AS APPLIED TO TEXTILE MANUFACTURES.

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THE term manufacture is no longer confined to its original signification—the production of human manipulation—but is now generally applied to articles made by machinery, from raw materials, supplied by a beneficent Providence, for adaptation by the industry and ingenuity of man for the wants and enjoyments of civilised society.

To some minds manufacturing has lost its dignity by the substitution of the iron arms and fingers of machinery, for the bone and sinew and nerves of the cunning artificer who, within little more than a century, produced all that then existed of manufacture. But this is surely a misconception; and a very different impression will, we conceive, be left on the minds of all who have had an opportunity, however cursory, of contemplating the tools and machinery applied to manufactures, so liberally displayed in the Exhibition of the Industry of all Nations, and which we are now to endeavour briefly to elucidate and explain.

The object we have in view is to convey to general readers such information on the principles and exact functions of manufacturing machinery, as will increase their interest in what they may have seen for the first, and, in many cases, it may be for the last time, in the Great Exhibition, and enable them to carry away with them truer impressions of the amount of thought and ingenuity that has been expended in the creation of the automatic fabricators of the most complex as well as simplest necessaries and conveniences they find in use in their routine life, than they otherwise could do. It is not our intention to describe this manufacturing machinery in detail, suited for the instruction of manufacturers; we shall only attempt to give a correct account of the mechanical processes exhibited, sketched with the view of making their characteristic excellencies understood, but without any pretension to set forth their comparative merits further than mentioning those features that display the progressive improvement of the various processes selected for our purpose.

As in the labour of the artificer there is combined a physical exertion and a manual dexterity,—the latter an emanation of mental exertion, the former requiring a regular supply of food and raiment to the body, in order that the "right hand may not lose its cunning,"—so in manufacturing machinery, there are two great principles developed; there are machines which are adapted to *receive and modify the powers of nature*, and machines which are contrived *for the transport and for the change of the form or texture* of materials.

Every machine is contrived to perform some given mechanical process, which supposes the existence of two other things besides the machine, namely, a *moving power* and *work to be done*, i.e., an object subject to the process in question. Machines, in fact, are interposed between the *power* and the *work*, for the purpose of adapting the one to the other.

As an example connected with our subject, the old spinning-wheel may be cited, in which the spindle and fly are made to revolve by application of the foot to a treadle. Here the motive power is derived from muscular action: the operation of spinning is carried on by drawing out the fibre from the *rock*, and supplying it regularly to the fly, which is caused to turn rapidly and twist it into a thread or yarn. The arrangement of the form of the fly and spindle, and its connection with the foot in such a manner that the pressure of the latter shall communicate the required motion to the former, is the function and object of the machine.

This machine, we see, consists of a series of connected pieces, beginning with the treadle, the construction, position, and motion of which are determined by the nature of the moving power, and ending with the fly and spindle: but this is, in fact, the description of every machine. There is always one or more series of connected pieces, at one end of which is a part especially adapted to receive the action of the *power*—such as a steam-engine, a water-wheel, a horse-lever, a handle or a treadle. At the other end of each series will be found a set of parts determined in form, position, and motion, by the nature of the work they have to do, and which may be called the working pieces: between them are placed trains of mechanism, connecting them so that, when the first parts move according to the law assigned to them by the action of the power, the second must necessarily move according to the law required by the nature of the work.

There are, we thus see, three classes of mechanical organs independent of each other, inasmuch as, on the one hand, any set of *operators* or working parts may be put in motion by power derived from any source. Thus, a fly and spindle may be turned either by the foot, by water, or by steam. Again, a given steam-engine, or water-wheel, or any other *receiver* of power, may be employed to give motion to any required set of working parts for any process whatever. Also, between a given *receiver of power* and set of working parts the interposed mechanism may be varied in very many ways. Moreover the principles upon which the construction and arrangement of these three classes of mechanical organs are founded are different. The receivers of power derive their form from a combination of mechanical principles with the physical laws which govern the respective sources of power. The operators derive their form from a combination of mechanical principles with considerations derived from the processes to be performed. The principles of the interposed mechanism are purely geometric, and may be developed without reference to the powers employed or transmitted. Mechanism is a combination of parts connecting two or more pieces, so that when one moves according to a given law, the others must move according to certain other given laws. A train of mechanism is composed of a series of moveable pieces, each of which is so connected with the framework of the machine, that when in motion every point of it is constrained to move in a certain path, in which, however, if considered separately from the other pieces, it is at liberty to move in the two opposite directions, and with any velocity. Thus, wheels, pulleys, shafts, and revolving pieces, generally are so connected with the frame of the machine, that any fixed point is compelled, when in motion, to describe a circle round the axis; sliding pieces are compelled by fixed guides to describe straight lines, and so on. These pieces are connected either by contact or by intermediate pieces, so that when the first piece in the series is moved from any external cause, it compels the second to move, which again gives motion to the third, and so on.

The act of giving motion to a piece is termed *driving* it, and that of receiving motion from a piece is termed *following* it. The *follower* receives motion from the *driver*.

In the view we are about to take of the Manufacturing Machines of the Exhibition, we exclude any reference to the *receivers of power*, important as is the part they play in the history and economy of manufactures. Our object is specially to record mechanical processes, and to give some idea of the mechanism of the machines applied to textile manufactures exhibited. We have chosen an order for treating of the mechanical processes by which textile fabrics are produced, which leads from the simple to the complex, and which shows the origin of the improvements that led to the wonderfully perfect machinery exhibited as applied to each and all textile fabrics.

These processes depend primarily on the nature of the materials—the raw materials to be worked up. *Silk, Cotton, Flax,* and *Wool,* require different methods of preparation for being *spun* and *woven,* the ultimate processes in the union of all textile fibres.

Silk Manufactures.—It would be out of place to enter into any details in regard to the little worm which produces the millions of pounds of raw silk annually produced and worked up on the continent of Europe, in India and China, and imported into Great Britain to supply this branch of industry.

In the French, the Milanese, the Piedmontese, the Tuscan, the Roman, Neapolitan, Algerian, Chinese, and Indian departments of the Exhibition, samples of the cocoons, and of the *reeled* or raw silk of these countries may be seen and examined.

The weight of cocoons varies according to the climate and management of the worms. About two hundred and thirty to a pound may be taken as an average, and twelve pounds of cocoons make a pound of raw silk. Thus 2760 worms are required for every pound of raw silk! For every *million* pounds weight of raw silk produced in France, it is reckoned that two hundred and fifty *million* pounds weight of mulberry leaves are consumed, and that five million of trees, of the average age of thirty years, are stripped to furnish them! Upwards of five million pounds of raw silk are now imported into Great Britain annually. In Britain the silk factories are almost confined to England.

The process of *Reeling the Silk from the Cocoons* is carried on in Europe in the months of July, August, and September, in establishments called *filatures,* and in the cottages of the peasantry of the countries where the silk is produced. The cocoons become an article of trade as soon as the insect inside has been killed by exposing them in an oven, or to the steam of boiling water: they are now to be *wound* off, or reeled. In the commencement of the operation, the cocoons, having been for a short time in a trough of hot water to soften their gum, the loosened ends are then taken (four together generally), twisted with the fingers, then passed through an eye on the end of a wire, and thence to the reel. Two *skeins* are generally thus formed at the same time, a child turning the reel, and a woman attending to mend the threads or fibres. The reel is so constituted, that while revolving it has communicated to it by wheel-work, a *lateral traverse* from right to left, and from left to right. The amount of traverse for each revolution being regulated so that the thread of one revolution does not overlay the other, for if it did, the natural gumminess would cause these threads to adhere. The extent of traverse is about three inches, and in the time employed in reeling this breadth of threads, the gum dries sufficiently to prevent the threads from sticking to each other at the points of crossing.

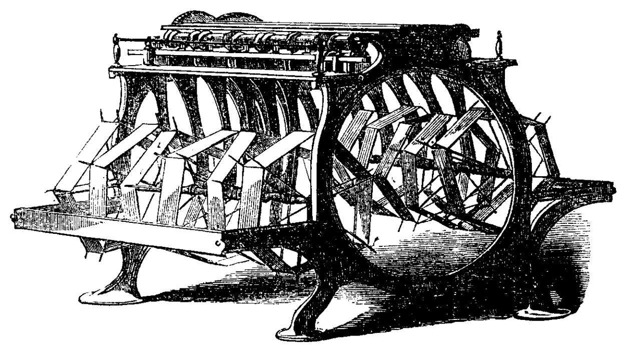
All kinds of silk which are simply drawn from the cocoons by the reeling, are called *raw silk,* but are denominated *fine* or *coarse,* according to the number of fibres of which the thread is composed.

The factories in which raw silk is spun into silk-thread for weaving are called *throwing* mills, the term *throwing* being formed from the word "throw," in the obsolete sense of "to twist," "to twine."

In 1719 a silk-throwing mill was erected at Derby. This was the first in England, and it still exists.

Winding is the first process which the raw silk undergoes.

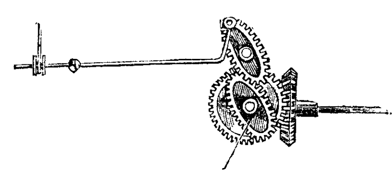
Winding—that is, transferring the silk skeins on to bobbins, was formerly done by hand, on machines carrying four or six reals and as many bobbins. The winding machines now are driven by power of steam or water, and are arranged in frames carrying as many as one hundred *swifts* or reels. The winding requires the unwearied attention of children to mend the threads that break as well in this process as in the next. There are about eight thousand children under thirteen years of age employed in British silk factories.



Our drawing represents the winding machine as made by Mr. Frost of Macclesfield, the skeins of raw silk are put on to the *swifts* which are *six-armed reels,* with string cross bars to form the fork in which the skein lies. The axles of the swifts lie loosely in centres, and the framing descends no lower than this centre, so that there is very little liability to knocking. The thread is passed through glass guides, arranged on a traversing guide bar, to the bobbins.

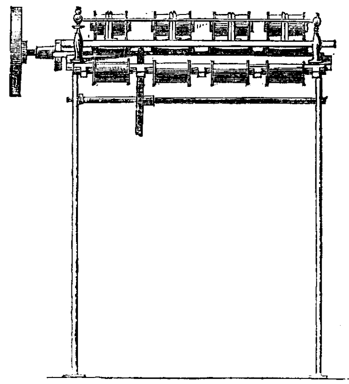
The bobbins are turned by double wooden rollers, turned out of one solid piece of wood causing them to run with greater truth than ordinary rollers: and by their being covered with leather, the use of chalk or rosen, to get adhesion is unnecessary, and thus a source of *soiling* the silk is avoided. By working with double rollers as is done in the machine, it is impossible that the *cheeks* and *spindles* of the bobbins can wear out.

The motion of the guide bar is produced by oval toothed wheels. The object of this motion is to *cross the threads* diagonally on the bobbins in order to prevent the threads from sticking together, that is to ensure that the unwinding them shall take the least possible force, and proceed without entangling. The drawing No. 1 represents only a small part of the length of a winding machine.

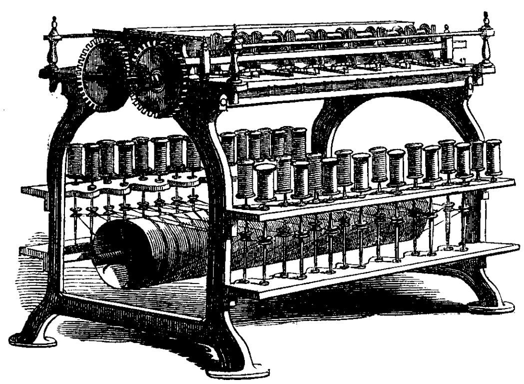


Cleaning.—The silk having been transferred from the skeins to the bobbins has to undergo a process of cleansing. This process is performed in transferring the silk from the bobbins produced on the last machine, to the bobbins or trams in the machine represented in the accompanying drawing.

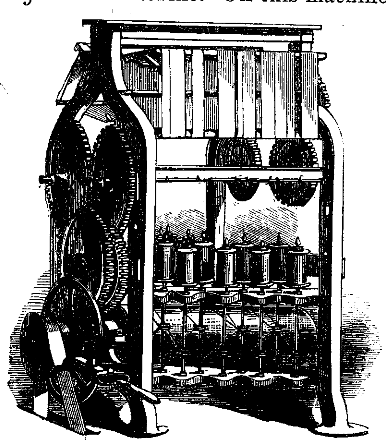
The silk has to be cleaned to rid it of adhesive gummy matter and dust. For this it is passed through a cleaner knife or double knife placed on the guide rail, by the motion of which the thread is uniformly distributed on the new bobbins. If by any accident a thread be left out of the knife, the fault is easily detected by the ridge which will appear on the bobbin. The cleaner knife rail is fitted up so as to move in a slot, and thus the degree of separation of the knife edges is adjustable to the quality of the thread or silk to be cleaned. This operation was formerly combined with a doubling of the threads, and a system of *drop wires* was introduced for stopping the bobbins when threads broke. This is now dispensed with, and *the spinning and doubling* frame in the annexed drawing performs the operation by one process and dispenses with the *stoving* of the silk, which was formerly necessary.



The silkworm-threads, perfectly cleaned, and become of a brilliant glossy appearance, are transferred to the spinning and doubling frame. In this machine, the threads from two or three of the bobbins from the cleaner are not now only wound together in contact upon another set of bobbins, but they are at once *spun* together. The lower set of bobbins are



placed vertically on spindles driven by bands from a large drum, and then, in being transferred from one set of bobbins to the other, two or more threads are laid together. The *twist*, or, more correctly speaking, the angle of lay, is kept exceedingly uniform, the *bobbin going slower as it fills*, by working an intermediate friction roller (not seen in drawing). The guider is, of course, attached to this machine again with a very slow motion, so that the doubled and spun thread is laid very uniformly and closely on the bobbins, which are now transferred to the *throwing mill* or machine. On this machine the doubled and spun threads are transferred from bobbins on to swifts or reels, and thus become *hanks* of silk in the state in which they are sent to the weaver. In this state, it is called *singles, tram*, or organzine, according as it has been made into hanks after being simply cleaned and twisted, after being doubled and twisted, or after being spun into thread by a second spinning operation.



The fineness of the silk is determined by the number of warp lengths, measuring seventy-two yards, in the ounce; fine warp silk, for instance, runs about eight score threads. That is to say, there are upwards of six miles of thread nearly in an *ounce*, or one hundred miles in a pound weight.

The mechanical processes of preparing and spinning silk are of a very simple character, and form a striking contrast to the processes to which cotton, flax, and wool have to be submitted ere they are fit for the loom. Silk-*weaving* is, on the other hand, attended with difficulties which are not met with in weaving the yarns spun from the other textile fibres of which we are to treat.

The machinery of cotton-manufacture has its application even before the "raw material" is brought to the factory.

The "cotton-wool" has to be separated from the seed. The machine now almost universally used for this purpose is the *saw-gin*, the roller-gin having been supplanted even in India. The best example of this machine is exhibited in the United States department. Till 1793, when Eli Whitney invented the saw-gin, the wool of the green-seeded cotton could only be separated from the seed by an amount of labour very discouraging to the growth of that hardy and productive article. By this invention, one man was enabled to do the work of a thousand, and there was no limit to the cultivation of the cotton save the limits to the acreage of suitable soil.

The quantity of raw cotton consumed in the cotton manufacture of Great Britain, in the year 1850, was 584,200,000 lbs., or nearly 835 tons per diem.

The machinery for manufacture of cotton—for performing the various operations that *prepare* the cotton wool, as imported from the countries where it is grown, for being spun and woven—are liberally displayed in the Exhibition by leading British manufacturers and by the French.

There are few things more interesting in manufacturing processes than the progress of the soft downy substance of the interior of the cotton-pod, with all its fine filaments and delicate colour, through its various stages, until it becomes a useful fabric for the daily wear of the industrious classes, or assumes those beautiful forms in which Art has added grace to mechanical skill and ingenuity. These gradations are at once so perfect and complete, while they are based upon the most admirable system of orderly progress, that cotton-spinning becomes a science of no ordinary character when it is carried to the perfection to which we see it here displayed. The examples exhibited illustrate the various gradations of the coarse and fine manufacture—there are cases commencing with a specimen of Sea-Island cotton, and having every stage of progress up to nine-cord sewing thread, and muslin and figured lace. The only drawback to their great interest is the crowding together of so many specimens in so small cases, since there is some difficulty in distinctly separating them. This is the more to be regretted, as the connection of the raw material with the examples around is so admirably illustrated, and, if studied in connection with the machinery, is capable of affording valuable lessons.

The yarns, exhibited as the basis of other products, show to what an extent the ingenuity of man can be carried, when employed in a given direction. There we have specimens of yarn spun by machinery, which is of so delicate a character, that the fibres of cotton can only be discovered in the fabric by the aid of the microscope; and so delicate is it that it falls to pieces by handling. This curiosity of manufacture is exhibited by Messrs. Thomas Houldsworth & Co., of Manchester, and is the result of the energy and enterprise of Henry Houldsworth, Esq., of that firm. In the contributions of this establishment we find specimens of cotton yarn ranging from No. 100 to No. 700, in single yarn; and No. 100 to No. 670, in double yarn, or lace thread. These figures express the number of hanks to a pound weight, each hank being 840 yards; and the last named number of 700 in single, and 670 in double yarn, is the triumph of cotton-spinning for all practical purposes, since we find that a pound weight of cotton is elongated, in the first instance, to a length of 338 miles; and, in the other, to a double thread 324 miles, at a cost of 28*l.*, as the price of a single pound weight. The most remarkable example, however, is the specimen shown as

No. 900, both of yarn and thread, as a curiosity, by which a single pound of cotton is extended to 430 miles. So late as 1840, 350 was the finest yarn attempted. In 1841, Messrs. Houldsworth spun 450, which was then considered as the limit. Another still more astounding specimen exhibited by Messrs. Houldsworth is that of 2150 yarn, in which we may fairly presume that they have reached the limit at which the fibre will at all cohere. A single pound of this yarn would yield the extraordinary length of 1026 miles!

The first operation of a *cotton mill* is to open up the cotton into its original spongy state and shake out any earth or vegetable matter accidentally mixed with it.

In order to mix the cotton, several bales of the same, or of different kinds, are put together in a "bing." A tool, like a hay-rake, is employed to draw down and tear asunder the agglomerated mass of cotton as it is wanted for the picking, and other cleaning processes. Fine cotton, such as the best Sea Island, is still sometimes cleaned and opened at first by the hand-labour of women and children; but various machines for accomplishing the same object have been contrived and applied to all qualities of cotton wool.

The *willow* is the machine in general use for opening out the entangled flocks of cotton.

A cylindrical cage, made of *willows*, with an axis carrying cross arms, and having a rotatory motion, was employed of old in Normandy for cleaning cotton-wool, under the name of *le panier de Normandie*. This simple machine is undoubtedly the original of the modern English willow, which has undergone various modifications, *retaining*, however, the essential features of its type.

We do not think it necessary to describe the willow properly so called, although the "conical willow," the most improved machine for this process, is exhibited both in Britain and in France. We take Calvert's patent machine for *opening* and *cleansing* cotton, as exhibited by Messrs. Hibbert, Platt, & Sons, as the most recent means of effecting this operation. This is, in fact, a scutching machine, so arranged that the preliminary process of willowing is performed within it.

The beating action is produced by rollers with long projecting wedge-edged teeth. The cotton is taken, in weighed quantities, from the bing, spread very uniform by hand on a feeding apron, which presents it to fluted rollers. These rollers present it to the toothed beaters, revolving at great speed, and so arranged that all the coarser impurities fall through. From these *beaters*, or *scutchers*, the cotton is taken up by fluted rollers, which, in their turn, pass it on to a hollow, serrated cylinder, revolving at great speed, and by which the fibre is drawn out, while the minute seeds pass through apertures left by the saw like teeth on the cylinder; and the interior of this being in communication with a fanner, which sucks through the air, the dust and fine impurities are almost completely got rid of. This cylinder is cleaned of the teazed cotton by means of brushes, which deliver the cotton on to *fluted rollers* so regularly, that it comes out of the machine *lapped* into the form of a broad, felt-like *web* of cleaned cotton.

The web of cleaned cotton thus obtained is passed through a *lapping* machine, and in this machine it undergoes a further teazing, in such manner that several laps of different qualities of cotton from the scutcher may be mixed in this machine, so as to obtain a uniform quality of *staple*. The cotton, once more formed into a fleecy lap, is brought out by rollers, and delivered on to wooden *lap cylinders*. This makes the third mechanical process to which the cotton fleece has been submitted.

The scutching machine was originally invented by the late Mr. Snodgrass, of Johnston, in Renfrewshire; and afterwards improved by Mr. Cooper, of the same place. Mr. Calvert's scutcher is, perhaps, the most perfect machine of the kind in use in any country.

From the lap machine, the cotton passes to the *carding engines*, or *cards*. The object of the carding operation is to separate or comb out the fibres of the cotton, which are still entangled in small tufts, so as to bring them into as perfect parallelism as possible. For this purpose the cotton is put through a long series of combings, which are effected by the reciprocal action of two surfaces which are mounted with slightly bent elastic wire points.

To Arkwright belongs the honour of having made the cylinder card a practical machine. This was about the year 1770.

Carding engines, says Dr. Ure, may be defined to be brushes of bent iron wire fixed in leather, applied to a set of cylindrical and a set of plane surfaces, the former being made to revolve so as to sweep over the surfaces of the latter at rest. Sometimes large cylindrical cards work against the surfaces of smaller cylindrical cards moving at a *less* speed; and sometimes both plans are combined in the same engine. The tufts or knots of cotton are held fast by the stationary or slow moving cards, while the quick moving cards teaze out the fibres, and gradually, very gradually, disentangle them. Thus we can understand how fixed cards, in which the cotton is exposed to an uninterrupted course of teazing, disentangle the long-stapled cotton better than the *squirrel* or secondary revolving cards, which bring the tufts under the action of the great drum-card only once in each of their own revolutions. They exercise a greater tearing force, and are therefore used for coarser and shorter stapled cottons, with which rapidity of work is an object of importance; in fact, much more cotton can be passed through in the same time, when both the main card and the counter cards revolve; and as the latter require less frequent cleaning than what are called the *flat-top* cards, this system is generally used in preparation for the lower counts of spinning; and occasionally in combination with fixed tops in that of the middling fine yarns.

The filaments, after emerging from the *flats*, lie in nearly parallel lines among the card teeth of the drum, when they are removed by a smaller drum card which turns in contact with it, called the doffer (stripper) or doffing cylinder, and is covered spirally with fillet cards. By its slow rotation in an opposite direction it strips the loosened filaments from the drum, and thus clothes itself uniformly with a fine fleece of cotton, which is shorn or combed off from the opposite side of the cylinder by the vibratory action of the doffing knife.

This knife is a blade of steel, toothed at its edge like a fine comb, and it is made to comb downwards with a rapid shaving motion along the edge of the cards. This is Arkwright's justly celebrated *crank and comb* contrivance. This admirably designed instrument doffs the cotton in a fine transparent fleece, and is beautiful to look upon. It is gathered as it comes off the whole width of the card, and passing through a funnel-shaped piece is gradually compressed into a riband and drawn through rollers in front of the engine. These rollers form the *card end* or *sliver*, which remains to be treated by the next process—viz., to be *doubled*. This is nothing more than a laying of forty slivers into one *fresh lap*. These forty slivers being the products of as many carding engines, and sometimes containing the fibres of many different varieties of cotton of various staples.

Uniformity and parallelism in the fibre are the great objects to be sought for in preparing cotton for the process of spinning.

The laps from the doubling machine are worked through a set of what are termed *finishing cards* which are used in many *coarse* and in all *fine* spinning factories. The finishing card does not differ in any essential respect from the *breaker card.* The large card-drum is generally surmounted by *urchin* or *squirrel* cards instead of tops, such as are used in the preparation of inferior cotton wools for spinning coarse yarns.

In a *fine* spinning mill, seven finishing cards will turn off 160 pounds of Sea Island cotton in sixty-nine hours (one week). Three yards of the lap presented to these cards weigh only four ounces. These *seven finishers* correspond to *six breaker cards.* For a *preparation*, as it is termed (one set), twelve card-ends go to form the first drawing. In the breaker-cards, 1600 grains weight of cotton are spread out upon seven feet of the apron-cloth to form one lap.

In such an establishment, 160 pounds constitute a preparation, which is confined to a given set of cards, drawers, and roving frames. One man *superintends* four such preparations.

In a *coarse* spinning mill (No. 30 and No. 40), the carding engines being surmounted with urchin cards, each does about 1000 lbs. per week. The drum makes 180 revolutions per minute.

The next process in cotton preparation is drawing out and elongating the downy slivers or ribands, to straighten the filaments, and lay them as parallel to each other as possible.

Before passing to a description of the process of drawing on the drawing frame, we must allude to the process of making *card cloth*, as exhibited in the Exhibition.

We have already indicated how much pains is taken to perfect the carding process of preparing cotton. It is the same for wool; and, in some respects, for the tow of flax. The carding depends more on the quality of the cards than upon any attention or skill in the operatives or *card-tenters*.

To make *card-cloth*, hides of leather are cut up into strips, varying in breadth according to the purpose to which they are ultimately to be applied. These strips are passed between iron rollers, adjustable to different distances, and furnished with a sharp-cutting edge below, by which, in the passage, the leather is shaved off in its thickest parts, and made uniform throughout. These stripes, thus reduced, are joined by bevelling off the ends for about an inch in length, applying to the bevelled surfaces a thin solution of glue, made of acetic acid and isinglass, and then subjecting them to a powerful press. The union is made so perfectly, that it is scarcely possible to distinguish the joint. A number of such pieces being united together in one length, the leather is fit for the operations of the card-making machine.

This machine delights all who look at its rapid and wonderfully accurate operation.

The card-making machine is an American invention; but the first patent for it was taken by Mr. Dyer, of Manchester. This was in 1811. Many patents have been taken for improvements since, Mr. Dyer himself having taken not fewer than five.

The mechanism is simple, and yet so complicated that no drawings, such as could come within the scope of this Essay, could represent it. The machines are variously arranged. In most machines the leather is placed vertically, as in that exhibited; in others, it is stretched horizontally. The process is the same in both. A hank of fine wire is put on a reel turning horizontally, at a short distance from the machine, and the end of the wire introduced into the frame. The machine being now put in gear, the wire is slid forward about an inch, and is instantly cut off at that length. Two side pieces of steel now press on the projecting ends of the wire, and bend the wire to the staple form, like a two-pronged fork. In the mean time two fine steel prickers are pushed forward to form two holes in the leather. These are below the two ends of the staple, and on the instant they are withdrawn the staple is thrust forward into the holes, while a pair of nippers takes hold of the back of the staple, and gives it that slight bend which we have described as necessary. The staple entering in one operation is pushed home; at the next at the instant the new holes are made. The whole of these operations is performed in *less* than half a second. A slight movement of the leather sideways, after each insertion, provides for the continuous progress of the operation.

Hundreds of these machines are at work in Manchester, in Leeds, in Glasgow, and elsewhere. *Miles*, many miles, of wire, are worked up by these machines daily. The difficulty of making card cloth increases with its fineness. The French have carried this manufacture to great perfection, as exhibited in numerous cases of samples in the Exhibition.

The Drawing Frame. The drawing out of the cotton slivers is effected by revolving rollers, and to use the words of Dr. Ure, it can only be clearly understood by an attentive and minute consideration of the operation of such mechanism upon textile fibres. Arkwright was so impressed with the importance of his drawing-frame in automatic spinning, that when any bad work was turned out he immediately desired his people to "*mind their drawings*."

The cards straighten many of the filaments, but they also double not a few by catching them by the middle. The drawing undoes all these foldings of the fibres when it is well conducted, and is, therefore, the most curious in a philosophical point of view, which factory genius displays.

The drawing-frame produces a succession of *slivers* which pass to the roving-frame.

Six slivers from the finishing cards are presented through the *curved guide-plate* to a first drawing-frame roller. The compound or sextuple sliver, in passing between the roller series, is drawn out principally by the front roller into a uniform attenuated and much elongated sliver, and two of these are generally drawn together through a conical mouth-piece, which delivers the new sliver into a revolving *can*.

The rate of the surface speed of the front roller to that of the back roller varies from four, or six, to one; and that rate may be modified by changing certain wheels according to the size of the sliver that is desired. The difference between the speed of the two back rollers is no more than one tenth part; the middle roller serving rather as a guide in leading the filaments to the front roller.

The sliver thus drawn with multiplied doublings acquires a regularity of texture which, if not impaired in the subsequent processes, ensures a level yarn to the cotton spinner.

The sextupling of slivers is generally continued through two drawing-frames, and then twelve slivers are put into one, and drawn by a frame which feeds the *slubbing* machine.

The number of doublings varies according to the fineness of spinning for which it is a preparation.

The process of drawing being finished, the next process is *the twisting the slivers*—that is, *laying the fibres* together by torsion.

It were vain to attempt an account of the expenditure of thought which the production of the roving frames at work in the Exhibition has occasioned in the progress of the arrangement of the mechanism to the state of perfection there exhibited.

This beautiful machine, consists of several pieces of mechanism, which may be separately considered. There is a set of rollers, a *roller-beam* similar to that in the drawing-frame, and there are *vertical spindles*, bearing on their tops a forked piece, called a "Flyer," of which one leg or branch is tubular, and serves to conduct the soft roving from the hose of the spindle to the bobbin. By the revolution of the spindle and flyer the cotton *slub* receives its twist, and by the difference of the rotation of the flyer and bobbin it is wound upon the latter exactly in proportion as it is given off by the rollers. This gives the *torsion*. The *winding-on* takes place in a ratio compounded of the difference of the speed of the bobbin and flyers, and of the circumference of the bobbin.

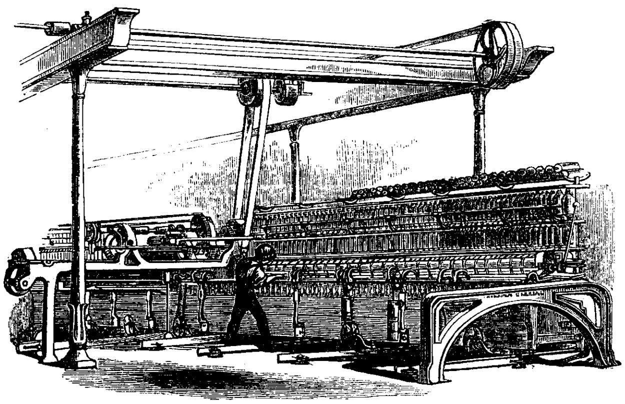
"Were the winding on to be a constant quantity, like the motion of the delivering rollers, the product of the two numbers would remain the same; but when one of them alters, as happens to the diameter of the bobbin, which is constantly increasing, the difference between the number of revolutions of the bobbin and flyer must be decreased; a change produced by increasing the speed of the bobbins while the flyers revolve uniformly, in order to give a uniform degree of torsion to a definite length of the delivered slub. As, therefore, the up-and-down motion of the bobbin, in the distribution of the roving over its surface, must be decreased in a constant progression, according to the grist of the roving, so the rotation of the bobbin is increased by a motion compounded of the regular speed of the driving-shaft of the machine, and the decreased speed of the other parts. We cannot attempt more minute details of description of this machine."

The process of spinning thus commenced is finished on the stretching-frame—the throstle and the mule. The cotton from the roving-frames is *pieced* up to either the *mule* or *throstle*, and spun into yarn, according to the quality of yarn intended to be produced.

We have been so minute in our account of the preparation of cotton, that we have only space left for a very brief account of mule-spinning. The stretching-frame is, in fact, a mule without the second draught and second speed. In the bobbin and fly-frames, the amount of lay, or quantity of twist given to the roving, is as little as is compatible with their being unwound without impairing their uniformity. The object of the throstle is to extend the rovings into fine threads at the same time that it twists them by the rotation of spindles or flyers, and winds them upon bobbins, somewhat resembling what we have endeavoured to describe in speaking of the bobbin and fly-frame.

The most interesting and perfect illustration of the throstle is that termed the *Danforth,* exhibited by Sharp Brothers of Manchester. There are various modifications of it; but we have not space to do more than name the machine.

The manufacture and improvement of the form of spindles and flyers has occupied the attention of many machinists, and specimens are to be seen from Manchester, Salford, Lille, and elsewhere, of the exquisite workmanship put upon these vital elements of modern spinning machinery. When it is



considered that these spindles and flyers revolve from 1000 to 2000 times in a minute, the perfection with which they must be finished and hardened, in order that they may move steadily and without self-destruction, and the consumption of power, may be easily conceived.

The Mule, or Mule Jenny, consists of four distinct sets of parts:—

1. The *drawing* rollers, already fully explained. 2. A *moveable carriage,* of a length equal to the roller-beam, mounted with as many spindles as there are threads to be spun. This carriage runs upon wheels upon edge-rails laid in the floor of the factory, which allows the carriage about five feet of forward and backward motion, relatively to the roller-beam. 3. The *headstock,* or the mechanism, by which the carriage is moved to and fro. In some Mules the headstock is placed in advance of the roller-beam, towards the middle of its length. In others, the headstock is put behind the roller-beam, so as to leave the whole length of the roller-beam and carriage without interruption.

The general action of the mule may be stated as follows:— The rovings being passed forwards from their respective bobbins, set upright in the creel, through between the rollers, and their ends being attached to their respective spindles, the rollers, and carriage with its spindles, are all set in motion simultaneously: the carriage being made to recede from the roller-beam at a somewhat quicker rate than the surface-speed of the front rollers, or the delivery of the soft threads. This excess of velocity is called the "gain" of the carriage, and is intended to render the thread *level,* upon the principle above explained—namely, that the greater quantity of twist runs into the slenderer or weaker parts of the yarn, and obstructs their due extension; whereas, if the quantity of twist be skilfully adapted to the occasion, the thicker portions of the thread will have time to be acted upon by the gain of the carriage, till their substance is reduced somewhat nearer to the average thickness required. When the carriage has moved out about 45 or 50 inches, according to the fineness of the work, a general change takes place in the operation of the mule. The rollers suddenly stop, the spindles begin to revolve with nearly a double velocity, and the carriage slackens its space to about one-sixth of its previous speed. This stage of the process is called the stretching, or the draw. The extension of the filaments, performed in part by the twin-roller system, is by this action carried on and completed in their softly twisted state. When the carriage, by its advance, has stretched the threads to the full extent they will bear without breaking, the second draw ceases by the stopping of the carriage, while the spindles still continue to revolve till the requisite quantity of twist is communicated, which is regulated by the twist-wheel having completed a certain number of turns. Upon the twist-wheel shaft a finger is usually fixed, which at each revolution disengages a catch, whereby the driving-strap is allowed to pass to the loose pulley, and the whole machinery stands still. In the hand-mule the spinner now puts down with his left hand the faller, or guide-wire, to the level requisite for guiding the threads into the proper winding-on position upon the caps of the spindles. In putting down the faller-wire, he at the same time unwinds that portion of the thread which is coiled spirally round the spindle, from its point to the nose of the cap, which he does by causing the spindles to turn the backward way, with his right hand working their main driving-pulley. This operation of undoing the coil is called *the backing-off.*

Whenever the faller has arrived at the degree of depression suited to the winding-on of the yarn, the spinner now reverses his backward motion, and winds on the yarn by causing the spindles to turn the forward way, while, at the same time, he pushes in the carriage at a rate commensurate with the revolution of the spindles. As the carriage approaches the roller-beam, the spinner gradually raises the *faller-wire,* to allow the last portion of the threads to be coiled again in an open spiral, from the nose of the cap up to their points. One operation being thus completed, another is immediately begun.

By winding successive portions of thread upon the spindle, a conical-shaped coil of yarn is formed, which, when sufficiently large, is slid off the spindle, in which state the article is ready for the market, under the denomination of Cop yarn. A considerable quantity of it, however,—particularly of that destined to be dyed or shipped to foreign countries,—is unwound from the cops upon reels, and thereby made up into skeins or hanks.

The rendering the machinery which performs all these processes automatic was first accomplished by Richard Roberts, of Manchester, between 1830 and 1835, and his headstock is still unrivalled. The late Mr. Smith, of Deanston, and Mr. McIndoe, of Glasgow, have modified the headstock in various ways, and their *self-actors* have earned great reputation for excellence. The self-actor of Mr. McIndoe has much to recommend it, and has been applied to spinning numbers as high as 150 with success, whilst self-actors in general are not applied to higher numbers than 120. The hand mule has still to be used in spinning finer numbers of cotton, and in spinning wool.

Weaving.—If we take the term, weaving, in its most comprehensive sense, as applying to the process of combining longitudinal threads into a superficial fabric, it will have relation to the whole series of textile fabrics; not only those woven in the loom, but likewise net-work, lace-work, and hosiery.

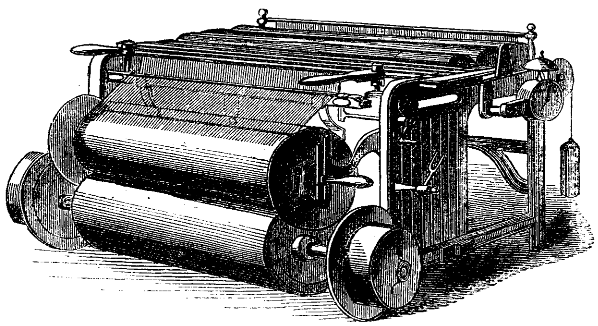
First, of plain weaving.—By this term we mean the weaving of all varieties of lathe manufacture; whether of silk, cotton, woollen, or linen, in which the weft threads interlace uniformly among the warp threads without producing twills, checks, stripes, sprigs, or any variety of figures.

Calico, Irish linen, and plain silk, are good representations of this kind of weaving. If we examine any of these, we find that the cross threads pass alternately *over* and *under* the long threads, no one thread passing over or under two other threads at once.

The long threads are called the warp-twist, or organzine; while the cross threads are called *weft, woof, shoot,* or *tram.*

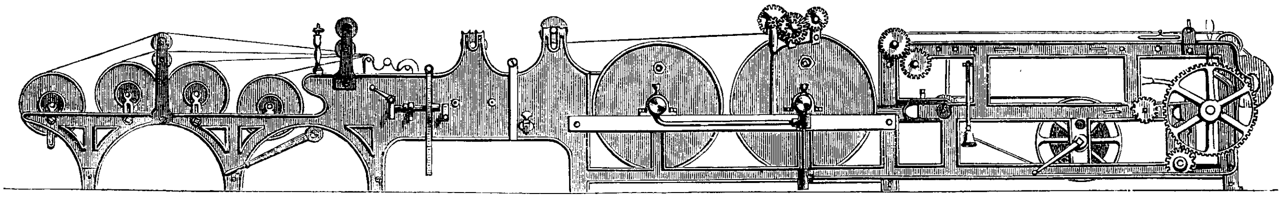
Twist is the term usually applied to the kind of yarn used for cotton warp; organzine to that for silk warp: and some of the other terms have, in like manner, only partial application. We shall speak simply of *warp* and *weft* to avoid ambiguity. The *warp* is always attached to the loom, or weaving machine, while the *weft* is contained in the shuttle—a small, canoe-like instrument. The winding of the weft on the spindle, which runs through the shuttle, is a simple matter; but the arrangement of the warp in the loom is very important, and must be understood, before we can follow the details of weaving.

In the process of the cotton manufacture before the yarn comes to the warping-machine, it is wound from the cop on to bobbins about four inches long, and about three inches diameter: these bobbins of yarn are then taken to the warping-machine, for the purpose of the threads being laid parallel to each other, to make them into a *beamed warp*, and to facilitate the arrangement of them after being *sized* and placed in the healds or 'heddles' of the loom in weaving. In the old system of preparing the yarn, before its being placed in the loom, a cumbrous machine, called the warping-mill, was used instead of this improved machine of



Mr. Kenworthy's, which warping-mill was worked by hand. After the yarn had been made into a balled warp, it was then taken to the old kind of sizing-machine, which soaked the yarn into the warm size (a kind of paste), then dried it, then squeezed it between iron rollers, and next it was reballed. The warp was then taken from this machine to a machine for winding it on a roller-beam, after which it was taken to the looming-frame, and next to the loom to be woven into cloth. But now, by the connection of Mr. Kenworthy's warping-machine, with the sizing-machine of Messrs. Hornby & Kenworthy, the process is made much shorter and more simple, and is withal systematic and mechanical.

It will be seen, on reference to the drawing, that the bobbins containing yarn are placed in a wooden frame called a 'creel,' so that they will revolve; the threads are then passed through a 'wraithe' on to a roller-beam. The 'wraithe' is for the purpose of keeping the threads separate and uniformly in the order in which they are intended to be wound off (after having passed through the size) on to the weaver's yarn-beam. In this machine is a beautiful adaptation of mechanism, by which the yarn may be backed off the beam, if by chance any broken thread has escaped the eye of the operative and got on the beam. This motion consists of a series of small cylindrical rods, so arranged that the threads of yarn pass under them; and supposing none of the threads had to break during the process, the beam would get filled without any necessity for calling this invention into action. But it so happens that breakages often do occur, and, as the machine works at a rather quick speed, those dissevered threads get on to the beam before the operative has sufficient time to stop the machine. The machine is provided with two sets of driving-pulleys, one pair at each end of the driving-shaft: that pair which drive the backing-off motion work at one half the speed the others do. The leathern straps or bands which connect these pulleys with the main shaft of the factory, are so arranged by the one (that which drives the backing-off motion) being crossed and the other being open, that the motion of the machine can be reversed whenever the threads are broken. The series of cylindrical rollers perform their office by moving down slots made in the framing of the machinery, in their progress bearing down with them the threads backed off the beam, until the severed thread is discovered and united, when the operative sets on the machine as before the breaking took place, and the cylindrical rollers return to their former position. After the beam is filled by this machine, it is placed, along with five others, in the improved sizing-machine. These beams are placed in bearings so that they will revolve at the left end of the machine, and weights are placed upon their pivots, so that they are kept in their places; the six threads of yarn are then passed through an ordinary comb-bar or 'wraithe,' and thus divided equally until passed through the healds, which, in this machine, are situated at the left end, for the purpose of effecting the cross shed, and thereby taking the 'lease' previously to the yarns being submitted to the sizing process. The 'lease' now being taken, and the cross band or threads being introduced for the purpose of 'looming,' or drawing in of the weaver's beam, the threads of yarn are passed over a 'wraithe' or comb-bar, formed by a row of teeth or pins of intervening spaces, for the purpose of laying the threads in parallel breadths side by side, and forming each division or band of threads (of any required number) into separate and distinct tapes or sheets (of any desired width), each thread being laid parallel side by side, and thus in lateral contact, the 'wraithe' or comb-bar being allowed to vibrate or oscillate freely as the threads proceed. The continuous threads now being thus made or separated into breadths or bands, are now passed over a conducting roller and immersed into the trough containing the sizing material, which is here kept in a heated state by steam passing through a pipe into the trough, and thus boiled into the warp-threads as they pass through it and under the adjustable tension roller, which can be adjusted to any required degree of tension at pleasure, or can be raised up, when necessary, entirely out of the trough by means of a winch, worm, and rack, with which the pinions of the rollers are connected. The threads are then passed forward through a pair of squeezing rollers, and again similarly immersed in the trough containing the size, to finish the yarn; from thence they are passed around the drying cylinder, also heated by steam, and now assume the form of tapes or bands, the sizing material, by its slightly adhesive properties, causing the threads thus to adhere slightly together, and thus proceed in a tape-like form, being of course much stronger, more regular and even, and less likely to be broken or



disarranged than in the old mode of sizing. A circular revolving brush is placed over the threads as they proceed over the drying cylinders, for the purpose of dressing or laying the fibres, and making the tapes or bands more compact and even. They now proceed in a sized, dried, and finished state, being conducted by two rollers through a similar 'wraithe' or comb-bar, but of a much finer pitch, and by passing through which the bands of threads are passed edgewise, and again similarly divided by the oscillating or vibratory action of the comb-bar, and laid over the tension roller at the right-hand end of the machine, in a proper state to be received and wound upon the warp-beam, ready for the operation of drawing in, after which operation it is taken to the loom and woven.

The warp in the last state described is received by the *weaver*.

We shall not do more than direct attention to the numerous power-looms exhibited, to the Jacquard looms, and to the machines for making the *healds* or heddles—for making reeds, for cutting cards, and for making other appendages to weaving machinery. Weaving in almost every fibre—cotton, flax, silk, worsted, and wool—may be learned in the department of Machinery in Motion.

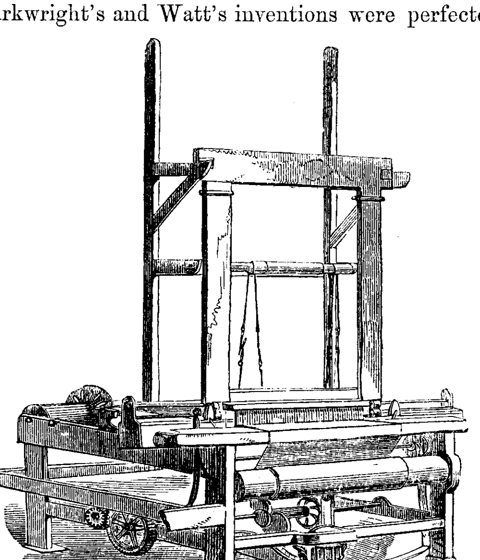
We must suppose our readers already acquainted with the process of weaving by the hand-loom. Nor can we enter into the description we intended to have done of *Pattern-weaving*, from the simple but effective "shot" patterns—the stripes and checks, the twills and all its varieties—as dimities, dornocks, bombazeens, satins, kerseymeres, &c., to the more complicated, embracing damasks and brocaded silks. By means of the *Draw*-loom, the order in which the warp threads are depressed or elevated, varies continually; strings being so arranged that the *Draw-boy* can draw down the requisite warp threads preparatory to the movement of the shuttle. The warp threads pass through the eyes or loops in vertical strings, each thread having one string, and these strings are so grouped that the attendant boy, by pulling a handle, draws up all those warp threads which are required to be elevated for one particular shoot of weft; and when a different order of succession is required, he pulls another handle. Hence it follows that the arrangement of the strings and handles must be preconcerted with especial reference to one particular pattern, and this is called "cording the loom." The *cording* used to occupy a skilful thoughtful man *several months*, and would then of course serve for only one particular pattern.

The first step in improving the *draw-loom* was the substitution of mechanism for the handle and boy called a *draw-boy*, and then the adoption of Duncan's automatic carpet loom or barrel loom, in which pins inserted in a rotatory barrel, like an organ barrel, moved a reciprocating lever, as in the draw-boy, and thus the way was paved for Jacquard's most perfect invention in 1800.

In all the kinds of weaving hitherto noticed, whether of plain goods, figured goods, bobbin net, stockings, or other fabrics, we have alluded to the weaving machine as *worked by hand*—or, more correctly speaking, by hand and foot—for the treadle is invariably the receiver of power in these machines.

So early as 1678 M. de Gennes invented "a new engine to make linen cloth without the aid of an artificer," and at various times during the last century, M. Vaucanson, Mr. Austin, and Mr. Miller, contrived looms which were to be worked by a winch, by water power, or some power extraneous to the common hand loom.

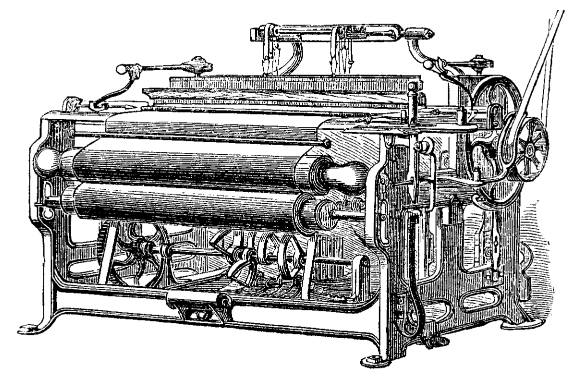
As Arkwright's and Watt's inventions were perfected and



extended in their applications, the necessity for having weaving machinery became more urgent. In 1802 the power-loom had not produced important saving in the expense of weaving, as a man had to be employed about each loom.

The power-loom of the present day is one of the most remarkable machines of the age we live in.

Mr. Harrison exhibits a power-loom made in 1798 or 1800



[it is engraved on the preceding column] alongside of the most improved looms of the present date, engraved on this column. How great the difference! Yet the honour due to Robert Miller, who commenced to introduce power-looms of the same construction as this old loom in 1796, is perhaps greater than to those who have produced the improvements, because his was the *beginning*.

The old machine can be worked to advantage at 60 picks per minute, requiring one person to each loom, or five persons to six looms. The new looms can be driven at 220 picks per minute, and are to be seen working at that speed in the Exhibition, and in all the best power-loom mills in England and Scotland. One person can attend two of these, and in many instances three looms.

An experienced operative of the manufacturing district, working the modern looms, produces 26 pieces of printing cloth, 25 inches wide, 29 yards long, and 11 picks per $\frac{1}{4}$ inch, in a week of 60 hours. The cost of weaving each piece is $5\frac{1}{2}$*d.* —less than 6*d.*! If the same cloth were woven on the old loom, one operative would produce only four pieces, and at a cost of 2*s.* 9*d.* each; or the weaver's wages in 1800 were as much as is the entire value of the *cloth* in the Manchester market at present. Wonderful mechanical result! What are the moral results?