

WOOL AND WORSTED MANUFACTURES. The development of the art of spinning and weaving took place so early in the history of civilization that no records of its beginning are preserved, and which of the textile fibres was used first for this purpose is unknown. But certainly the art of producing woven woolen fabrics was practiced by many different peoples at a very early period. At the time of Alexander's expedition to India the natives of that region wore shawls of great beauty. The Greeks learned many processes of woolen manufacture from the Egyptians; the Romans from the Greeks; and from the Romans the knowledge generally passed to the Occidental world. Among the ancients, the method of manufacture was, after thoroughly cleansing the wool, to sort, card, and spin the material by hand. The loom for the weaving was remarkably simple, even crude, but under the delicate manipulation of dexterous fingers, skilled operators produced fabrics that have never been excelled in fineness of texture or delicacy of construction, even at this later day. (See WEAVING and LOOM.) Woolen garments were worn by the Romans at a very early period. It is probable that the early lessons the ancient Britons received in the art were derived immediately after the Roman conquest, and woolen manufacture as carried on in England was at the outset but a repetition, and afterward an elaboration and improvement on the methods previously known. It is generally supposed that certain Flemish weavers went to England in the time of William the Conqueror, and obtaining the royal patronage, established the first manufactories of woolen goods. At various periods in the reigns of succeeding monarchs, other Flemish weavers were imported, and established at different points in the kingdom. Henry II established guilds of weavers in his reign, and the exclusive privilege of exporting woolen cloth was by him granted to the city of London. In the thirteenth century Spain produced her own cloth, and the beauty of her fabrics was celebrated far and wide. Italy followed, and for a time employed processes apparently superior to any others in use.

For many centuries the manufacture of wool was carried on as a household industry, although in occasional instances a large number of looms were gathered together under one roof and their products controlled by a single individual, as in the modern factory. The fulling of the woven fabrics was at an early date developed into a separate business, and here and there on convenient water powers fulling mills sprang up. The use of the teasel burr for raising the nap on the fullled fabric was of early origin. The distinction between ordinary woolen fabrics and worsteds made from combed wool is mentioned in the earliest records of European wool manufacture. The combing of the wool was done by hand till well into the nineteenth century and the wool combers formed an important industrial class, but it was not till the latter half of the nineteenth century that all the processes connected with the production of a woolen or worsted thread were grouped together in one establishment.

History of the Wool Industry in the

United States. In the United States, as in Europe, the development of the textile mill began with the introduction of the neighborhood fulling mill. Next came the public carding mill, where the wool was converted into rolls ready for the spinning wheel. Previous to its introduction carding had been done by a couple of hand cards, which were small, oblong boards, covered with leather filled with points of fine wire. By manipulating the wool between these teeth the fibre was opened up. (See **CARDING**.) The first wool-carding machine was put in operation in Pittsfield, Mass., in 1790. The same year, at Newbury, Mass., the first successful woolen mill was put in operation. By 1810 several woolen mills were in operation and the amount of homespun was appreciably lessening, and the value of woolen cloth annually produced as a household industry declined so rapidly that not enough cloth was produced in the factories to make up the deficiency, and large quantities were imported. The value of the factory output from 1820 to 1850 was as follows: In 1820, \$4,413,068; in 1830, \$14,528,166; in 1840, \$20,696,999; in 1850, \$49,636,881. The value of imported woolen goods was: In 1821, \$7,238,954; in 1831, \$13,197,364; in 1840, \$10,808,485; in 1850, \$19,620,619. By the close of the first half of the nineteenth century all the great improvements which had been invented in textile machinery had been adapted to the woolen industry, and during the last half of the century the development of the industry, except as disturbed by war or other political condition, was more steady and natural. The invention of the Crompton loom in 1837 and its successive improvements were of immense importance to the woolen industry. In 1873 the open shed fancy cassimere loom of L. J. Knowles enlarged still more the field of weaving possibilities and facilitated the manufacture of many refractory patterns. Since 1865 automatic wool-scouring machines have been introduced, taking the place of hand washing, and during the same period the carbonizing process of freeing wool from vegetable fibre, such as cotton, to procure a grade of shoddy, has come into use. The art of dyeing also advanced. In the United States the woolen industry has been subject to great fluctuations, due to political events, such as the Civil War, which suddenly created an enormous demand for a certain class of woolen goods, and to tariff legislation. Statistics showing the present status of the industry are given at the close of the article.

Structure of the Wool Fibre. The wool of the sheep differs from all other fibres, animal or vegetable, on account of its great felting power. (See **WOOL**.) This is due to its overlapping epidermal scales, which make the individual hairs, when brought in contact at an angle, tend to mat together. Another striking characteristic of wool is the curliness of the fibre. The transformation of wool into cloth is divided into two distinct branches: the manufacture of woollens and the manufacture of worsteds. In making woolen fabrics or cloths the natural characteristics of the fibre—its curliness and felting power—are developed by the manufacturing processes and produce a soft cloth with a nap and with the fibres so matted together that the weave is but slightly visible. In worsted manufacture the aim is to produce a smooth, wiry yarn, more like that of the other textile fibres, and to this end the fibres are straightened, twisted hard, and the shorter projecting

ones which would form a nap combed out. This produces a cloth in which the weave is evident and great variety of design in weaving is possible.

After being sorted, the wool is subjected to a process of beating, not only for the purpose of eliminating the dust and other impurities, but the procedure has the effect of disposing the staple to open and thus render the material softer and less resisting when washed and worked over in the various machines. The wool must be thoroughly dry, else many difficulties will be encountered. If the beating process be well carried out, it will not only dispose of many impurities, but will invariably treble and quadruple the volume of the fibre.

Scouring. The washing received by the live sheep before the removal of the fleece is not enough for the purposes of the manufacturer. There is a subsequent cleansing which could by no possibility be given while the material was a part of the animal. The necessity of thorough scouring is due not only to the dirt adhering to the wool, but also to the natural secretion of the oil and sweat glands, called yolk or suint, which is in the wool. This oily substance is usually reclaimed from the wash water and sold under the commercial name of degreas. From it lanolin and potassium salts are extracted. Soft water is required for washing, because the insoluble lime soap formed in dissolving soap in hard water is deposited on the wool fibre and becomes inextricably entangled. Wool washed with hard water is always harsh to the touch; it takes dyes unevenly and is not readily cleansed. Wool is scoured with a dilute soap solution, with or without soda or potash according to the kind of wool, and heated not above 120° F. The wool is passed by machinery from one tub to another, in each of which the cleansing operation is carried a step further until it emerges from the last tub, clean. It is dried in automatic driers, having been first dyed or bleached.

The wool having been dried is still found to retain many objectionable features that are not disposed of in the previous manipulations. These are bunches, matted locks, dust, sand, and other impurities, all of which must be removed before the article can go towards final manufacture. The process of removing these objectionable features is termed willowing or willeying (the latter term being given in honor of the inventor, Willey). It is accomplished by a machine consisting of a large drum and three small cylinders mounted on an inclosed frame. Powerful hooked teeth are geared on a drum which rotates with great rapidity, and the matted sections of wool, being fed into the drum, pass on to the spikes of the lesser cylinders; the matted locks are gently torn asunder, and the whole wool is delivered in a light, free, and disentangled condition. In various of the South American products there is a difficulty which requires additional care. There are little burrs and small adherent seeds which insist on remaining in the wool, no matter what the processes previously described may have accomplished. One method of eliminating them is chemical; another mechanical. In the chemical process, technically known as carbonization, the organic matter in the wool is decomposed by the use of chloride of aluminium, chloride of magnesium, weak sulphuric acid, or acid vapor, after which it is subjected to a baking process. The wool is now cooled and the carbon dusted out. Finally it is washed in a strong soda solution to remove the acids. This process is now

used not only to remove the vegetable matter from new wool, but also the cotton from the union shoddy. The operation of burring is sometimes performed by mechanical burr pickers, which crush the brittle burrs under powerful, closely set rollers, without injury to the more elastic and flexible wool. The pieces are then shaken out.

Mixing. This is an operation of great importance designed to secure uniform quality of yarn. It is accomplished by spreading the wool from different lots or from two or more qualities or colors into as many thin layers as possible, one on top of another. The greater the amount of wool mixed and the more thorough the mixing, the better will be the quality of the cloth produced. If other materials are to be added to the wool, as silk, cotton, or shoddy, the blending of these with the wool is performed at this stage.

Oiling. The wool having been thoroughly cleansed is more or less harsh and wiry to the touch, owing to the removal of its natural lubricant, the yolk. To restore its natural pliancy it is, while being mixed, slightly oiled, either by hand or machine. Oiling also imparts a certain adhesiveness to the fibres, useful in the subsequent operations. The lubricant usually employed is olive oil or emulsions of mineral oil.

Difference between Woolen and Worsted Process. The preliminary operations thus far described are common to both woolen and worsted manufacture. But at this point the two branches separate. In making woolen yarn the wool is simply carded and loosely spun; in making worsted thread the wool is combed and the thread is twisted until it becomes very hard. The aim in making a woolen thread is to criss-cross the fibres; in a worsted thread, to lay them parallel. In making woolen goods a short-stapled wool may be used and a fibre having good felting qualities is preferred. The opposite characteristics are sought in wool to be used in the manufacture of worsted. During the process of combing, described later on, the short fibres, known as *noils*, are pulled out and cast aside to be utilized in the woolen mill.

Returning to the process of woolen as distinguished from worsted manufacture, the wool, now oiled and thoroughly mixed, is next passed through a wool picker, the object of which is to loosen up the fibres. The wool is then passed through a series of carding machines similar to those used in the manufacture of cotton. See COTTON and SPINNING.

Carding. This process produces a thread whose fibres lie loosely projecting from the main thread in little ends which form the nap of the finished cloth. The condensing machine is attached to the cards, and its object, as the name implies, is to condense or reduce into compact slivers the sheet of fibres delivered by the last main cylinder of the carding engine. The condensed fibre is simultaneously wound on spools, and is ready to be passed on to the spinning department, where it is converted into a finished thread ready to be woven into cloth. See SPINNING.

Worsted Manufacture. In making a worsted thread, if a comparatively short or medium staple fibre is used, the wool is first carded as in woolen manufacture. But if a very long staple wool is used, having a fibre 5 inches or more long, the wool is not carded at all, because the fibre would be broken by the cylinder engaging it before it was released from the preced-

ing cylinder. There is still a third class of worsted yarns, such as are required for carpet weaving, where a soft open thread is desired, which are not combed at all, but are carded, drawn, and spun. With the exception of this third class of worsted yarns, the first distinctive operation, after the wool has received the preliminary treatment already described, is gilling. The object of gilling is to level the fibres and make them parallel. The machine by which this is accomplished consists of a pair of rollers which catch the wool, and of a second pair of rollers, which draw it forward over heavy steel bars, called fallers, covered with projecting steel pins. The machines are generally used in sets, each successive machine having the pins on the rollers finer and more closely set than the preceding. The wool is fed to the rollers; it is caught by the rows of steel pins which rise in close and constant succession and penetrate the wool presented to them, traveling forward with it to the second pair of rollers, which in their turn catch the fibre and draw it away. The fallers are so called because when they accomplish their journey, they, through the agency of an endless screw mechanism, fall down, and by the action of other endless screws are returned to their original position. There is thus a continuous line of fallers traveling between the feed rollers and the back rollers, and there is a steady and constant drawing of wool away from the front rollers and through the teeth of the fallers. Five or six of these machines usually constitute a set. They are all constructed on the same principle, but with the pins finer and more closely studded as the fibre travels onward. In the first three machines it is usual to have the wool delivered in the form of a broad lap, but in the later machines, or gill boxes, as they are called, the product is condensed into a sliver and is received in large cylindrical cans. Six of these cans are brought to the front of the next gilling machine, and the six slivers are fed in, and passing through are drawn into and delivered as one. The operation is repeated three or four times, and the fibres are brought even with each other and a very level and uniform thread produced. It is usual to interpose a combing machine between the preparatory and the final gilling.

After the worsted has been gilled and combed it is put through drawing machines, much like those used in cotton spinning. It is then spun, the worsted thread being twisted much harder in spinning than woolen thread. The spun yarn is now reeled, warped, beamed, sized, and otherwise prepared for weaving.

For the process of weaving, the articles on WEAVING and LOOM should be consulted. The woven fabric requires several supplementary operations. The character and appearance of woolen fabrics are more altered by these finishing operations than any other material. Indeed, different fabrics may owe their distinctive peculiarities wholly to their finish, the processes of manipulation up to this point being exactly identical. In woolen goods, owing to the nap and its felting power, patterning is much less effective than in the weaving of worsted, but a greater variety of effects due to the character of the finish is possible. Among the principal varieties of finish of woolen goods are the dress-faced or doeskin finish, the velvet or erect pile finish, the Scotch or Melton finish, and the bare-faced finish. In the dress-face finish the nap

is raised and spread in one direction over the face of the cloth so as to hide completely the warp and weft threads. To this class belong broadcloths, beavers, and the other woolen fabrics having a nap. The velvet finish is another form of finish with a heavy nap. In overcoatings and similar materials the nap is formed in little curls on the outer surface of the goods. In other goods it is left standing out like velvet.

to give them solidity and strength. Tweeds have still less. The proper stage of beating or rolling having been reached, the soapsuds is gradually supplanted with pure water, tepid at first, but each new supply being cooler, until the fabric is finally worked in thoroughly pure and cold water.

On being taken from the machine the cloth is stretched uniformly in all directions by hooks

WOOL PRODUCED AND IMPORTED, DOMESTIC EXPORTS AND ANNUAL SUPPLY OF THE UNITED STATES, 1906 to 1915 *

YEARS	Domestic production, pounds	Imports, pounds	Total production and imports, pounds	Domestic and foreign exports, pounds	Net supply, pounds	Per cent of imports to supply
1906-07.....	298,715,130	203,847,545	502,562,675	3,446,748	499,115,927	40.8
1907-08.....	298,294,750	125,980,524	424,275,274	5,626,463	418,648,811	30.0
1908-09.....	311,138,321	266,409,304	577,547,625	3,523,975	574,023,650	46.4
1909-10.....	328,110,749	263,939,584	592,050,333	3,926,992	588,123,341	44.8
1910-11.....	321,362,750	137,647,641	459,010,391	8,205,699	450,804,692	30.5
1911-12.....	318,547,900	193,400,713	511,948,613	1,719,870	510,228,743	37.9
1912-13.....	304,043,400	195,293,255	499,336,655	4,423,161	494,913,494	39.4
1913-14.....	296,175,350	247,648,869	543,824,219	1,141,874	542,682,345	45.6
1914-15.....	290,192,000	308,083,429	598,275,429	15,418,234	528,405,985	58.3

* Estimate of the National Association of Wool Manufacturers.

In the bare-face finish the nap is sheared off completely. While the process of finishing the woven fabric differs according to the character of the desired finish, the general method is the same. The first step is known as fulling or milling. The operation of fulling or milling is to saturate the cloth with hot soap and water, when it is worked either by the fulling stocks or the fulling machine, or pressed and rubbed between rollers in the more modern milling machine. The more the cloth is soaked and beaten, the more it will shrink, and the operation can

on a frame, that it may dry without wrinkle or curl. At this stage the operation of giggering or teasing is entered upon. This is the raising of the pile or nap by the agency of the cone-like spikehead of the teasel, a plant of the genus *Dipsacus*. The head is covered with imbricated scales which end in sharp recurved hooks of great elasticity, but stiff enough to do the work required. The work was formerly done by hand manipulation, but is now accomplished by the giggering machine, or gig mill, where the teasels are arranged on the face of revolving

THE WORLD'S PRODUCTION OF WOOL *

COUNTRIES	Pounds	COUNTRIES	Pounds	COUNTRIES	Pounds
North America:		Europe:		Africa:	
United States.....	290,192,000	United Kingdom.....	125,122,063	Algeria.....	33,184,000
British Provinces.....	11,210,000	Austria-Hungary.....	41,600,000	British Africa.....	157,761,470
Mexico.....	7,000,000	France.....	79,500,000	Tunis.....	3,735,000
Central America and West Indies.....	1,000,000	Germany.....	25,600,000	All other Africa reported.....	13,000,000
Total.....	309,402,000	Spain.....	52,000,000	Total.....	207,680,470
		Portugal.....	10,000,000		
		Greece.....	16,000,000		
		Italy.....	21,500,000		
		Russia (Europe).....	320,000,000		
		Turkey and Balkan States.....	90,500,000	Oceania:	
		All other Europe.....	18,000,000	Australia (exports).....	632,296,878
		Total.....	799,822,063	New Zealand.....	194,627,789
South America:				Australasia.....	826,924,667
Argentina.....	264,500,000	Asia:		All other Oceania reported.....	100,000
Brazil.....	1,130,000	British India.....	60,000,000	Total.....	827,024,667
Chile.....	27,745,080	China.....	50,000,000		
Peru.....	9,420,707	Russia (Asiatic).....	60,000,000	Total world.....	2,872,487,987
Falkland Islands.....	4,324,000	Turkey (Asiatic).....	90,000,000		
Uruguay.....	143,293,000	Persia.....	12,146,000		
All other South America reported.....	5,000,000	All other Asia reported.....	1,000,000		
Total.....	455,412,787	Total.....	273,146,000		

* Given in the 1915 Bulletin of the National Association of Wool Manufacturers as the latest available figures.

be carried on till the cloth is reduced to half its original length and breadth. The degree of fulling is a distinctive feature of many varieties of goods. In broadcloths, and all kinds of nap-finished goods, the milling is carried on until the fibres become densely matted, and the appearance of weaving is entirely obliterated. Venetian cloths and diagonals, to which no pile finish is given, are fullled or milled only enough

cylinders before which the fabric is made to pass. By this operation the loose ends of the wool are drawn to the surface, thereby forming the nap. Wire teasels are sometimes used, but nature's creation of the vegetable teasel is regarded as having never been improved upon.

The pile is now trimmed to produce uniform surface. Formerly the work was done by hand with huge shears, but now a machine containing

a cylinder armed with a series of helical knives, and made to revolve with great rapidity, is employed. The machine was invented by Leonardo da Vinci, but not brought into practical use until 400 years later.

The final process is the brushing of the cloth, winding it tightly around a huge drum, and immersing it in hot water. It remains in that condition for three or four hours, when it is unwound, the ends reversed and rewound, and again the cloth is subjected to the hot-water process. The closing act in its manufacture is the pressing in a hydraulic press, during which time steam is forced through it, this last proceeding adding to the solidity and smoothness of the cloth, and developing the lustre characteristic of a well-finished fabric.

ing factories for hosiery and knit goods, shoddy mills, and wool-scouring establishments, the number of woolen mills in 1910 was 1397, as against 1675 in 1850. These figures, however, simply show to what extent the industry has been concentrated in large establishments, for the capital invested in the woolen industry and the carpet and rug industry combined in 1910 was \$506,205,584, and in 1850 only \$31,971,631, and the value of products in 1910 was \$507,166,710, and in 1850 only \$48,608,779.

The unit of calculation for the productive capacity of a woolen mill is the set of carding machines necessary to prepare the wool for spinning. The corresponding unit for a worsted mill is the combing machine, which, in its productive capacity, is taken to be equivalent to

THE WORLD'S WOOL SUPPLY SINCE 1870

COUNTRIES	1870	1880	1890	1900	1915 *
	Pounds	Pounds	Pounds	Pounds	Pounds
United Kingdom.....	150,000,000	149,000,000	†138,392,215	†140,232,392	125,122,063
Continent of Europe.....	485,000,000	450,000,000	805,761,000	805,761,000	674,700,000
North America.....	176,000,000	270,000,000	289,191,330	305,636,621	309,402,000
Australasia.....	175,000,000	308,000,000	520,000,000	510,000,000	826,924,667
Cape of Good Hope.....	43,000,000	60,000,000	105,000,000	100,000,000	†157,761,470
River Plate.....	197,000,000	256,000,000	460,000,000	466,000,000	407,793,000
Other countries.....	69,000,000	133,000,000	363,475,000	357,475,000	370,784,787
Grand totals.....	1,295,000,000	1,626,000,000	2,681,819,545	2,685,105,013	2,872,487,987

* Estimate of the National Association of Wool Manufacturers.

† Returns of the United Kingdom are for the preceding year.

‡ Total for British Africa.

Utilization of Wastes. Shoddy is wool recovered from woolen fabrics that are not heavily felted or milled. Mungo is made from fragments of felted or milled cloth, and the fibre is therefore shorter. These two terms, however, are often used with different meanings and are sometimes interchangeable. (See SHODDY.) Extract wool is wool produced from goods which are part wool and part cotton, the wool being extracted by the process of carbonization already described. In 1900 71,496,508 pounds of shoddy were used in wool manufacture in the United States. In other words, of the total raw material 76.9 per cent was new wool and 23.1 per cent shoddy. These second-hand or recovered wools are reduced to fibre in grinding machines, from which they emerge in a flossy wool-like state.

Flocks are soft fluffy fibres which are cast out of the machines during the various processes of cloth manufacture. Noils are simply the shorter and more curly fibres which are pulled out during the process of wool combing for worsted manufacture. Both of these wastes are used in woolen manufactures.

Sophistication. The practice of weighting woolen and worsted fabrics prevails, as does the sophistication of silk. The goods are soaked in mineral salts, such as sulphates of alum, lead, zinc, and magnesium, which increases their weight from 15 per cent up.

Statistics. According to the Thirteenth Census of the United States there were in 1910 2887 establishments in the country devoted to various branches of wool manufacture, which put forth an annual product of \$765,910,476. Of the 2887 establishments, 587 were woolen mills, 324 worsted mills, 139 carpet factories, 43 felt goods factories, 31 wool hat mills, 1374 hosiery and knit goods factories, 273 fur hat factories, 88 shoddy mills, 28 wool-scouring plants. Deduct-

2½ sets of cards for the same fineness and quality of work.

Consult: Beaumont, *Woolen and Worsted Cloth Manufacture* (London, 1890); Posselt, *Textile Fibres and Fabrics* (Philadelphia, 1891); Lesters, *Manufacture of Wool and Worsted* (London, 1900); Sadtler, *Industrial Organic Chemistry* (Philadelphia, 1900); Vickerman, *Woolen Spinning* (London, 1894); Barker, *Textiles* (New York, 1910); Woolman and McGowan, *Textiles* (ib., 1914).