WOOLLEN AND WORSTED MANUFACTURES. The manufactures in wool and in worsted are so closely connected, in reference both to their past history and to the industrial arrangements involved in them, that it will be convenient to treat of them under one heading. Wools are divided into two great classes—*clothing-wools* and *combing-wools*, or *short-wools* and *long-wools;* and the fabrics woven from them are termed *woollens* or *worsteds*, according as the one or the other is employed. Clothing-wools possess in high perfection that peculiar property which enables the fibres to felt or interlace one among another, and to form thereby the dense compact material of which men's garments are so largely made in this country, as well as the still thicker felt for hats [HAT MANUFACTURE]; whereas combing-wools, though long in fibre, are deficient in the felting property, and are therefore employed for stuffs, merinos, hosiery, and a large number of fabrics which do not undergo the felting or fulling process.

History.—It is probable that no other of the textile manufactures is so ancient as that of wool. Sheep were reared from the earliest times, and there can be little doubt that the use of the wool for clothing was soon adopted. If a mass of woollen fibres be pressed firmly together in a flat layer, the fibres, by virtue of their felting property, will cohere into a continuous sheet even without the process of weaving; and this property could not fail to attract notice. The passages in the Bible which seem to allude to the use of woollen garments are well known; and we have indirect evidence from various quarters to show the prevalence of a similar custom in the East generally, in early times. The spinning of the fibres was most probably effected by the fingers; while the thistle or teazle, as at present, was used to comb out the fibres; the dyeing of the threads, too, it is quite evident, was well understood by the ancients. Among the Greeks and Romans the woollen manufacture was of a domestic character; but yet it would seem that the clothing of large armies must have required arrangements of a more extensive kind. The natives of India, after the epoch of Macedonian conquests in that country, made shawl-cloths of exquisite beauty, consisting, as is supposed, of short wool woven without felting: and the Greeks and Romans may have derived some of their modes of proceeding from such a quarter. But however this may be, the Romans of both sexes wore woollen garments very generally.

The decay of the arts consequent on the irruption of the barbarians into Rome did not appear to have extended to this manufacture. Woollen clothing was still made in most of the countries where the Romans had established colonies; and there are indications that in the 10th century the manufacture became the occupation of a particular fraternity in the Low Countries. The wool employed was at first the produce of their own country; but they afterwards imported wool from other countries, and carried on the manufacture to such an extent that the Low Countries became in a great measure the clothing district for Europe. Spain produced cloth for herself, and acquired, about the 13th century, considerable reputation for the beauty of the fabrics produced, consequent, we may suppose, on the fine wool which the Spanish sheep have for centuries produced. The Italians and French entered upon this manufacture at a later period.

In the time of William the Conqueror, an inundation which occurred in the Netherlands drove many of the clothiers into other countries, and some of them came to England. William of Malmesbury says that the king, glad of such an accession, placed these Flemish clothiers first in Carlisle and then in the western counties. From that time the mention of clothiers is frequent in the old chronicles; London, Oxford, Lincoln, Huntingdon, York, Nottingham, and Winchester, being enumerated as towns wherein the manufacture was carried on; while at other towns there were cloth-dealers who paid a licence-duty to the king for the privilege of buying and selling dyed cloths. It has been stated [WOOL AND THE WOOL TRADE] that the king frequently derived considerable revenues from English wool; and this circumstance led to the enactment of many laws, tending to the exclusion of foreign wool and the use of English wool only in our manufactures. The exclusion of Spanish wool from English broad-cloth; the limitation of the width of broad-cloth to two yards; the determination of the width of striped cloth made at Bristol; the appointment of towns where alone cloth could be bought and sold; the appointment of the office of king's *Aulnager*, whose duty it was to attend the cloth-markets, and measure all the cloth sold, to see that there was no deficiency of length, and who received a fee for every piece of cloth to which he attached his seal; the prohibition to export woollen cloths until they had been fulled; the granting of permission to make certain coarse kinds of cloth three-quarters of a yard in width; the fixing of a leaden seal to pieces of cloth wrought in London and the suburbs—these are some of the laws by which the government tried or hoped to regulate the manufacture; and they will serve to convey an idea of the general character of others.

Edward III. brought about a great extension of the manufacture by inviting over some skilful weavers from the Netherlands. English wool was said to be worked up more successfully in the Netherlands than in England; and Edward thought that by getting over some of the Flemings to this country, he could improve the native manufacture. This seems to have been done; and the following distribution of the manufacture, consequent on this immigration, shows how widely this branch of industry became spread—Norfolk, fustians; Suffolk, baize; Essex, says and serges; Kent, broad-cloth; Devon, kerseys; Gloucestershire, cloth; Worcestershire, cloth; Wales, friezes; Westmoreland, cloth; Yorkshire, cloth; Somersetshire, serges; Hampshire, Berkshire, and Sussex, cloth.

For several reigns subsequent to that of Edward III., the woollen cloths made in England appear to have been chiefly of a coarse quality; the majority of the manufacturers directing their attention chiefly to worsted fabrics; while the finer broad-cloths were imported from Brabant, a proof that the exertions of Edward, though successful as regards the extent of the manufacture, were not so in respect of quality. By the reign of Henry VIII. the exports of English cloths became very large, insomuch that when, through foreign wars, the markets of Spain and the Netherlands were closed to the English, great complaints arose among the manufacturers, who could not sell the cloth which they sent to Blackwell Hall, a kind of Cloth Hall whence London dealers and merchants were supplied. About this time the manufacture in the counties of Somerset, Gloucester, Wilts, and Worcester was limited to corporate towns; and the most absurd laws were passed to confine it to those favoured spots. During the reign of Elizabeth, owing partly to many of these restrictions being removed, and partly to the immigration into England of many weavers driven from the Netherlands by the persecutions of the duke of Alva, a considerable advance was made in the English manufacture. In the following reign the English dyers succeeded in obtaining a law prohibiting the export of cloth in the white or undyed state, under the expectation that they would be gainers thereby; but, like many other monopolies, it defeated its own aim; the Dutch and Germans refused to buy English cloth in the dyed state, and thus the exports fell so enormously that dyers as well as manufacturers lost by the impolitic prohibition.

During the time of the Stuarts a narrow policy almost ruined the manufacture. At one time there was an attempt to get all Spanish wool brought to this country, and to no other countries; at another time the exportation of English wool, of fuller's earth, and other materials of manufacture, was prohibited; English clothiers refused to receive Flemings among them, from a feeling of jealousy; the London merchants procured an act prohibiting all foreigners from buying and selling; and many other measures were passed, either by parliament or by corporations, tending to cripple the free spread of the trade and manufacture. Ireland suffered severely by this mischievous system; for after being compelled to give up the exportation of cattle to England, on account of the complaints of the graziers, she turned attention to the growth of wool; but this offended the English wool-growers; and if Irish cloths were sent to England, this roused the opposition of the English clothiers; so that from about 1640 to the end of the century there was one continuous struggle in Ireland to bear up against the selfish policy of England in respect to wool and its manufactures.

Throughout the greater part of the 18th century the manufacture steadily increased in England, especially in those fabrics made of long or combing wool. When the inventions in spinning-machinery gave an extraordinary impetus to the cotton-manufacture, that of woollen became thrown comparatively into the shade; but the application of improved machinery has since increased the power of the manufacturers; while the great improvements in the quality of German and Australian wools, combined with the maintenance of a liberal policy in commerce and interchange, have given to the woollen and worsted manufactures in England a more healthy tone.

Woollen Manufactures.—It has been before explained that the woollen manufacture relates to such fabrics as require the use of short or felting wool. This wool undergoes a very large number of processes in the course of the manufacture. If we take a piece of superfine broad-cloth as a representative of this manufacture generally, the following are the successive processes by which it is produced:—

1. Sorting the wool.	12. Carding.	23. Burling.
2. Scouring.	13. Slubbing.	24. Fulling.
3. Washing.	14. Spinning.	25. Scouring.
4. Drying.	15. Reeling.	26. Tentering.
5. Dyeing (when dyed in the wool).	16. Warping.	27. Teazling.
	17. Beaming.	28. Shearing.
6. Willying.	18. Singeing.	29. Boiling.
7. Picking.	19. Sizing.	30. Brushing.
8. Oiling.	20. Weaving.	31. Picking.
9. Moating.	21. Scouring.	32. Pressing.
10. Scribbling.	22. Dyeing (when dyed in the cloth).	33. Steaming.
11. Plucking.		34. Packing.

More than one-half of these, in the most improved forms of proceeding, are effected by machinery.

The sorting of the wool is the first operation, and is one of much importance, since the quality of the cloth depends greatly on a due admixture of different kinds of wool. Each pack of wool contains many different qualities, according to the part of the fleece whence it was taken, and other circumstances; and much tact and discrimination

are called for in the separation. The sorter has to make his selection in relation to the *fineness*, the *softness*, the *strength*, the *colour*, the *cleanness*, and the *weight* of the wool; and in reference to these qualities he separates the wool into many parcels, which receive the names of *prime, choice, super, head, downrights, seconds, fine abb, coarse abb, livery*, &c. The finest fibre is that of Spanish ewe, the mean diameter of which is $\frac{1}{1500}$ of an inch; while the coarsest is that of Wilts ewe, measuring $\frac{1}{500}$ of an inch. All woolly fibres are thicker at one end than the other; but the less the difference in that respect, the more valuable is the wool; and this is one of the favourable points in Merino wool.

When the proper kinds are selected, they are next *scoured* and *washed*, to free them from the grease which invariably attaches to them. The wool is soaked in an alkaline ley at a temperature of about 120°, rinsed with cold water, and passed between the rollers of a powerful press to free it from nearly all moisture.

If the cloth is dyed in the wool, that operation succeeds the scouring; but if dyed in the piece, many other processes intervene; and it depends a good deal on the kind of colour as to which plan is followed. Supposing the dyeing to be completed, however, the wool undergoes the process of *willying* or *willowing*, which is somewhat analogous to the *batting* or *scutching* in the cotton-manufacture; the object being to open and disentangle the locks of wool, and cleanse them from sandy and other loose impurities. One among many forms of willy is a kind of hollow truncated cone, having an axis running through its centre; on this axis are fixed three wheels of different diameters, bearing on their circumference four longitudinal bars studded with sharp spikes. The cone revolves with a rapidity of three or four hundred revolutions per minute, within an outer cylindrical casing, whose inner surface is armed with similar spikes. The machine is fed, by means of an endless apron, with wool, which enters at the small end of the cone, and travels to the larger end by virtue of the centrifugal force produced by the rotation. As it passes onwards between and among the spikes, it becomes opened and disentangled, the fibres of each lock separated, and the impurities detached. When the wool has reached the lower end of the cone, it passes into a receptacle where a fan is revolving with great rapidity, by which a current of air is generated sufficient to blow away all the dust mixed with the wool; while at the same time a kind of revolving cage distributes the wool in a flat equable layer or stratum. Thus the same machine disentangles the fibres, separates the impurities, blows away the dust, and lays the wool in a smooth sheet.

Some kinds of wool require willying more than once; but this is not the case with the finer qualities. There are however frequently some impurities which cannot be removed by the willy; and such are afterwards picked out by boys or women, called wool-moaters, or wool-pickers. A further opening of fibres results from the process of *scribbling*; but before this is effected, the wool undergoes that of *oiling*; it being spread out on a floor, sprinkled with olive-oil, and well beaten with staves. The *scribbling-machine* consists of several cylinders, on whose external surfaces are rows of teeth or wires. These are combined in a strong frame, and so fitted as just to touch and work against each other; the wires on one cylinder are bent in a direction contrary to those in the adjoining one; so that when all the cylinders are revolving, and wool is applied to the first one of the series by an endless apron, it is caught from tooth to tooth, carried rapidly from cylinder to cylinder, separated completely from all entanglement, and finally given forth in the shape of a delicate fleece or sheet. It becomes wound on a revolving roller, after having passed through the scribbling-machine; but when it leaves the carding-machine it presents the appearance of slender rods, cylinders, or pipes, which are called *cardings*.

These cardings are then spun into yarn for the use of the woollen-weaver; the process of spinning being generally effected by means of the *slubbing-billy* or *slubbing-machine*, and afterwards by the common *jenny* or *mule-spinning* machine; the slubbing-billy bringing the wool to the state of a soft weak thread, and the spinning-machine giving it the proper firmness and hardness for yarn. The *slubbing-billy* has a wooden frame, within which is a moveable carriage, running on lower side-rails on friction-wheels. The carriage contains a number of steel spindles, which receive a rapid motion from a long cylinder, by means of separate cords passing round the pulleys of the respective spindles; this cylinder is a long drum of tin plate, six inches in diameter, covered with paper, and extends across the whole breadth of the carriage. The spindles are placed in a frame so as to stand nearly upright at about four inches apart; their lower ends being so formed as to act as pivots. The drum lies horizontally before the spindles, with its centre a little lower than the line of the spindle-pulleys. The drum receives motion by a pulley at one end with an endless band from a wheel placed on the outside of the main frame, turned by the spinner with his right hand applied to a winch; and by this movement the spindles are made to revolve rapidly. Each spindle receives a soft card or slubbing, which comes through beneath a wooden roller at one end of the frame. A child is employed here, who brings the cardings from the card-engine, and places them upon an inclined cloth. These cardings, being drawn beneath the roller, are then caught between two rails. The movement then is very similar to that in Hargreave's spinning-jenny; a small portion of each carding is allowed to pass between the rails or clasp; and this portion is then drawn out or elongated to the state of a thread by the recession of the carriage towards the other end of the frame. Meanwhile the spindles have been kept in motion, by which a slight twist is imparted to the thread or slubbing. A faller-wire and a rail assist in regulating the winding of the thread uniformly on the spindles. The process then is thus conducted. A child, called a *piecener*, takes the cardings from the carding-machine, and lays them on the inclined apron; they are thence carried up beneath the roller and between the clasp, and the workman or *slubber*, by managing his moveable carriage with one hand, and the wheel which turns the spindles with the other, elongates the *carding* into *slubbing*, and winds it on the spindles. The piecener are employed and paid by the slubber; and some years ago great cruelty was said to be inflicted on the children by the workmen for any neglect of their duty; but the inspectorship of factories has removed such sources of discredit to the factory system.

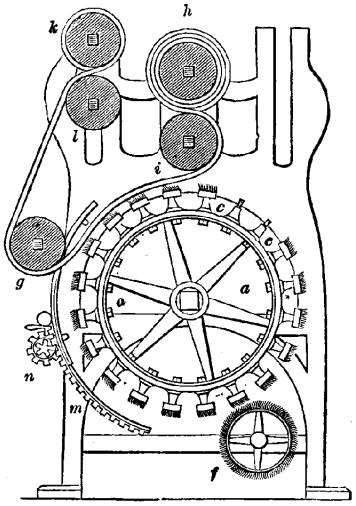
In the *spinning* of the wool, which follows the slubbing, the kind of machines employed and the general character of the processes are so similar to those exhibited in the cotton manufacture, that it will suffice to refer to COTTON MANUFACTURE and SPINNING for details, with the following few additional remarks. The soft cord or sliver is caused to pass between two pairs of rollers; the space between the two pairs being rather more than equal to the length of the fibres. The two pairs of rollers between which the sliver is compressed do not separate farther from each other in order to stretch it, but that effect is produced by making the second pair of rollers revolve faster than the first. It is necessary to arrange the distance between the two pairs of rollers with reference to the average length of the filaments of which the sliver is composed; because if the two pairs of rollers were too far apart, the soft cord would be liable to separate between them, and if they were too near, so that the opposite ends of a filament should be compressed between them at the same time, the sliver could not extend or lengthen by the sliding of the filaments, but the filaments themselves must break with the strain. Hence, in machinery for spinning wool, on account of the variable length of the filaments, the drawing-rollers are so mounted that they may be readily adjusted to different distances. In consequence of the greater elasticity of wool, the relative velocities of the two pairs of rollers are so arranged as to produce a greater degree of stretching or extension than is usual with cotton.

The process next following that of spinning is *weaving*, by which the yarn is worked up into a textile fabric. If it be a plain cloth, the loom employed is very simple in its arrangements; if it be a twill or an ornamental fabric, the loom is somewhat more complex; but the general arrangements will be sufficiently understood by a reference to WEAVING. Hitherto woollen cloths have been principally woven by hand-weavers; but the power-loom is every year becoming more and more applied to this purpose. Some of the cloths are woven as broad as twelve-quarters, to allow not only for the shrinkage occasioned in the subsequent process of fulling, but for an edging or list, made either of goats' hair or of coarse yarn, into which the tenter-hooks are thrust in the process of *tentering*.

As the wool has been dressed with oil before spinning, and with size before weaving, it becomes necessary to cleanse it from these impurities immediately after the weaving. This is the object of a second *scouring* process, in which the cloth is beaten with wooden mallets in a kind of trough or mill; soap and water being let in upon it first, and then clear water. Being then carried to the drying-room, or the tenter-ground, it is stretched out by means of hooks on rails, and allowed to dry in a smooth and extended state. It is then taken into a room and examined by *burlers*, who pick out all irregular threads, hairs, or dirt. After this it is ready for the important process of *fulling*, or *felting*, which imparts to woollen goods that peculiarity of surface whereby they are distinguished from all others. A large mass of cloth folded into many plies is put into the *fulling-mill*, where it is exposed to the long-continued action of two heavy wooden mallets or stocks. Superfine cloth receives four fullings of three hours each, a thick solution of soap being spread between each layer of cloth every time. During the violent percussions which the cloth thus receives for twelve hours, the fibres, being at every stroke strongly impelled together, and driven into the closest possible contact, at length hook into each other by means of the little serrations on their surfaces, until they become firmly and inextricably united; each thread, both of the warp and weft, being so compacted with those that are contiguous to it, that the whole seems formed into one substance, not liable, like other woven goods, to unravel when cut with the scissors. This compacting process in the cloth manufacture is effected by beating, and is called *fulling*; in the hat-manufacture it is effected by pressure and rolling, and is called *felting*; but the two are clearly analogous in principle. This process thickens the cloth remarkably, but diminishes it both in length and breadth nearly one half.

In the fulled state the cloth presents a woolly and rough appearance, to improve which it goes through the processes of *teazling* or *raising*, and *shearing* or *cutting*. The object of the first is to raise the ends of the fibres above the surface, and of the second to cut them off to a uniform level. The raising of the fibres is effected by thistle-heads, teazling-cards, or wire brushes. Teazles are the seed-pods of the *dipsacus follonum*, having small hooked points on their surfaces. They were formerly used in the cloth manufacture thus: a number of them

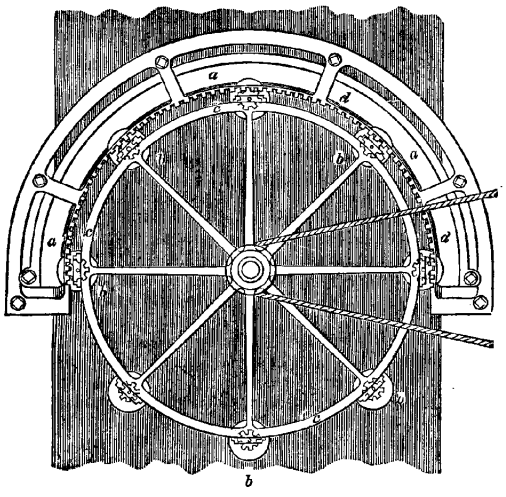
were put into a small frame with handles, so as to form a kind of curry-comb; and this was worked by two men over the surface of the cloth, which was suspended horizontally, the direction of working being first parallel with the warp, and then parallel with the weft. From the trouble required to clean the barbs of the teazles when filled with woollen fibres, from the weakening of their points by the water with which the cloth was saturated, and from the high price which the large demand enabled them to command in the market, numerous attempts were made from time to time to substitute metallic points; but from various causes the teazles are still preferred, and are now used in a more efficacious way than formerly. The teazles are arranged on a cylinder in a machine called a *gig-mill;* the cloth is stretched on



Gig-Mill.

two cloth-beams; the cylinder moves in one direction and the cloth in another, and the fibres become thereby worked or combed up. The annexed cut shows the section of such a machine; where the cloth, passing from a roller *h*, round the roller *i*, comes in contact with the brushes *c* on the wheel *a*, and afterwards passes round *g* and *l* to the roller *k;* the roller *g* being so regulated by the pinion *n* and the rack *m* as to keep the cloth thoroughly stretched; and the revolving brush *f* being so adjusted as to clean the teazling-cards *c*. In some machines the teazling-points are made of wire, to obviate the waste of 3000 natural teazles, which takes place in the dressing of one piece of cloth.

When the ends of the fibres have been thus raised to the surface, they are next *sheared* or *cropped*, a process of great beauty and singularity. Originally this process was performed by means of large hand-shears, the cloth being stretched over a stuffed table, and the workman proceeding to clip the ends of the fibres in a regular and equable manner. This was an operation requiring great dexterity; and the men who worked at it being in the receipt of good wages, were so



Cloth-shearing Machine.

alarmed at the introduction of shearing-machines, in the early part of the present century, that serious riots occurred in the west of England. But the machines became by degrees extensively employed. They consisted each of a pair of shears, as in the hand-method; but all the movements were effected by machinery. More recently a machine has been introduced, the action of which is regulated on a different principle, as will be seen from the annexed cut: *b b b* are disk-formed cutters, working against a thin bar of steel, *a a a*, of a semicircular form; which cutters in their revolution travel round against the edge of the bar or blade in such a way as to shave off the filaments standing up on the surface of the cloth beneath. The cloth is represented by the shaded part. The wheel *c c c*, set in motion by machinery, imparts action to the circular cutters attached to it through the medium of the rack *d d*. It is easy to see that, whether the machine travels along over the cloth, or the cloth travels along beneath the machine, every part of the fibrous surface is acted upon in precisely the same way by the double rotation of the wheel and the disk-cutters. There are other shearing machines in use, of equal ingenuity.

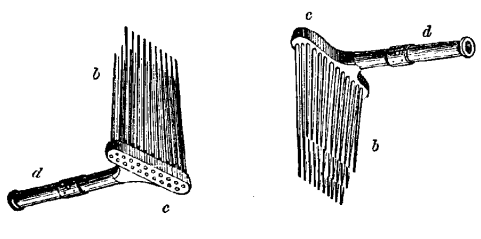
When the cloth has been raised and sheared (which operations are repeated two or three times for superfine cloth), it is *brushed* by a machine consisting of a system of brushes affixed to cylinders; the cloth being exposed at the same time to the action of the brushes and of steam. A few subsequent operations are carried on, having for their object the imparting of smoothness, gloss, &c. to the cloth, preparatory to its being placed in the hands of the dealers.

We have described most of the manufacturing operations in their simpler forms, for more ready comprehension; but it is well to bear in mind that new machines and new processes are being continually brought into this department of industry. A meeting of Leeds woollen manufacturers took place in 1860, to examine a new French machine invented by MM. Tavernier and Vouillon, "to convert slivers or rovings, as they came from the carding-engine, into threads suitable for weaving, by felting and friction, without any spinning process." It was declared that "many gold medals had been awarded in France for the invention; that many of the machines were at work; that no oil or size is necessary as a dressing; and that 30 per cent. of wool is saved." So far as we are aware, this favourable description failed to make the intended impression on the manufacturers. Many of the recent novelties in the trade relate to the employment of cotton for warp-threads, and of rag-wool mixed with new wool for weft; a subject briefly noticed under SHODDY MANUFACTURE. One inventor has brought into use a machine called a *combiner*, by which, when attached to the carding-engine, the wool is brought off in a continuous sliver wound on cylinders, ready to be conveyed to the spinning-machine. Mr. Archibald, of Tillicoultry, in 1858, introduced a machine for piecing the lengths of carded wool as they leave the carding-engine, and forming them into a continuous length or roving; the rolls drop into reversing channels, and thence to travelling belts, which convey them to a machine where they are connected into a length more uniformly than in the ordinary way. Without noticing the almost numberless new machines and processes, we may just mention a very curious process, patented by Messrs. Tolson and Irving, for imparting a metallic lustre to fine woollen cloth. The cloth, either in the yarn or when woven, is steeped in a solution of sulphate or oxide of copper, lead, or bismuth, and then exposed to steam charged with sulphuretted hydrogen gas, by which a metallic deposition takes place.

Other matters relating to the manufacture of woollen cloth will come under notice presently.

Worsted or Stuff Manufacture.—The long wools for worsted fabrics, not being felted or fulled, pass through a series of operations different from those hitherto noticed; since the object in view is rather to lay the fibres in a parallel position than to twist and entangle them one among another. All combing-wools are longer in fibre than the clothing-wools, but they are subject to the division into *long* and *short* combing wools; the long, varying from six to twelve inches in length, being used principally for coarse worsted goods; and the short, from four to seven inches, being used for hosiery and some other purposes.

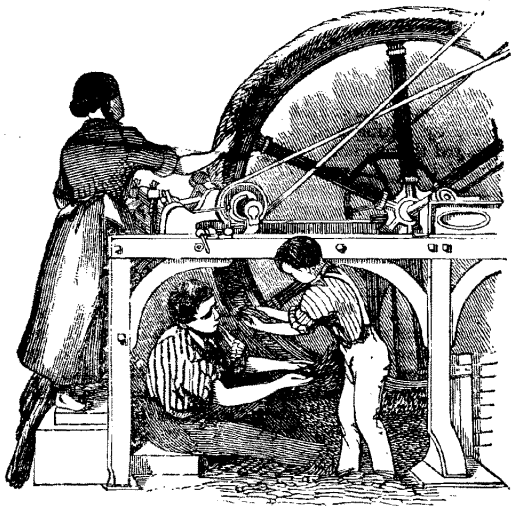
After the wool has been *sorted, washed*, and *scoured* from the adherent grease, and *dried* in a heated room, it is carried to a machine called a *plucker*, containing a pair of spiked rollers, by the action of which the wool is cleansed, separated, and the fibres straightened, preparatory to the process of combing. In *hand-combing*, which, until modern times, was the only mode followed, and which is rather laborious work, the proceedings are somewhat as follow:—The comber is provided



Wool-Combs.

with a pair of combs such as are here represented, a comb-post to which to attach the combs, and a comb-pot or stove for heating the

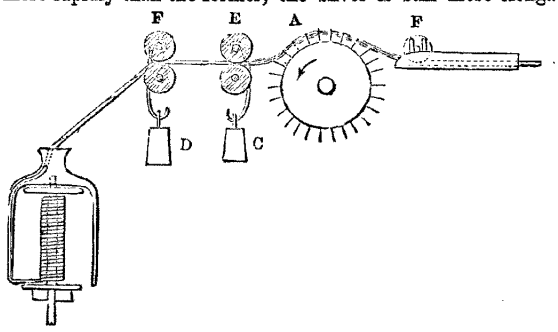
teeth. Each comb consists of two or three rows of steel teeth, *b*, one row longer than the other, inserted in a wooden stock or head, *c*, from which protrudes a handle, *d*, at right angles to the direction of the teeth. The workman first heats the teeth of one of the combs in the stove, and fixes it in the post, teeth uppermost. He then takes a small handful of wool, consisting of about four ounces, sprinkles it with oil to increase the pliancy and ductility of the filaments, and works it about between his hands to equalise the oil on every part of the fibres. The comber then takes half the bundle of oiled wool, and dashes it on the upturned teeth of the comb, till it is all deposited there, and caught between the teeth sufficiently firm to be retained. The comb with its wool is placed, points downwards, in the stove; and the comber next fixes the other heated comb in the comb-post, lays the other half of the bundle of wool on it, and places this likewise in the stove. When both combs with their supply of wool are properly warmed, the comber holds one of them over his knee with his left hand, while seated on a low stool, and with the other comb, held in his right hand, he combs the wool upon the first, by introducing the points of the teeth of one comb into the wool contained in the other, and drawing them through it. This is repeated till the fibres are laid parallel. The wool which remains uncombed on the teeth, and which constitutes about one-eighth of the length of the fibres, is unfit for spinning into worsted, and is consequently applied to other purposes. In *machine combing*, the apparatus sometimes consists of two wheels of large diameter, like the



Combing-Wheel.

one here sketched, having wires placed round the circumference, parallel with the axis, and pointed at one end so as to act like teeth. A boy, sitting on the ground, strikes wool on the points of the teeth in one wheel, so as to make it adhere to and between them. The two wheels are then made to rotate, the distance between them being such that the teeth of the one can draw through or comb the wool lying on the teeth of the other. This is effected with great rapidity; and when the combing is completed, the *top* or combed worsted is taken off by a boy or girl in a continuous sliver from the upper part of the wheel, while the *noils* or uncombed part is removed by another boy.

When the wool has been combed either by hand or machine, it is transferred to the *breaking-frame*, the object of which is to open out any fibres which may have escaped the action of the combs. In this machine the wool, after passing between rollers, is exposed to the action of a kind of endless comb, travelling round two rollers distant from each other; and the arrangements as to relative velocities are such, that the wool becomes somewhat drawn out as well as combed parallel, and leaves the machine in the form of a roll or narrow belt. The sliver of wool proceeds to a large bobbin or cylinder, round which it is lapped into a continuous roll. It is then passed a second time through a breaking-frame, having teeth finer and more closely set than the former. The soft woolly riband is then subjected to the action of a machine analogous in principle to the *drawing-frame* of the cotton manufacture; the object being to extend the length, diminish the thickness, and equalise the number of fibres of the sliver. Hitherto the woolly fibres are merely slightly coherent, without having any twist; but they are now passed through a *roving-machine*, preparatory to the process of spinning. The working parts of this machine are slightly shown in section in the annexed cut. The wool-carding or sliver passes beneath a roller F, towards a cylinder E, the surface of which is studded with points or teeth. The wool, after being acted on by these teeth, passes between the pair of rollers A, where it is pressed by the upper roller being urged downwards by the weight C. Of these rollers the upper one is of wood covered with leather, and the under one of iron, fluted parallel with the axis; and the rollers being made to rotate faster than the feeding-roller F, it necessarily follows that the sliver of wool becomes elongated to a state of still greater tenuity while passing between them. It is then caught by a second pair of rollers B, kept in close contact by the weight D; and as these rotate still more rapidly than the former, the sliver is still more elongated,



Roving-Machine.

until its thickness is so small that the fibres can scarcely cohere. But in order to give them the requisite coherent strength, they are slightly twisted by the bobbin and fly G, that beautiful contrivance which is so extensively adopted in the textile manufactures. One fork or leg of the rotating flyer G is hollow or tubular, and down this tube the delicate cord of wool passes; then, by the rapid rotation of the flyer, the wool or *roving* becomes wound on the spindle of the bobbin concentric with the flyer. The straight or rectilinear motion of the roving while approaching the flyer, combined with the circular motion at the flyer itself, imparts a twist to the roving, sufficient to enable it to undergo the process of spinning.

The spinning of the worsted bears so close a resemblance to that of cotton, as described in COTTON MANUFACTURE, and SPINNING, that a reference to those articles will suffice to convey a general notion of the process. When spun, the worsted yarn is wound on a reel, and is thence made up into hanks of 560 yards each. These hanks receive denominations according to the number of them which go to a pound, and the yarn derives its name in like manner: thus, No. 24 yarn has 24 hanks to the pound. In some instances the hank is reckoned at 840 yards. The hanks are tied up into pounds; the pounds are combined into bundles; and the bundles are made up into bales of 240 lbs. each, ready for the market.

Here terminate the operations of a worsted-mill; for the dyeing of the yarn, and the weaving into the various kinds of textile fabric, lead us to other departments of industry. [DYEING; WEAVING.]

The worsted manufacture, like that of woollen, has been marked by the introduction of many new machines and processes within the last few years. Two or three of these may be briefly noticed. English wool is becoming less and less fitted for cloths, and more and more fitted for worsteds. Moreover, a length of staple, necessary under the old process of combing, is less needed under the modern. From both of these causes any kind of English wool, from three-inch staple upwards, is rendered available for one or other of the numerous kinds of worsted manufactures. Carding-machines in great variety have been adopted; and the chief inventor, Mr. Lister, made an attempt in 1855 to overturn the patent-claims for many of them, but failed in a court of law. Messrs. Croft and Steel's machine, introduced at Keighley in 1857, has a number of combs, each forming a circular segment; they are fixed to the outer ends of radiating arms carried by a horizontal disc, which rotates on a vertical axis. The combs, while rotating, pass in front of a feeding apparatus, and have a peculiar combing motion given to them by means of cranks; they advance and retire, rise and fall, and rotate, all at once. Each comb takes its proper quantity of wool from the feeder, and carries it round to the drawing-off roller. There are circular brushes to clean each comb after its passage, and a hot chamber in which the teeth are warmed. The great increase in the facility of machine-combing has been one cause of the more rapid advance of the worsted than of the woollen manufacture. Another is, that the fly-spindles, which so late as 1848 only made 2800 revolutions per minute, are now driven at the enormous velocity of 6000 revolutions. Another is, that while woollen cloth, from its great width (often 9 feet before being milled), cannot be woven at more than about 50 picks of the shuttle per minute, worsted weaving is often conducted at the rate of 160 picks. So great is the facility now offered for the use of cotton in mixed goods, or stuffs and worsteds, that out of 100 pieces of all kinds, taken indiscriminately from those produced in the Bradford district, it is estimated 95 have cotton warps; while the total weight of the whole produce is supposed to be two-thirds wool and one-third cotton. One of the curious novelties of recent years is Messrs. Saunders and Smith's process for utilising the *grease* resulting from the various scourings and washings to which the wool is subjected. Iron pipes convey the greasy water to a tank, whence a pump draws it up to other tanks, where it is heated by steam to 160° Fahr. Certain chemical substances are added, by which the creamy sud is converted into a scum and a sediment, with a liquor between them. The liquor is drawn off as useless. The scum

and the sediment, nearly alike in composition, are drained in bags of matting, pressed forcibly, and made to yield an oily fluid. The fluid is used in making stearine, soap, and other saleable chemicals, while the refuse oil-cake is sold as manure. The patentees supply all the additional apparatus, besides buying the greasy wash at a stated price, *Crcash*, or wool-waste so saturated with oil as to contain more oil than wool, is eagerly bought up by farmers as a powerful manure.

Localities and Varieties of the Trade.—When it is considered that woollen and worsted goods differ primarily in the length of fibre, it is easy to imagine that many varieties may be produced, according to the extent to which this separation is carried out. The various modes too in which the warp and weft threads are made to interlace, as explained in WEAVING, naturally lead to the production of many different classes of goods. These four conditions, namely, the length of fibre, the application or not of the felting quality, the production or not of a velvet-like nap or pile, and the diversities depending on the loom, give rise to innumerable and fancifully-named kinds of woollen and worsted goods. Blankets, flannels, stuffs, merinos, mousseline-de-laines, bombazines, tammies, shalloons, says, moreens, calimancoes, camlets, lastings, baize, and a host of other names, some of which are now nearly or quite out of use, or are giving way to others, point to the diverse applications of long-wool in the production of woven fabrics; while kerseymere and other names indicate distinctions in the felted-wool goods. But besides these diversities, there are others depending on various circumstances; such as the admixture of woollen with worsted, or of either of them with cotton or silk, in the same fabric; the dyeing of the material, sometimes in the piece, sometimes uniformly in the yarn, and sometimes in a party-coloured mode called *clouding*; and the printing of devices on one surface.

A few examples may suffice to illustrate this diversity. Plain *broad-cloth* is a specimen of plain weaving, followed by the fulling process; whereas *kerseymere* is a twilled fabric, similarly fulled. *Serges* are twills, having worsted warp and coarse woollen weft. *Blankets* are made of very soft yarn, afterwards worked up into a kind of pile by milling; and many varieties of coarse cloth are of analogous structure. *Bombazeen* is a twilled mixture of worsted and silk; whereas *Poplin* is an untwilled mixture, showing more silk than worsted at the surface. *Saxonies* and *Orleans* are made of wool, sometimes mixed with cotton, and afterwards printed. *Stuff* is made wholly of worsted; while *Merino* is a fine woollen twill, sometimes printed. The material called *Cashmere*, if properly so named, is made of the shawl-goat wool, much in the same way as merino; but most of the fabrics so called are made of sheep's wool. *Challis* is a mixture of woollen weft with silk warp, and is generally printed. *Mousseline-de-laine* was originally all wool, but is now frequently mixed with cotton, and generally printed. *Norwich crape*, unlike common crape, is composed of wool and silk, something like challis, but without being printed. *Crêpe de Lyon* is formed of worsted and silk; and *Italian net* of worsted only. In *Waistcoatings*, fancy-weaving adds another to the sources of diversity. Many of the above kinds are briefly described under their proper names in this Cyclopædia; while a number of additional kinds will be found noticed under SHODDY MANUFACTURE.

The West Riding of Yorkshire, the most important clothing-district in England, exhibits an area of nearly 40 miles by 20 occupied by clothing towns and villages. Leeds, Bradford, Halifax, Huddersfield, Dewsbury, and Wakefield are the great manufacturing centres. Mixed or coloured cloths are made principally in the villages west of Leeds and of Wakefield; white or undyed cloths are made chiefly in the villages occupying a belt of country extending from near Wakefield to Shipley. Flannels and baizes are the principal woollen articles made in and near Halifax, together with army cloth. Blankets are made on the line between Leeds and Huddersfield. Bradford provides very largely the spun worsted required for the various manufactures. Stuffs are made at Bradford, Halifax, and Leeds; and narrow cloths at Huddersfield. Saddleworth furnishes broad-cloth and kerseymeres. In the neighbourhood of Batley and Dewsbury are the shoddy mills. The West of England takes rank next to Yorkshire, and formerly took precedence of it. The finest kinds of broad-cloth, from Saxony, Australia, and Spanish wool, are made in Gloucestershire. The manufacture is carried on in a district called the *Bottoms*, and in other parts of the country; the town of Stroud being a kind of centre for the whole. Wiltshire produces very fine cloths, at Bradford, Trowbridge, Westbury, Melksham, Chippenham, and the surrounding villages; while cloth of various kinds is made at Wilton, Warminster, Heytesbury, and Calne. Taunton, Frome, Tiverton, and the surrounding villages constitute the Somersetshire clothing district. Devonshire and Dorset have little woollen manufacture. The Norfolk district was long the principal seat of the stuff or worsted manufacture. Bombazeens, crapes, camlets, and shawls have constituted the chief fabrics for which Norfolk has been celebrated. These are the three great English districts engaged in the consumption of wool; to which may be added Leicestershire, where nearly all the worsted stockings are made. It must be noted, however, that Yorkshire, with its abundant machinery and cheap coal, is every year absorbing a larger and larger proportion of the whole manufacture. In Wales the principal manufactures relating to wool and worsted are strong webs or high-country cloths, small webs or low-country cloths, flannels, stockings, socks, wigs, and gloves; the chief counties being Montgomery, Merioneth, and Denbigh. The strong webs are used principally for workmen's jackets, ironing cloths, &c.; while the small webs are largely used for slaves' clothing in the West Indies. In Scotland the fine woollen manufacture is upon a very limited scale; but a good deal is done at Aberdeen, Stirling, Galashiels, Jedburgh, Hawick, Inverness, Kilmarnock, and Paisley, in the production of various kinds of woollen and worsted goods, such as coarse plaiding, clan-tartans, woollen-hose, blankets, flannels, and especially carpets and shawls. The manufactures of woollen and worsted goods in Ireland are small in extent.

Different usages prevail in different counties respecting the connection between employers and employed, buyers and sellers, in the woollen and worsted manufactures. In the West of England the general plan of operation is this:—The master-clothier buys his foreign wool from the importer, and his English wool from the wool-stapler. He employs in all the different processes through which the wool passes in the course of manufacture, distinct classes of persons, who sometimes work at their own houses, and sometimes in the factory of the master-clothier. Each workman confines himself exclusively to a particular branch of the manufacture; and this has been supposed to have led to the excellence of the West of England cloth.

A second mode is on the factory system, now extensively adopted in the West Riding of Yorkshire. The master-manufacturer, who generally possesses a large amount of capital, employs a great number of workmen in one or more buildings, under the inspection of himself or a superintendent. In this system, as in the master-clothier system, the workman has no property in the material on which he is employed.

In the domestic system, which was the one originally adopted, the arrangement is altogether different. Under this system the manufacture is conducted by a number of small masters, who are generally possessed of very limited capital, and who, besides their business as manufacturers, mostly occupy farms of a few acres, partly for the support of their families, and partly for the convenience of their manufacture. The domestic clothiers have in their houses from one to four looms, on which they employ themselves, their wives, and children, and perhaps other assistants. During harvest their wives, children, and servants are sent out into the fields to work. Formerly these clothiers used to carry the wool through all the stages of its manufacture, till it was brought to the state of undressed cloth; but of late years they have availed themselves of public mills, which are established in and among the clothing-villages, for the performance of some of the processes. These mills have been erected on a joint-stock principle, by shares of 50*l.* or 100*l.* each, principally subscribed by the domestic clothiers. When machinery began to be extensively employed in the woollen manufacture, in the early part of the present century, the domestic clothiers became violently excited, under the apprehension that their trade would be taken from them by the newly-invented machines. A parliamentary committee was appointed to inquire into the probable operation of machinery in respect to the well-being of the domestic clothiers; and after examining numerous witnesses they made a report, in which they detailed the distinctive features of the factory and the domestic systems, and came to a conclusion that "the two systems, instead of rivalling, are mutual aids to each other; each supplying the other's defects, and promoting the other's prosperity." "Experience," says Mr. M'Culloch, "has proved the correctness of these conclusions. The number of small manufacturers, and the quantity of cloth produced by them, have both increased since 1806; but, as the number of factories, and the quantity of cloth made in them, have increased still more rapidly, the former constitute, at present, a less proportion of the trade." One circumstance which has enabled the domestic system to maintain its ground, is, that the great width of woollen cloth has been a difficulty in the way of power-loom weaving; the hand-loom cannot compete with steam in the stuff trade, but it can in broad-cloth. The domestic system would nevertheless have succumbed, had not the clothiers prudently adopted the joint-stock principle for their mills. Each shareholder takes his own wool to the mill to be cleaned, dyed, carded, and spun; brings it home to weave by himself and family; takes it to the mill to be fulled, washed, and tentered; and sells it at the cloth halls to merchants who employ dressers to finish it.

As respects the *sale* of the cloth, halls have been established for this purpose at Leeds, Halifax, Bradford, Huddersfield, and other towns, which are attended on the public market-days by thousands of the smaller class of manufacturers. The halls are divided into long walks or galleries, consisting of rows of stands, each of which is marked with the name of the person by whom it is occupied. On these stands the cloth is exposed for sale; and when the market opens, the manufacturers take their stations at the stands behind their goods, the merchants or buyers passing, to make their purchasers, through the avenues between the rows. The time during which the halls are open is limited usually to about one hour and a half; but in this short interval purchases to a very large amount are made. The cloth-halls at Leeds are appropriated exclusively to the use of those who have served regular apprenticeship to the business of cloth-making. They are managed by trustees, and many of the stalls are the freehold property of the persons who occupy them. All the cloth sold in the halls is rough and undressed. Those by or for whom it is bought have what are termed finishing-shops, where the cloth is shorn, dressed, and fitted

for use. This is analogous to a system pursued by the bobbin-net manufacturers at Nottingham, where the net is sold by the maker in the rough state as it leaves the loom, and purchased by other parties, who singe, dress, and finish it ready for the market.

Statistics of the Trade.—In 1739, the writer of a pamphlet on the subject of wool estimated the number of persons engaged in the woollen manufacture at 1,500,000, and their wages at 11,737,500*l.* per annum. This estimate was obviously an overcharged one. Dr. Campbell, in 1774, thought that there might probably at that time be 1,000,000 persons employed in the manufacture in England; that the value of the wool used was 3,000,000*l.* per annum; and that this value was increased to 12,000,000*l.* by the processes of manufacture. In 1800 the woollen manufacturers, in committee before the House of Lords, made the extravagant estimate that there were then 1,500,000 persons directly engaged in the manufacture; that an equal number were collaterally employed in it; that the value of the wool used was more than 6,000,000*l.* sterling; and that of the manufactured goods nearly 20,000,000*l.* sterling. In 1815 Mr. Stevenson supposed that there were half a million persons employed, receiving 9,600,000*l.* per annum wages; and that this sum, added to the value of the raw material, the interest on capital, the manufacturer's profit, &c., gave 18,000,000*l.* as the annual value of the cloth produced. Mr. M'Culloch ('Statistical Account') forms an estimate on the following data:—That there are about 150,000,000 lbs. of wool worked up yearly; that this may be worth about 7,500,000*l.*; that the value of the manufactured goods is three times that of the raw wool, making therefore 22,500,000*l.* per annum; that this value is thus made up:—

Raw material	£7,500,000
Oil, soap, dye-stuffs, &c.	1,600,000
Interest, profit, &c.	4,650,000
Wages	8,750,000
	£22,500,000

And dividing this amount of wages at the rate of 26*l.* a year to each operative on an average, he arrives at the number 334,600, which he thinks a probable approximation to the number of persons employed in the woollen manufacture in this country. Mr. Chapman (one of the Assistant Hand-Loom Commissioners) made an estimate which agrees pretty nearly with that of Mr. M'Culloch; although at the first glance the two estimates seem discordant. He thinks that, in 1831, the number of families directly dependent on the manufacture were—

In the West Riding of Yorkshire	85,096
In the West of England	20,851
In Norfolk and Kendal	17,570
In the hosiery district	20,464
In all other places	20,000
	163,981

Then, taking the average number of persons in a family at 5⅓, he arrives at an aggregate of 874,565 persons directly supported thereby. He further supposes that this number must have increased, by 1841, to 226,298 families, or 1,218,424 individuals. Mr. M'Culloch's estimate is of the number of persons *employed*, while Mr. Chapman's is of the number of persons *supported*; and this may explain the apparent discrepancy between the two estimates. As to the value of the manufacture, Mr. Chapman proceeds thus:—226,298 families, earning, on an average, 17*s.* 6*d.* per week each family, which amounts to 10,296,559*l.*; and the relation between this and the other items of the cost he thus states:—

Value of wool employed	£10,000,000
Oil, dye-stuffs, soap, &c.	1,500,000
Wages	10,296,559
Wear and tear, profit	4,359,311
	£26,155,870

In the last edition of his 'Commercial Dictionary,' Mr. M'Culloch makes an estimate, which he supposes to approximate pretty nearly to the true figures for the year 1858. He takes the consumption of English wool at 110 million lbs. at 1*s.* 3*d.* per lb., and that of foreign at 60 million lbs. at 2*s.* Then he makes up four large items thus:—

Wool	£12,875,000
Wages	7,725,000
Soap, oil, dyes, &c.	1,200,000
Profit, interest, wear and tear	4,200,000
	£26,000,000

Besides 2,000,000*l.* worth of shoddy and mungo manufactures. So far as regards woollen and worsted mills, and the persons engaged in them, see FACTORIES. Some writers have guessed the total value at 50,000,000*l.*; but this is only a guess. At a recent period, in a woollen factory at Leeds, 570 persons were found to be earning 12*s.* 11*d.* per week on an average: namely, men's average 22*s.* 3*d.*; women and girls', 8*s.*; boys', 6*s.* 8*d.* Mr. Baines, in an article in the 'Statistical Journal' for 1859, estimated that the woollen manufacturers (without the worsted) use up 156 million lbs. of British and foreign wool, 45 million lbs. of shoddy and mungo, and cotton to the value of 200,000*l.*; that the value of these fibres is about 10,500,000*l.*; and that the wages, oil, soap, dyes, profit, interest, rent, and wear and tear, raise the total value to 20,290,000*l.* He estimates that 150,000 persons were employed in the woollen manufactures in 1858; Mr. M'Culloch estimates 275,000 persons employed in the *woollen and worsted* manufactures in the same year.

From 1725 to 1820 all the cloths made and fulled in the West Riding were measured and stamped by officers appointed for that purpose, and from the returns made, it appears that there were fulled, in the West Riding, the following number of pieces of broad and narrow cloth, in the years named:—

	Broad.	Narrow.		Broad.	Narrow.
In 1726	26,071	..	In 1786	158,792	123,025
1746	56,637	68,775	1806	290,269	175,334
1766	72,575	78,893	1816	325,449	120,901

The woollens and worsteds exported in 1820, 1830, and 1840, had a value of 5,587,758*l.*, 4,728,666*l.*, and 5,327,853*l.* respectively. In 1845, 1850, and 1855, the value rose to sums varying from nine to ten millions sterling annually. The figures for the year 1860, given somewhat more in detail, will show in what way the manufacture subdivides itself into kinds. The exports in the year just named were as follow:—

Woollen cloth of all kinds	579,135 pieces.
Mixed stuffs, flannels, blankets, and carpets	93,079,584 yards.
Mixed stuffs entered at value	£493,526
Worsted stockings	272,332 dozen pairs.
Worsted stuffs	2,616,756 pieces.
Woollen and worsted yarns	245,839 cwts.

The value of all these exports exceeded 16,000,000*l.* The United States were the largest purchasers of the woven goods; the yarn went in greater quantity to Germany.