the rude contrivances of the Oriental weavers. Among the thousands engaged in this domestic manufacture, some possessed greater manual skill and higher ingenuity than others, and consequently their cloths were more in demand; and the assembling of their looms and spinning-wheels in a single building gave them some advantages. The dyeing and fulling of the cloths was a separate business, and for this a water-power was required, and so fulling-mills sprang up wherever there were considerable quantities of cloths made. The use of the teasel for combing out a nap on the fulling cloths dates from an unknown antiquity. There were frauds in those days—stretching of the goods and the extravagant use of flocks. *Flocks* are shorn fibers or the nap cut from the face of one piece of cloth, then fulling into the back of another piece. If judiciously used, they improve the fabric, as they not only increase the bulk, but retard the whole felting process, and thus render the cloth firmer. From the end of the thirteenth to the end of the seventeenth century this domestic manufacture of worsteds, baizes, kerseys, serges, friezes, broadcloths, and other cloths was carried on very extensively in England, and considerable quantities of each were exported. The English cloths were mainly of coarse qualities, and inferior to some of those made on the Continent, the Spanish and Flemish fine wools enabling them to make finer and more desirable goods. In the eighteenth century the manufacture of both worsteds and woolens began to be concentrated in Yorkshire, and Leeds, Stroud, Chippenham, and Huddersfield gradually became the seats of the woolen goods manufacture; while Bradford, Halifax, Norwich, and their vicinities absorbed the manufacture of worsted goods and carpets. But, though large quantities of goods were made and sold, their quality was far from uniform, and there was no improvement in the processes of manufacture until the invention of the carding-machine, which first came into use for wool in England about 1753, and the SPINNING-JENNY (*q. v.*). The gradual introduction of these machines, and the application of steam both as a motor and for dyeing and dressing purposes, greatly improved the character of the English and French cloths, but until the introduction of the power-loom (which, though invented in 1785, did not come into general use till about 1800) and the Jacquard loom (invented in 1811), the woolen and worsted manufactures had not received their greatest impulse in Great Britain. The French manufacturers were moving meanwhile in a somewhat different direction. With their fine and soft wools they directed their attention very largely to the production of fabrics for women's wear, and with their admirable taste and delicacy of workmanship soon achieved great success. The French merino goods, introduced by Pallotat at Rheims in 1801, have never been surpassed by any all-wool product in softness, durability, and beauty. Other goods, both of wool and worsted, pure and in combination with silk, cotton, and linen, have been produced in vast quantities in England and France. The broadcloths of the highest grade made in France are of better quality than any others, except some of the west of England goods; but the practice of adulterating these, as well as cassimeres, satinets, and indeed almost every description of the heavier wool goods, with shoddy or the ground and picked fibers of old woolen rags, first undertaken in 1813 at Batley, England, but not largely used till 1840, has done much to impair the value and durability of the lower and medium priced goods. This practice has

been carried to a greater excess in Great Britain and Belgium than elsewhere. The modern *shoddy* is fiber of yarns or threads picked and broken into the semblance of wool. *Mungo* is the fiber of felted rags thus picked. Both these articles, being mixed with wool, are carded and spun; they are never fulled or carried into the fabric like flocks.

In the U. S. the manufacture of woolen goods was almost entirely domestic as late as 1790, and though there had been fulling-mills from the first settlement of the colonies, there was no woolen-factory in successful operation before 1794, when one was established in Byfield parish, Newbury, Mass. An attempt had been made at Hartford in 1788. In 1794 the first carding-machine for wool was put in operation in Pittsfield, Mass. Between that time and 1801 four or five were started. Gray-mixed broadcloth of good quality was made at Pittsfield in 1804, and President Madison's inaugural suit of black broadcloth was made there in 1808. In 1809 a woolen-mill was erected by Dr. Capron at Oriskany, Oneida co., N. Y., and in 1812 what was then considered a large manufactory of fine cloths was established at Middletown, Conn., which made 30 or 40 yards of broadcloth a day. In the same year were produced what are known as the helicoidal shears, a cutting-machine with spiral blades on a cylinder acting against a straight steel blade, and shearing the nap of the cloth evenly and perfectly. This was first adopted in France. To the inventors of the U. S. the world is indebted for the original and best processes for making felted goods, carpetings, hat-bodies, etc.; the knitting-frame, and later the various knitting-machines, the burring-machine, the Crompton and Knowles power-loom for weaving fancy cassimeres, which, with their successive improvements, are now far superior to any other loom for this purpose; the still more wonderful automatic Bigelow carpet-loom; the best processes for making a mixed mousseline delaine; Crompton's improvement of Noble's wool-comb; and the Smith moquette carpet-loom. The woolen-manufacturers in the U. S. have had great difficulties to contend with. In addition to the high price of labor as compared with European countries, and the lack for many years of native wool of those qualities best adapted to their use, they have been unduly affected by high and low tariffs, and their goods systematically depreciated by the importers and free-traders; but they have at length reached a position in which they can supply more than three-fourths of the woolen and worsted goods consumed at home, and, except in a few classes of goods, produce those of quality equal to those of their European rivals.

From 1790 to 1810 there was a large domestic manufacture in proportion to the population, and the greater part of the men and all the boys were clothed in homespun, while the women wore for everyday use linsey-woolsey, a fabric composed of linen and wool. In 1810 the value of this domestic manufacture was estimated at \$25,608,788. But after this date the domestic production fell off rapidly, and at first the factory-made goods did not supply their place. In 1820 the total value of woolen goods reported was \$4,413,068; in 1830, \$14,528,166; in 1840, \$20,696,999; in 1850, \$49,636,881; in 1860, \$80,734,060; in 1870, \$217,668,826. In 1876, owing to the depression of business, there was a slight falling off in production, and a still larger one in importation. The value of the woolen goods produced in 1880 was \$267,252,913; in 1890 it had risen to \$337,768,524, of which \$137,930,014 was in woolen goods proper, \$72,194,642 in worsted goods, \$8,958,205 in felted goods and hats, \$39,769,441 in carpets, and \$55,457,642 in hosiery and knit goods. Massachusetts has from the first maintained the leading position in these manufactures, her production of all-wool goods, carpetings, worsted, and mixed goods of cotton, linen, or silk and wool, amounting in 1890 to \$72,681,408, or more than one-fourth of the whole production of the country. Pennsylvania, New York, Connecticut, and Rhode Island are the other largest producers, though nearly every State has some woolen manufactures. The value of importations in 1821 was \$7,238,954; in 1831, \$13,197,364; in 1840, \$10,808,485; in 1850, \$19,620,619; in 1860, \$43,141,988; in 1870, \$37,064,001; in 1880, \$35,356,992; in 1890, \$56,582,432; in 1891, \$41,060,080.

Processes.—The variety of goods wholly or in part made of wool, and of those wholly or in part of worsted, is so great that the processes to which each is subjected in its manufacture can only be named in the most general way. The distinction between the woolen and worsted goods begins in the character of the wool used; for all heavy wool goods a more or less fine, short-stapled, and readily felting

wool is required; for goods wholly or in part of worsted the wool must be strong in fiber, of long staple (fibers 2½ to 5 or 6 inches in length, although shorter wool can be combed), not very fine, and either naturally or by the combing process freed from the noil or short fiber, which is afterward mixed with wool, carded, and spun for felted goods. The wool, which is usually purchased in bales, is first sorted and scoured. The sorter arranges the parts of each fleece according to fineness, length of staple, and silkiness of texture; and the scouring is accomplished by throwing the wool into large tanks filled with water and an abundance of soap, keeping it at a high temperature by means of steam, and continually moving it by means of rakes or stirring-sticks driven by machinery. When thoroughly cleansed it is drawn out through rollers to squeeze out the water, and then dried by revolving fans or other means. By this scouring and washing not only is the dirt and soil removed from the fleeces, but the yolk or suint—a peculiar fatty secretion of the sheep most abundant in the merino breeds—is also discharged. The British manufacturers extract these matters from the water by a chemical process, and make *dé-gras*, a low form of grease, from the product. Similar processes for extracting the fat are now being introduced into the U. S. The wool is next dyed (if it is necessary to dye it in the wool). The next process is wilying, or, in the case of Western and South American wools, burring. The object of this is to remove seeds and burs which have become entangled in the wool. The American burring-machines of various kinds do this very perfectly and in combination with the carding-machine. Picking, teasing, or moating is the next process, and is performed by a machine which tears open the matted portions and separates the wool into small tufts. Either before or immediately after this process the wool is oiled, oleic acid or olein being now generally used for this purpose, instead of olive oil, and sometimes a mixture of olein and paraffin oil; these oils are much more readily removed from the yarn or tissues by a brief scouring with carbonate of soda and pure water than the olive oil, and there is much less danger of spontaneous combustion than from the use of the vegetable oils. The wool is now ready for the carding and slubbing processes, which, though formerly separate, are now continuous by the use of a patent feeder and condenser. Their office is to convert the wool into rolls, which are drawn out before they are spun. The spinning is the next process, and herein is another difference between woollen and worsted yarns, the yarns for woollen cloths being but slightly twisted, so as to leave them more free for felting, but those for the warp twisted more than those for the weft, as they have to bear more strain; while the worsted yarns are hard-spun and made into a much stronger thread. The slight twisting and comparative lack of strength in woollen yarn renders it more difficult to weave it on a power-loom than the worsted, cotton, silk, or linen yarns. The yarn, when spun, is reeled, and, if to be made into cloth, warped, beamed, sized, and otherwise prepared for weaving. The weaving is generally done on an ordinary power-loom for broadcloths, flannels, cassimeres, satinets, blankets, etc.; on a Crompton chain-loom for fancy cassimeres, yarns of different colors being introduced; or on the Barnshaw needle-loom, where the goods are made with two faces or different colors are used. Broadcloths, and indeed most woollen goods, are next scoured to remove the oil, and then, if thought necessary, dyed again, and tentered or stretched upon hooks to dry. Burling, or picking off irregular threads, hairs, and dirt, succeeds this, and then, for the cloths, come the fulling process and the teasing or raising the nap, which is sheared evenly by the helicoidal shears. It is next steamed or scalded to prevent its spotting unevenly from the rain, and pressed between polished iron plates in a powerful hydraulic press, or, as is more common now, in a rotary or calendaring press. The flannels, blankets, etc., do not go through these last processes. The knit goods are made from the yarn on knitting-machines, and finished by hand. Delaines have usually cotton warp, and are woven on cotton looms, and printed, like calicoes, from rollers. Merinos, Tibets, empress and Henrietta cloths, alpacas, with many other kinds of dress goods, are made from worsted yarns. Carpets are made from coarser wools, and do not go through so many preliminary processes before spinning; they are woven on the Bigelow carpet-looms, or some modification of them. The worsted wools are combed on a combing-machine with teeth heated by indirect application of steam, to make the fibers straight and

parallel, and the noil or shorter fiber is combed out. The other processes before the spinning are much the same as already described. But the spinning of worsted and woollen yarns is entirely different. Woollen is drawn finer by the draft of the mule carriage after the roving passes through rollers. Worsteds is drawn between rollers as a cotton thread. The front pair of rollers runs faster than the back pair, and thus the size is reduced. Then the thread is twisted by the revolutions of the spindle. The yarns are hard-twisted, and for some purposes, as for alpacas, mohairs, and lustered goods, the lustered wools and the hair or wool or the alpaca and vicuna and of the angora goat are used. The weaving and dyeing of these goods are watched with great care. The cow's hair, camel's hair, and calf's hair goods are of cheaper grades, and in quality belong rather to the woollen than the worsted trade. Most of them contain a considerable proportion of the lower grades of wool, woollen waste, and shoddy.

Revised by W. B. WARDEN.