

WOOL, Manufactures of. At the time of the Macedonian conquest the natives of India wove shawls of great beauty. The Greeks also learned many processes of woollen manufacture from the Egyptians; and the Romans and also the people of Spain and Byzantium in turn obtained instruction from the Greeks. Woollen garments were generally worn by the Romans of both sexes at a very early period. A fraternity engaged in cloth manufacture appears to have been formed in the 10th century in the Netherlands; the wool of the country was first used, and imports were afterward made, until this district furnished a considerable portion of the cloth demanded in Europe. But Spain already produced her own cloth, and in the 13th century the beauty of cloths made from her finewools was celebrated. Early in the same century some friars of St. Michael established a woollen manufactory in Florence, and apparently employed processes superior to those previously in use; and this city appears to have had at that time about 300 shops, producing annually about 100,000 pieces of cloth. Accounts 30 years later tell of 200 shops as

PARTICULARS.	1860.	1870.
MATERIALS.		
Cotton, lbs.....	15,200,061	17,571,929
Shoddy, ".....		19,872,062
Warp cotton, yds.....		1,812,560
Warp, lbs.....		140,733
Wool, domestic, lbs.....	70,862,829	154,767,095
" foreign, ".....		17,811,824
Yarn, cotton, ".....		3,268,949
" woollen, ".....		2,573,419
Chemicals and dye stuffs, value.....		\$5,839,346
All other materials.....		\$5,670,250
All materials.....	\$86,556,287	\$96,492,601
PRODUCTS.		
Blankets, pairs.....		2,000,489
" horse, number.....		58,552
Beavers, yds.....		261,208
Cloth, cassimeres, doeskins, yds.....		63,340,612
" felted, yds.....		1,941,865
Cloths, negro, ".....		1,332,382
Cottonade, yds.....		75,000
Coverlets, number.....		226,744
Flannels, yds.....		58,965,286
Frocking, ".....		75,000
Hosiery, dozens.....		21,460
Jeans, yds.....		24,489,985
Kerseys, yds.....		5,506,902
Linseys, ".....		14,180,274
Repellants, ".....		2,668,767
Carriage robes, number.....		22,500
Rolls, lbs.....		8,683,069
Satinets, yds.....		14,072,559
Shawls, number.....		2,312,761
Skirts, balmoral, yds.....		280,000
Tweeds and twills, &c., yds.....		2,853,458
Warp, lbs.....		122,000
Yarn, ".....		14,156,237
" hosiery, lbs.....		233,000
" shoddy, ".....		1,569,000
Miscellaneous articles, value.....		\$3,251,365
All products.....	\$61,894,986	\$155,405,358

WORSTED GOODS.

PARTICULARS.	1860.	1870.
Establishments, number.....	3	102
Steam engines, horse power.....		3,382
Water wheels, ".....		4,634
Machines:		
Braidors, number.....		7,334
Cards, sets.....		98
Domestic combing machines, number.....		95
Foreign combing machines, number.....		66
Knitting machines, number.....		176
Looms, number.....		6,128
Spindles, ".....		200,617
Hands employed.....	2,378	12,920
Capital.....	\$3,230,000	\$10,085,778
Wages.....	\$543,684	\$4,368,857
MATERIALS.		
Chemicals, &c.....		\$1,259,016
Cotton, lbs.....	1,653,000	2,463,808
Shoddy, ".....		12,342
Domestic wool, lbs.....	3,000,000	13,317,319
Foreign ".....		3,836,982
Cotton yarn, ".....		2,146,500
Woollen ".....		46,240
Worsted ".....		1,258,880
All materials, value.....	\$2,442,775	\$14,308,198
PRODUCTS.		
Braids and lacings, lbs.....		2,324,330
Cloaking, yds.....		5,000
Delaines, ".....		40,804,335
Fancy goods, value.....		\$1,974,957
Shawls, number.....		111,404
Shirts and drawers, dozens.....		4,080
Balmoral skirts, yds.....		433,288
Other skirting, ".....		51,851
Webbing and tape, yds.....		2,006,000
Worsted dress goods, yds.....		12,057,906
Woollen yarn, lbs.....		284,100
Worsted ".....		4,047,750
Zephyr goods, ".....		3,900
All products, value.....	\$3,701,378	\$22,090,331

HOSIERY (WOOL AND COTTON).

PARTICULARS.	1860.	1870.
Establishments, number.....	197	248
Steam engines, horse power.....		2,223
Water wheels, ".....		4,275
Machines:		
Cards, sets.....		519
Knitting looms.....		438
" machines.....		5,625
Sewing machines.....		1,668
Spindles.....		148,385
Hands employed.....	9,103	14,788
Capital.....	\$4,035,510	\$10,931,260
Wages.....	\$1,661,972	\$4,420,085
MATERIALS.		
Cotton, lbs.....	3,802,342	11,463,508
Cotton yarn, lbs.....		2,188,722
Domestic wool, ".....	2,927,626	5,304,635
Foreign ".....		292,300
Shoddy, ".....		189,857
Woollen yarn, ".....		2,229,777
All other materials, value.....		\$1,110,992
All materials.....	\$3,202,317	\$9,835,823
PRODUCTS.		
Cotton hose and half hose, doz. prs.....		1,299,342
Shirts, drawers, and jackets, doz.....		1,132,189
Gloves and mittens, pairs.....		206,800
Opera boas and scarfs, doz.....		426,749
Shawls, doz.....		14,347
Stockinet, yds.....		289,372
Woollen and mixed hose, doz. prs.....		2,970,170
All other products, value.....		\$369,784
All products.....	\$7,280,606	\$18,411,564

CARPETS, OTHER THAN RAG.

PARTICULARS.	1860.	1870.
Establishments, number.....	213	215
Steam engines, horse power.....		3,017
Water wheels, ".....		702
Hands employed.....	6,681	12,098
Machines:		
Combing machines.....		100
Cards, sets.....		241
Hand looms.....		3,975
Power.....		1,451
Capital.....	\$4,721,768	\$12,540,750
Wages.....	\$1,545,692	\$4,651,718
MATERIALS.		
Cotton, lbs.....	395,000	974,440
Cotton and linen yarns, lbs.....		1,140,787
Jute or flax, lbs.....	800,000	3,691,309
Wool, lbs.....	8,843,691	25,189,399
Woollen yarn, lbs.....		7,835,954
All other materials, value.....		\$1,577,632
All materials.....	\$4,417,986	\$13,577,998
PRODUCTS.		
Brussels, yds.....		806,505
Felt, yds.....		586,000
Ingrain, 2 and 3 ply, yds.....		16,924,711
Jute, yds.....		600,000
Tapestry, yds.....		1,711,000
Velvet, ".....		107,000
Venetian, ".....		1,350,017
All other products, value.....		\$670,047
All products.....	\$7,857,636	\$21,761,578

The chief centres of the woollen industry in the United States are in New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, and Pennsylvania. In 1870 Massachusetts ranked first in woollen goods, New York in hosiery, and Pennsylvania in capital in worsted goods, and in products in carpets. In the opinion of Mr. George William Bond of Boston and other authorities, this industry reached its maximum in 1872, since which time there has been a marked decline. In 1876 a large proportion of the mills and machinery

were idle. The value of the imports of woollen manufactures into the United States during the years ending June 30, 1874 and 1875, has been as follows:

KINDS.	1874.	1875.
Cloths and cassimeres.....	\$13,016,671	\$13,680,288
Woollen rags, shoddy, mungo, waste, and flocks.....	151,156	149,109
Shawls.....	2,181,887	2,143,498
Blankets.....	13,472	12,604
Carpets.....	3,649,863	2,643,932
Dress goods.....	21,162,635	19,759,488
Hosiery, skirts, and drawers.....	505,109	683,761
Other manufactures.....	6,202,395	5,597,024
Total.....	\$46,883,188	\$44,609,704

—*Processes of Woollen Manufacture.* If a piece of superfine broadcloth, as requiring in succession all the operations upon the wool, yarn, and fabric needful for woollens of any sort, be taken as the representative of the whole class, the following are the processes through which the materials are passed: 1, sorting the wool; 2, scouring; 3, washing; 4, drying; 5, dyeing (when dyed in the wool); 6, wilying; 7, picking or teasing; 8, moating; 9, oiling; 10, scribbling; 11, plucking; 12, carding; 13, slubbing; 14, spinning; 15, reeling; 16, warping; 17, beaming; 18, singeing, sizing, and other preparation of the threads for—19, weaving; 20, scouring; 21, dyeing (when dyed in the piece); 22, drying or tentering; 23, burling; 24, milling or fulling; 25, scouring; 26, drying, or tentering, again; 27, raising, dressing, or teasing; 28, shearing; 29, boiling; 30, brushing; 31, picking; 32, drawing and marking; 33, pressing; 34, steaming; 35, folding or packing. The shearing and pressing are sometimes repeated, the processes of picking, drawing, and marking then coming between them on this second application. Of these processes, more than one half of which are now effected by machinery, some have already been considered in separate articles. (See CARDS, DYEING, FULLING, TEASEL, and WEAVING.) Of the remaining processes, some are too simple to require particular description, and the others are too technical to be well understood except by actual observation of the processes themselves. The sorting of the wool, as determining the different qualities that shall be mixed for a given quality of cloth, is important. The qualities to be considered in this sorting are chiefly those of fineness, softness, trueness, strength, color, cleanness, and weight, as previously explained. In the English factories, the usual distinctions are into the grades known as “prime, choice, superhead, head, downrights, seconds, fine abb, coarse abb, livery, and breech.” In the United States, the grades made by merchants of pulled and clipped or fleece wools, and in the latter of short staple and long staple, or clothing and combing wools, are at the factories again subdivided each into a definite number of sorts, presenting a regular gradation of quality. Af-

ter sorting, the several packs of wool are separately scoured, washed, and dried. The scouring is effected by soaking the wool in stale urine, or in an alkaline lye heated to 120°; the washing, by placing the wool, after removal from the lye, within wire baskets in running water, or by rinsing in warm suds, and afterward in clean water; and the drying is much facilitated by subjecting the rinsed wool to pressure in passing it between iron rollers. If the cloth is not to be white, it is either wool-dyed or piece-dyed. If the former, the dyeing follows directly on the scouring or washing. Common colors, as browns and olives, are dyed by the larger manufacturers; but the true colors, as blue, black, and green, and those of all cloths of the smaller manufactories, are left to the special dyers. The process of wilying or twilying (a term probably derived from winnowing) is analogous to that of bating or scutching in cotton manufacture; the object is to disentangle and open the locks, and free them of sand or other loose impurities. One of the best forms of wily is that in which a hollow truncated cone, with four bars projected beyond but running parallel to its surfaces, and armed with iron spikes, revolves 300 to 400 times per minute within an outer cylinder, armed on the inside with similar spikes. The wool, fed to the smaller end of the cone by an endless apron, travels in revolving by virtue of centrifugal force to the larger; and after being thus opened and beaten up, it escapes into a wire cylinder or receptacle provided with a fan, which blows away the disengaged dust, and finally lays the cleaned wool upon another apron in a continuous sheet. Coarser wools for cloths are willed more than once, sometimes before dyeing, and again after oiling and scribbling. Some larger impurities, such as the wily does not remove, as burs, pitch, or dirt, are then picked out of the wool while spread upon a wire screen, by boys or women; this includes both the picking and moating, the persons engaged being called wool moaters. The wool is then spread upon a floor, sprinkled with olive oil, and well beaten with staves. It is thus prepared for the scribbling machine, the purpose of which is further to open and cleanse the fibres. This process is really a coarser carding, effected by passing the wool successively between several cylinders studded with rows of teeth or wires, and made to revolve rapidly; the wool is conveyed to the cylinders by an apron, and given forth at the last in a delicate sheet, which is wound on a revolving roller. This operation also may be repeated two or three times. From the carding machine, through which the wool is afterward passed, it is delivered in the form of slender cylinders or pipes, called cardings. Slubbing, which is a preparatory spinning, is performed by the slubbing billy, and consists in drawing out and twisting the cardings to the state of a soft, weak thread. This is ef-

fectured by means of several spindles set nearly upright in a frame, and receiving a turning motion, at the same time that the frame itself is made to recede (upon friction wheels running in rails beneath it) from a roller facing the spindles, and from which roller a carding is fed by the machinery to each spindle at the rate required; the spindles alternately draw out and wind the lengths of thread produced by movement of the carriage, the entire action being quite similar to that of Hargreaves's spinning jenny. (See COTTON MANUFACTURE.) Besides the workman managing the machine, another, or a child, is employed to put fresh cardings in place as they may be required. The proper spinning consists in bringing the soft yarn thus furnished to the fineness and firmness requisite for weaving; and the machinery and operation are again quite similar to those employed in spinning cotton. In view, however, of the variable lengths of the filaments of wool, the two pairs of drawing rollers between which it passes in spinning are so mounted as to be adjustable at different distances, so as neither to allow the soft thread to part between them from its undue length, nor to be broken when too short because of want of space for the fibres to slip one upon the other; while the greater elasticity of wool also allows the velocities of the two pairs of rollers to be so regulated as to produce a greater extension of the thread than in the case of cotton. After the preparation for and the process of weaving follows that of scouring the cloth, in order to remove the oil, sizing, dust, &c., introduced into it purposely or accidentally in the mean time; this is accomplished by beating the cloth with wooden mallets moved by machinery, while it lies in a sort of inclined trough, soap and water being first allowed to flow upon it, and afterward clear water. Piece dyeing and washing may then follow; otherwise, the cloth is next removed to the drying room, or stretched in the open air by means of hooks upon rails or tenter bars, and allowed to dry. Being removed when dry to a suitable room, the operation of burling follows, the burlers picking out of it irregular threads, hairs, and dirt; and the process of fulling then succeeds. (See FULLING.) After the cloth has been full'd one or more times, as may be required, it is again subjected to scouring, fullers' earth being now usually added to the water; and after rinsing, the cloth is again stretched upon the tenters and dried. The cloth in the full'd state has both its surfaces woolly or rough; and that surface which forms the proper face of the cloth, whether either one of them if they do not differ, is then subjected to the operations of teasing and rearing. The object of the former process is to raise a sufficient number of fibres upon the surface, and of the latter to cut these to the proper length to form the pile or nap of the finished cloth. To the old plan of fixing the teasels in a hand frame worked over the piece

by two men, succeeded some years since that of the gig mill, in which the teasels are set in the periphery of a cylinder; and in the most improved form of this, the teasels are arranged along longitudinal bars in the surface of the large cylinder, with interspaces between the bars, the whole having the appearance of an immense reel. The cylinder revolves rapidly, while the cloth, passing slowly from one roller to another, is brought against one side of it, and receives the action of the teasels. Owing to the readiness with which the points of the burs become soft when wet, and their comparative scarcity and high price, gig mills with what are called metallic teasels, or cards with fine metallic teeth, have been constructed; but though some of these perform satisfactorily, the natural teasels are still preferred. Of these 3,000 are not unfrequently consumed in dressing a single piece of cloth. The shearing of the nap thus raised to a proper and uniform length was, until the beginning of this century, performed by stretching the cloth over a stuffed table, and carefully clipping it with long hand shears; in the first mechanism the only change was in working similar shears by the machinery; but at present several more ingenious modes have been devised. Among the best of these is that invented by Mr. George Oldland of Gloucestershire in 1832. In this, the cloth, being made to move slowly along in a horizontal sheet, is passed directly beneath and in contact with a semicircular cutting edge or "ledger blade," extending across the width of the piece, while directly within this semicircle there is continually turned by a band from the machinery a revolving wheel fitting the curve of the former, and at once carrying and by suitable arrangements of teeth causing to revolve eight small circular cutters about its periphery; as these are thus made successively to play along the ledger blade, they form a sort of endless shears in the highest degree delicate and true. Superfine cloths are dressed and sheared several times in succession, being also once pressed before the last shearing. In the intervals of the preceding operations, or after their completion, the best cloths are now boiled, or "roll-boiled," being wound tightly round a cylinder and immersed for two or three hours in scalding water. The results of this process, patented by Messrs. Daniell and Wilkins of Tiverton in 1824, and improved by Mr. William Hirst of Leeds, are to prevent spotting of the cloth when used, and to impart to it a lustre which was unattainable by any previous process. Other methods, as that of steaming the cloth while stretched or under pressure, though shorter, are said to be less advantageous. Brushing the cloth, which in any case next follows, is effected by passing the piece, while steamed, in contact with revolving cylinders studded with suitable brushes. Picking is then performed, to remove blemishes; and fine-drawing, to close any minute breaks in the fabric; and the usual trade marks, denoting quality, number,

&c., are then worked in at one end of the piece. The brushing is then again performed, and the piece folded is subjected between polished pressing boards to the action of a hydraulic press. A deceptive gloss may be produced in inferior cloths, by hot pressing by means of heating the iron plates; and in any case, with or without a final steaming and drying, the cloth is then folded and packed for sale. Such is a general description of the nature and order of the operations required in converting wool in the fleece into marketable cloths; though some of the less essential of these may not enter into the preparation of all the species of woollen goods, and in particular instances other slight deviations from the usual order besides those already named may occur. It would be impracticable to describe or enumerate the many minor changes or improvements connected especially with the working of the wool previous to carding, with the operation of spinning, and with those to which the cloth is subjected, and of which taken together a great number are every year patented, and many of them introduced into use, not only in this country and in England, but also in countries of continental Europe. We may mention, however, the machine introduced in 1858 by Mr. Archibald of Tillycoultry, Scotland, for piecing the cardings, so as to form them into a continuous length or roving; and that patented by Messrs. Tolson and Irving of England, for imparting to woollen cloths a metallic lustre, in which the yarn or piece is impregnated with a salt of copper, lead, or bismuth, and the metal then disengaged and left upon the fibre by exposure to steam charged with sulphuretted hydrogen. In the United States, in 1858, Mr. Waterman Smith of New Hampshire patented mechanism for keeping the soft woollen thread or sliver of other fibrous materials hot while being drawn, by passing it over or against heated surfaces, the objects being to render the fibres more soft and pliable than otherwise, and to straighten and elongate them in drawing; and Messrs. Kennedy and Plummer of Connecticut, in the same year, obtained a patent for a novel combination of tubes and drawing rollers, and means of working the rollers, by which the processes of drawing and twisting can be performed simultaneously, or either of them separately, and in consequence of which, when the two actions are combined, it is claimed that great convenience is secured, in the way of varying the relative degrees of draught and twist, to suit various lengths and quantities of fibre. Among woollen goods proper are broadcloths and narrow cloths, cassimeres (or kerseymeres), and beaver or double cloth, the last named of which, coarse and warm on one side, and presenting a finely finished surface on the other, was the invention of Daniell and Wilkins, in 1838.—*Processes of Worsted Manufacture.* The object in view in preparing the long wools for manufacture is not to produce that thorough

interlacing of fibres which is completed in fulling, but rather to produce a simply spun and woven fabric. The chief preparation of the wool accordingly consists in obtaining the fibres in a straight and parallel condition; and this is effected by combing. The combing wools are themselves subdivided into the long and the short; the former, of lengths varying from 6 to 12 in., are chiefly used for carpets and other coarser goods; the latter, of lengths from 4 to 7 in., for hosiery, merinoes, &c. The principal processes are: 1, sorting; 2, scouring; 3, drying; 4, plucking; 5 (for certain fabrics only), carding; 6, combing; 7, breaking; 8, drawing; 9, roving; 10, spinning; 11, reeling; 12, weaving; 13, dyeing, &c. The wool may be scoured, and mainly dried by passing between rollers; but by the washing machine of Messrs. Petrie and Taylor, both the scouring and drying are more speedily and effectually performed. The wool, in this, is rapidly agitated in hot suds in an iron trough by iron rakes; and being then drawn from the trough by a cylinder with metallic teeth, it is briskly winnowed until dry. Plucking is performed by passing the wool through a machine in which spiked rollers beat up and separate the fibres. The combing of the wool is still performed by hand in some instances, though now more commonly by machinery. In hand combing, the workman uses as required either of two pairs of combs, one having three, the other two rows of long teeth; the rows in either case, from the outermost inward, growing successively shorter. The handle is set into the head of each comb at right angles to the direction of the teeth; and by means of holes, one vertically through the handle, the other entering it at the end, and of corresponding pins projecting from a comb post near the workman, and upon which the handle is to be fixed, the comb can be steadied when required. Near to each workman is also a comb pot, or stove. The teeth of the combs are placed in an opening in the top of the stove long enough to heat them. The workman meanwhile takes about four ounces of wool, sprinkles it with olive oil, and thoroughly rubs this through it with his hands. One of the heated combs, and after it the other, is affixed upon the comb post; among the teeth of each of them in succession the comber jerks or "lashes" one half the wool; and as each is thus charged he returns it, teeth and wool downward, into the heated space in the stove. When the wool is properly warmed, seating himself on a low stool, he holds one comb with the teeth upward by his left hand over his knees, and with the right hand works the other comb, the teeth of which point downward; and he continues this operation, using the teeth of either comb to straighten the wool on the other, and thus working through the wool from the outermost portions until the combs nearly meet. The fibres of the greater part of this quantity of wool are thus properly straightened, and

such portion is fitted for spinning into worsted; the small portion remaining on the combs, and called the "noils," is applied to other purposes, being usually mixed with the wool for certain cloths. The wool then undergoes recombining at a lower temperature. The machines for wool combing are very numerous. The first, that of Cartwright (1790), attempted, by means of a circular comb and of a cylindrical working comb and an oscillating frame moving over the former, to imitate closely the process of combing by hand. The machine which first succeeded in displacing this was that of Platt and Collier (1827); in this, two wheels studded about their peripheries with teeth parallel with their axes, forming circular combs, have their disks set crossing at a slight angle with each other, and almost in contact by their near edges. A boy is employed to strike the wool upon the teeth of one comb, and the wheels being at the proper distance, and rotating, the teeth of the empty wheel draw through or comb the wool upon the charged one. When the combing is completed, the "top" or combed worsted is taken off by a boy or girl in a continuous sliver; and by another boy the noils or uncombed part are removed. In improved forms of this machine, the wool having been sufficiently combed, and now equally distributed on both wheels, the rotation of these is discontinued, and the top is disengaged from both of them while turned slowly, by the action of pairs of small rollers between which it is passed. For more detailed accounts of the principal combing machines in use at the time of its publication, see James's "History of the Worsted Manufacture" (London, 1851). Breaking is performed by the breaking frame, the object of which is to open out fibres that may have escaped the combs. In this, the sliver passed between rollers is again acted upon by the teeth of a sort of endless comb, the relative velocities of the two being so regulated that the sliver is extended as well as combed. The smaller roll of sliver thus obtained is wound continuously upon a cylinder, from which it is passed to a second breaking frame with finer teeth. The sliver is afterward subjected to the action of a machine similar to the drawing frame of the cotton manufacture; and it is thus further extended and equalized. The sliver, now greatly reduced, but as yet untwisted, is then brought to the roving machine, in which it is passed successively between two pairs of small rollers, the second pair moving the more rapidly, so as to draw it out in length, while at the same time it is slightly twisted by a turning movement of the hollow bobbin or fly through which the thread is drawn. The spinning is conducted in much the same way as in the case of cotton manufacture; and this and the remaining operations to which the yarn and cloth are subjected do not require especial mention. The worsted yarn is reeled in hanks of 560 yards each; and

these are named according to the number of them that make a pound, as No. 24, and so on. The worsted manufactures of England have long been gaining upon those of woollens; among the causes of this change being, that the wool of the country has deteriorated in fineness and felting capacity; that the improvements in machinery have greatly facilitated the combing of the wool, and even of that having a shorter fibre than could formerly be worked in this way; that the fly-spindles in the preparation of the yarn, instead of about 2,800 as formerly, can now be made to perform 6,000 revolutions per minute; that while broadcloths, often 9 ft. in width before fulling, cannot be woven at more than about 50 movements of the shuttle per minute, certain worsted goods are woven at the rate of 160; and that the facility of working cotton into worsted fabrics is very great. It is supposed that 95 per cent. of the worsteds worked in the Bradford district have cotton warps, and that of their total weight at least one third is cotton. Among styles of worsted goods which have been or are now well known are stuffs, merinoes, muslin-de-laines, bombazines, shalloons, says, moreens, camlets, and lastings. (See also CARPET, and STOCKING.)—In connection with the subjects of wool and its manufacture, the reader is referred to "Sheep Husbandry," &c., by Henry S. Randall (New York, 1860), and to "Fine Wool Sheep Husbandry," by the same author (New York, 1863); "The Shepherd's Manual," by Henry Stewart (New York, 1876); and James's "History of the Worsted Manufacture," above mentioned.