WEAVING. If we take the term *weaving* in its broadest sense, as applied to the process of combining longitudinal threads into a superficial fabric, it will have relation to the whole series of textile manufactures; not only those which are prepared in the loom, but likewise net-work, lace-work, and hosiery. We shall endeavour therefore in the present article to complete the details of manufacturing many textile fabrics which have been partially described in former articles.

History of Weaving.—From many passages in the Bible, and from the general character of dress, it is apparent that woven fabrics were known in very early times. In all probability weaving was practised before spinning; that is, the combination of reeds, strips of leather, or rude fibres into a material for dress, by a process analogous to that of weaving, preceded the practice of spinning yarn from a congeries of elementary fibres. Sir J. G. Wilkinson ('Manners and Customs of the Ancient Egyptians') observes,—"The Egyptians, from a most remote era, were celebrated for their manufacture of linen and other cloths; and the produce of their looms was exported to, and eagerly purchased by, foreign nations. The fine linen and embroidered work, the yarn and woollen stuffs, of the upper and lower country, are frequently mentioned, and were highly esteemed." The same authority states that the looms, found depicted on the tombs at Thebes, are of an exceedingly rude construction; but he does not think that this circumstance militates against the production of fine fabrics, since it is known at the present day that the Hindu produces exquisite muslins on his rude loom. In a specimen of mummy-cloth, examined by Mr. Thompson of Clitheroe, the texture was close and firm, yet elastic; the yarn of both warp and weft was remarkably even and well spun; the weft was single, while the warp-yarn consisted of two fine threads doubled; and it was observable, in that as well as in other specimens, that the number of threads to an inch in the warp uniformly exceeded that in the weft, a difference not commonly observable in European fabrics. Mr. Thompson examined ancient Egyptian cloths brought to England by Salt and Belzoni, and found that the selvages were well made, that striped goods similar to modern ginghams were often made by the Egyptians. and that indigo was used as one of the dyes Wilkinson gives copies from some of the pictures at Thebes, Beni Hassan, and Eileithyas, representing weavers at their looms; in one instance the loom appears to be horizontal, while in another it is vertical, with the weft driven upwards; and from representations of five different sorts of shuttles, it would appear that they were generally about half a yard in length.

Weaving appears to have been carried on as a distinct trade in the larger towns of Greece; but every considerable private establishment had also a loom at which the females of the family were employed; the weaving being carried on chiefly by female slaves, while the superintendence rested with the mistress and her daughters. In large houses a particular room was set apart for this occupation.

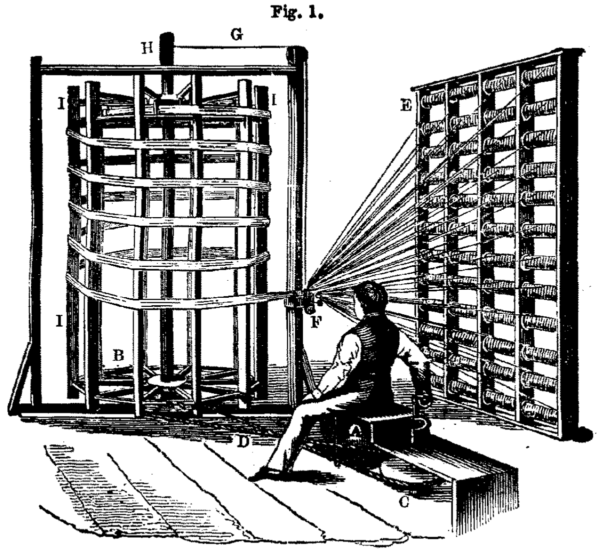
Plato mentions one of the most important differences between the warp and the weft, namely, that the threads of the former are strong and firm in consequence of being more twisted in spinning; whilst those of the latter are comparatively soft and yielding; a comparison which is strictly applicable at the present day. The Greeks evidently understood much of what is now termed "mounting a loom," that is, arranging strings in such a manner as to separate the warp-thread into two or more groups, between which the weft may be introduced: the leash (μίτος) being one such string, and a woven pattern being termed δίμιτος (from which the word *dimity* appears to be derived), τρίμιτος, or πολύμιτος, according as it contained two, three, or more groups of strings, or, as we should now say, leaves of heddles. After the weft was thrown, it was driven up close, either by a kind of bat, called a spatha, or by a kind of comb; both of which appear to be combined in the batten, or lay, of the modern loom. The checks produced by having different coloured warp threads, and stripes, formed of multi-coloured wefts, were known to the Greeks and Romans; as were likewise numerous kinds of fancy weaving derived from these two combined. Among the Romans, as among the Greeks, weaving was a female employment, and, as with them, it was carried on in most towns and in many large private establishments. Weaving, as practised among the ancients, may be illustrated by the proceedings of the weavers among existent imperfectly civilised nations. The Hindu weaver takes his station under the trees, where he stretches his warp-thread between two bamboo rollers, which are fastened to the turf by wooden pins. He digs a hole in the earth large enough to contain his legs when in a sitting posture; and then, suspending to a branch of a tree the cords which are intended to cause the raising and depressing of the warp-threads, he fixes underneath two loops for his toes, by which he produces a substitute for treadles. His shuttle acts also as a batten, or lay, and completes his simple arrangements.

We shall now proceed to describe the weaving processes, classifying them under the names of *Plain-weaving, Pattern-weaving, Double-weaving, Cross-weaving, Chain-weaving, Pile-weaving*, and *Power-weaving*,—giving cross references to former articles, in which some of these subjects have been treated.

Plain-weaving.—By this term we mean the weaving of all varieties of textile manufacture, 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 representatives of this kind of weaving. If we examine any of these, we shall 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. In the language of weavers, the long threads are called *warp, twist, caine*, or *organzine*; while the cross threads are called *weft, woof, shoot*, or *tram*. Twist is the general term 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: if therefore we speak simply of *warp* and *weft*, we shall avoid ambiguity, and be sufficiently correct for the object in view. The warp is always affixed to the loom or weaving-machine; while the weft is contained in the shuttle, a small boat-like instrument.

The first operation consists in laying the requisite number of threads together to form the width of the cloth: this is called *warping*. Supposing there to be 1000 threads in the width of a piece of cloth; then the yarn, wound on the bobbins as it leaves the hand of the spinner, must be so unwound and laid out as to form 1000 lengths, constituting when laid parallel the warp of the intended cloth. The ancient method was to draw out the warp from the bobbins at full length in an open field; and this is still practised in India and China: but the climate of Europe is too uncertain for such a method, and hence the *warping-frame* was devised. This is a large wooden frame fixed up vertically against a wall, the upright sides being pierced with holes to receive wooden pins, which project sufficiently to receive the clue or group of yarns. The warper, having placed the bobbins of yarn in an adjacent frame, ties the ends of all the threads together, and attaches them to one of the pins; then gathering all the threads in his hand into one clue, and permitting them to slip through the fingers, he walks to the other end of the frame, where he passes the yarns over the fixed pin. He walks from end to end of the frame, attaching the clue of yarns to the pins each time, until he has unwound from the bobbins enough yarn to form the warp. But this method, although still followed in some places, has yielded to the use of the *warping-mill*, a much more convenient piece of apparatus. The bobbins are placed in a frame E (*fig.* 1). The

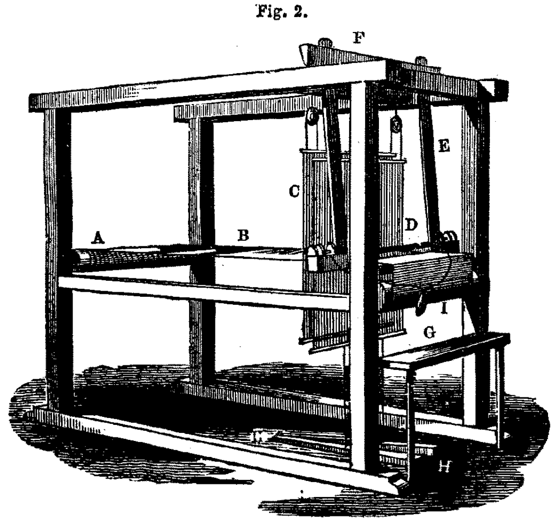
Fig. 1.



warper, sitting at A, rotates the vertical reel or cylinder B, by means of the wheel C and the rope D. The yarns from all the bobbins, collected together in a group at F, there pass through a sliding piece, which through the intervention of the cord G and the revolving shaft H, rises and falls. By this arrangement it is easy to see that when the handle is turned by the warper, the clue becomes wound spirally on the reel. The diameter of the reel is so regulated, that when the spiral equals the intended length of the warp, the clue of yarns is twisted round pins at I I, and then by a reverse motion of the handle is wound spirally down again; and so on up and down alternately until the grouped clues of yarns constitute a sufficient number for the width of the warp. Certain minor adjustments are at the same time made, to facilitate the subsequent operations of the weaver. The more modern warping-machines we shall have to mention when we come to power-weaving.

When the warp is completed on the warping-mill, the warper takes it off and winds it on a stick into a ball, preparatory to the process of *beaming*, or winding it on the beam of the loom. The threads, in this latter process, are wound as evenly as possible on the beam; a separator, ravel, or comb being used to lay them parallel, and to spread them out to about the intended width of the cloth. Arrangements are then made for *drawing*, or attaching the warp-threads individually

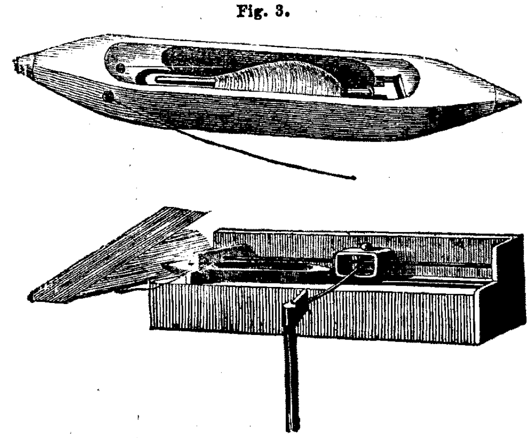
Fig. 2.



to certain mechanism of the loom. This we may illustrate by *fig.* 2, representing the common loom in its simplest state. The yarn-beam is at A, capable of revolving on its axis, and of allowing its threads to be drawn out in a horizontal layer B. At C are two leaves of heddles or healds, each leaf consisting of a number of strings ranged vertically attached at bottom to two treadles H H, and at top to a cross-bar F. At about the middle of every heddle or string is a loop or eye, through which the warp-yarns are drawn, one through each eye; and the passing of the yarns through these loops constitutes the process of *drawing*. Half of the warp-yarns, that is, every alternate yarn, pass through the loops in one leaf of heddles, and the other half through the other leaf; and as the two leaves are so connected by pulleys that one rises when the other sinks, the warp becomes divided into two portions, one above the other, near the anterior end of the loom. The weaver sits at G, drives the shuttle by means of the handle I, and drives up every successive weft-thread by the batten, lay, or lathe E, suspended from F. However complicated the loom, the principle of action is nearly as here described.

There are three movements attending every thread of weft which the weaver throws across the warp. In the first place he presses down one of the two treadles, by which one of the two halves of the warp is depressed, thereby forming a kind of opening called the *shed*. Into this shed, at the second movement, he throws the shuttle containing the weft-thread, with sufficient force to drive it across the whole web. Then, at the third movement, he grasps the batten, which is a kind of frame carrying at its lower edge a comb-like piece having as many teeth as there are threads in the warp; and with this he drives up the thread of weft close to those previously thrown. One thread of weft is thus completed, and the weaver proceeds to throw another in a similar way, but in a reverse order, that is, by depressing the left treadle instead of the right, and by throwing the shuttle from left to right, instead of from right to left. In the commonest mode of weaving the shuttle is thrown by both hands alternately; but about a century ago John Kay invented the *fly-shuttle*, in which a string and handle are so placed that the weaver can work the shuttle both ways with one hand. The fly-shuttle is illustrated in CHECK; while *fig.* 3

Fig. 3.



will show more clearly the mode in which the weft is wound round the spindle or pirn of the shuttle, and the arrangement for driving the shuttle into the open shed of the web. The spindle of the shuttle contains enough weft for several shoots or throws; the weft unwinding as the shuttle travels along, and forming the selvage of the cloth when the shuttle returns in the opposite direction.

In cotton and some other fabrics, the warp-yarns must be *dressed* as the weaver proceeds, that is, rubbed over with some kind of vegetable mucilage, such as paste or size, for the purpose of giving them tenacity, of diminishing friction by smoothing down the little hairy filaments of the yarn, and of imparting a smoothness or gloss. In hand-weaving, the weaver suspends his operations from time to time, in order to apply dressing to his warp. He first applies a kind of comb to the warp, to clear away knots and burrs; then lays on the paste with a brush; and lastly dries the paste by a current of air excited by a large fan. The more modern and complete *dressing-machine* we shall have to notice in connection with power-weaving.

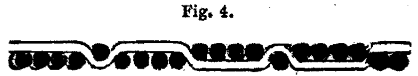
In weaving plain silks, calicoes, and other webs of moderate width, there are two leaves of heddles and two treadles, for dividing the warp into two parcels. In weaving broader webs, such as floor-cloth canvas, the heddles and treadles are equally simple, but more power and dexterity are necessary in throwing the shuttle, since the width of the web is sometimes as much as eight yards. In weaving very narrow webs, such as ribbons, galloons, &c., there would be a waste of power and of time if only one shuttle were thrown across a distance of two or three inches at each movement; and there has consequently been devised a kind of loom called the *engine-loom*, in which several shuttles work several webs at one time in each machine: this has been explained in RIBBON. Various details concerning plain woven goods will be found under COTTON; LINEN; MUSLIN; SILK; WOOLLEN.

Pattern-weaving.—The number of woven webs which can come under the designation of plain-weaving is much smaller than that of those now to be considered. Whenever the warp and weft are of the same colour, and intersect each other in regular order, so as to produce a uniform surface totally divested of pattern, we may deem that *plain-weaving;* but every day's experience shows that pattern, of some kind or other, is a more prevailing characteristic of woven fabrics.

In the first place we may take the case in which all the threads of the warp are of one colour, and all those of the weft another colour: this produces the peculiar effect called *shot* patterns, but involves no new arrangements as to weaving. Next come the two varieties known respectively as *stripes* and *checks*. A stripe is a pattern in which parallel lines run either along or across the warp; while a check is an alternation of rectangles like a chess-board, or, more properly, like the varieties of Scotch plaid. The production of a stripe depends either upon the warper or the weaver; the production of a check depends upon both. If the stripes are of different colours, and extend lengthwise of the cloth, then the warper so disposes the threads of his warp that the two colours shall succeed each other at regular intervals; but if the stripes are of the same colour, but of different quality as to fineness, then the warper uses two qualities of warp in alternate succession. If the stripes extend across the cloth, the warper arranges his threads as for plain-weaving; but the weaver uses two or more shuttles, carrying two or more coloured wefts, and throws the shuttles at regular intervals in succession If a check is to be produced, the warper first produces his alternation of colours in the warp, and the weaver then throws in wefts of different colours by using two or more shuttles, so that the interlacing of the long stripes with the cross-stripes produces the check, the pattern of which depends on the comparative width of the various stripes. The manner of using the combined shuttles is described under CHECK.

The next to be noticed is the production of the *twill*, a very extensively adopted variety of woven work, since it comprises satin, bombazeen, kerseymere, and numerous other kinds. In the twill, the weft-threads do not pass over and under the warp-threads in regular succession, but pass over one and under two, over one and under three, or over one and under four, six, &c., according to the kind of twill. The effect of this is to produce a kind of diagonal ribbed appearance, on one side of the cloth, and a smooth and glossy appearance on the other, according as the one thread is crossed above or below by the weft. *Fig.* 4 will assist our comprehension of this point. If we suppose the

Fig. 4.



round dots to be sections of successive warp-threads, and the white double line to be one thread of weft, we shall see that the weft passes over four, under one, over four; then under four, over one, under four; and if the specimen were continued, we should see that these cycles of changes succeed each other in regular order. This arrangement furnishes the *twill* for some particular varieties of cloth; and the weaver has thus a kind of numerical formula for diaper, dimity, dornock, damask, bombazeen, satin, kerseymere, &c.; each one having a certain order of succession in which the weft crosses the warp. [BOMBAZEEN; DAMASK; DIAPER.]

Now in order to allow the weft to pass under four or more threads at once, some mechanism must be devised for elevating all those four at one movement, or keeping them stationary while every fourth thread is depressed. If the weft always passed under the same four threads, no cloth would be produced, for no reticulation would be made; but the groups of four passed under by one weft-shoot are not the same as those crossed at the next following shoot. Hence more than two leaves of heddles are required, and more than two treadles to work them. There must, in such a case as we have above supposed, be five leaves of heddles, to each of which every fifth warp-thread is attached; and to each of these leaves a treadle is appropriated; so that when one treadle is pressed down, one-fifth of the warp-threads becomes drawn out of the horizontal plane; when another treadle is depressed, another fifth is affected; and so on. The weaver, by the management of his treadles, has the power of raising or depressing four-fifths of his warp-threads, in groups of four each, leaving every fifth thread stationary; and in this state of things he throws his shuttle. By various combinations among his five treadles, he can produce many varieties of movement, which give rise to different kinds of twill.

When, instead of, or in addition to, a twill, the weaver has to produce sprigs, flowers, spots, or any kind of figure, a great increase of complexity occurs. The weft may pass over four and under one at one part of the width of the cloth; over two and under two at another; over one and under four at another—according to the part of the figure which may happen to occur at any particular part of the width of the cloth. Hence the order in which the warp-threads must be depressed or elevated varies continually, and the number of leaves of heddles would become so numerous that the loom could not hold them, nor could the feet of the weaver move the requisite treadles. This difficulty gave rise to the invention of the *draw-loom*, in which strings are so arranged that a boy can draw down the requisite warp-threads preparatory to the movement of the shuttle. The warp-threads pass through 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 necessarily 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 would sometimes take one man three or four months, and would then only serve for one particular pattern. Early in the present century two inventions were made with the view of rendering the draw-loom more automatic. One of these, called the *draw-boy*, not only superseded the necessity of employing a boy to pull the handles, but removed, by the unerring certainty of its operation, all possible chance of mistake in pulling the wrong handle. This was a very ingenious arrangement of mechanism by which a treadle, worked by the foot of the weaver, gave a vibratory motion to a curved lever which drew down some of the warp-threads and elevated others; and the skill consisted in so causing the lever to travel along a rack or toothed bar as to act upon different warp-threads in succession. The draw-boy has been very much employed; while another invention, equally ingenious perhaps, has, from various causes, failed to come into use. This latter was the *automatic carpet-loom* of Mr. Duncan. Here the warp-threads, instead of being elevated and depressed by the handles as in a draw-loom, or by the reciprocating lever as in the draw-boy, were moved by pins inserted in a rotating barrel, the pins being placed in an order of succession according to the pattern to be produced, just as those on the barrel of a street-organ or a musical-box are disposed according to the tune to be played. But the draw-loom, the draw-boy, and the barrel-loom have been alike eclipsed by the exquisite apparatus of M. Jacquard, which is very properly named after the inventor. [JACQUARD APPARATUS.]

Double Weaving.—In all the fabrics hitherto noticed, there is but one layer of threads, formed by the intersection of the weft among the warp, both weft and warp being individually single. But there has long been practised the weaving of a kind of double cloth, composed of two webs, each consisting of separate warp and weft, but both sets interwoven at intervals. The junction of the two webs is formed by passing each of them occasionally through the other, so that each particular part of both is sometimes above and sometimes below. Kidderminster or Scotch carpeting is one of the few kinds of double-fabric now woven in this country; and it will therefore be sufficient for us to refer for details to the article CARPET MANUFACTURE.

Cross Weaving. This term may conveniently be applied to those varieties of woven fabric in which the warp-threads, instead of lying constantly parallel, as in all the cases hitherto noticed, cross over or twist around one another, thus forming a plexus or interlacing independent of that produced by the weft. *Gauze* and *bobbin net* are perhaps the most remarkable examples of this kind of fabric. [GAUZE; LACE MANUFACTURE.]

Chain Weaving.—This is a term usefully applied to a mode of using threads in which a series of loops is formed by a continuous thread, each loop or link being so connected with others as to form a kind of chain; and this chain work may either be worked upon a ground woven at the loom, or may constitute the woven material itself. *Sampler work, Berlin work, sewed muslin work, tambouring, embroidery, tapestry, pillow lace,* and *hosiery*, are all examples, more or less varied, of this chain-weaving. [EMBROIDERY; HOSIERY MANUFACTURE; LACE MANUFACTURE; TAPESTRY.]

Pile Weaving.—If we examine a piece of silk velvet, or any kind of fustian, such as velveteen, moleskin, or doeskin, or a Turkey or Wilton carpet, we shall find that in any or all of these fabrics the warp and weft threads are almost concealed by a kind of down, nap, or pile, which imparts a peculiarly soft and smooth texture to them. It may seem strange to class together such very different materials as silk velvet, fustian, and Turkey carpeting; but the classification is strictly correct, because all of them owe their characteristic beauty to the downy surface which they present. Fustians are in fact a kind of cotton velvet, as Turkey carpeting is a woollen velvet. The weaving of these pile-fabrics, so far as regards the decussation of the warp and weft threads by means of the shuttle, resembles that of plain fabrics, or of pattern-fabrics, according to the nature of the design. But there is, besides the warp and weft properly so called, another kind of warp, whose threads are left standing in loops above the general surface till cut, and the cutting of which constitutes the pile. In some kinds of fustians the pile is cut so as to give a smooth velvet surface; while in other kinds it is cut into parallel cords, forming corduroy and such like fabrics. The cutting used formerly to be done by peculiarly shaped knives held in the hand; but some very ingenious machines have been contrived for effecting it more quickly and correctly. For the application of this peculiar manufacture to different fabrics, see CARPET; FUSTIAN; VELVET.

Power-Weaving.—In all the kinds of weaving hitherto noticed, whether of plain goods, figured goods, double cloth, bobbin-net, stockings, or velvet fabrics, we have uniformly spoken of the weaving-machine as being worked by hand, or rather by hand and foot, for the treadle is an almost invariable component of such a machine. We have however now briefly to notice the important steps by which the steam-engine has been brought to bear on this department of industry.

In the 'Philosophical Transactions' for 1678, a loom, invented by

M. de Gennes, is described as "a new engine to make linen cloth without the aid of an artificer," by applying water-power as the moving force. The advantages are thus enumerated: "1, That one mill alone will set ten or twelve of these looms at work; 2, the cloth may be made of what breadth you please, or at least much broader than any which has been hitherto made; 3, there will be fewer knots in the cloth, since the threads will not break so fast as in other looms, because the shuttle that breaks the greater part can never touch them. In short, the work will be carried on quicker and at less expense, since, instead of several workmen, which are required in making up of very large cloths, one boy will serve to tie the threads of several looms as fast as they break, and to order the quills in the shuttle." This description remarkably well expresses the excellences of the power-loom of the present day; but we have no evidence that De Gennes' machine ever came into use. At various times during the last century M. Dolignon, M. Vaucanson, Mr. Austin, and Mr. Miller contrived looms which were to be worked by a winch, by water-power, or by some contrivance more expeditious than the common hand-weaving. The first power-loom for weaving cotton fabrics was put up by Mr. Austin in the factory of Mr. Monteith, near Glasgow, in 1798; but before that time another machine had been invented, whose history is curious and interesting.

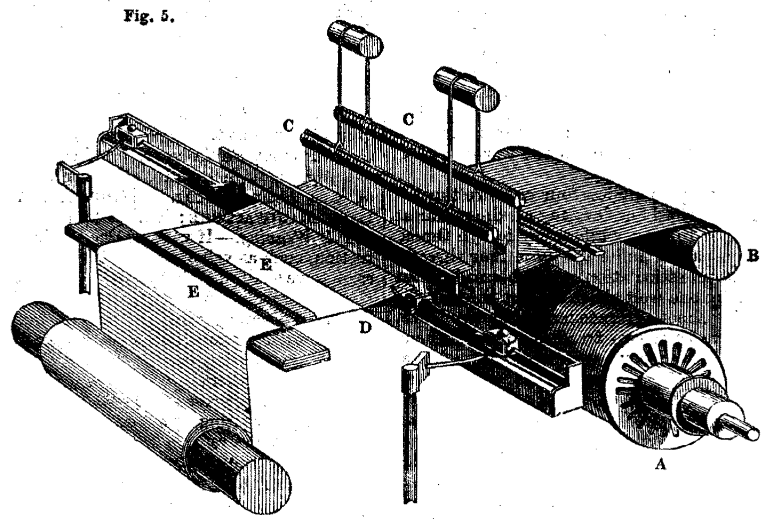
The Rev. Dr. Cartwright, brother of the late Major Cartwright, happened, in 1784, to be in conversation with some gentlemen, concerning Arkwright's spinning machinery. It was observed that, so soon as Arkwright's patent expired, so many mills would be erected, and so much cotton spun, that hands would not be found to weave it. Cartwright remarked that Arkwright must, in that case, invent weaving machinery; and the idea, thus suggested by himself, seems to have taken hold of his mind; for he soon afterwards endeavoured to form a machine which should imitate the three movements in weaving. He succeeded so far as to produce a machine, which he patented in 1785; and another, for which a patent was obtained in 1787. He tried to establish a power-loom weaving factory at Doncaster, but failed: Messrs. Grimshaw also endeavoured to set Cartwright's machines at work at Manchester, but similarly failed from various causes; and, after many years of labour, many patents, and an expenditure of 40,000*l.*, Dr. Cartwright was compelled, in 1808, to ask for a grant from Parliament as a return for his losses and exertions. Parliament awarded him 10,000*l.* One cause which thus delayed the adoption of power-looms was the necessity for stopping the machine frequently, in order to dress the warp as it unrolled from the beam, which operation required a man to be employed for each loom, so that there was no saving of expense. In the year 1802, Mr. Radcliffe, a cotton manufacturer of Stockport, aided by a workman, Thomas Johnson, made many contrivances with a view to remedy this inconvenience, and at length produced the admirable *dressing-machine* of modern factories, by which the warp is dressed before it goes into the loom. At a subsequent period Mr. Horrocks and Mr. Marsland, both of Stockport, made other improvements, which brought the steam-engine fairly into use for weaving operations, and thus power-looms became established. Still more recently, Mr. Roberts, of the firm of Sharp and Roberts, at Manchester, brought the power-loom to a state of high perfection; and every year adds more and more to the number of such looms employed in manufacturing districts.

The application of the power-loom renders necessary the employment of other machines likewise, to effect those preparatory operations which, in hand-loom weaving, are effected by very simple means. If we take a piece of calico as the representative of plain fabrics generally, the mode of proceeding in power-loom factories may be shortly sketched as follows:—

The *warping-frame*, instead of being employed on the same principle as the warping-mill sketched in a former page, is so arranged as to be worked by steam-power. Several bobbins, arranged with their axes parallel and horizontal, in a compartment at one end of the frame, yield the yarn which is to be collected into a warp. The yarns, proceeding from the bobbins, pass under some rollers and over others, until all are brought into a parallel layer, a comb of fine wires being employed to separate the yarns equidistantly. The yarns are then collected and coiled on a cylindrical beam, which is removed from the *warping-frame*, and transferred to the *dressing-machine*. This latter is a large piece of mechanism, by which the contents of eight rollers from the warping-frame are collected on one roller or beam, which is to form the warp-beam of the loom; and in their passage the yarn-threads are coated with the paste or mucilage-dressing, and dried. Four of the rollers are placed at one end of the machine, and four at the other; and the yarns, proceeding from thence, pass between rollers, of which the lowermost dips into the paste, and becomes thus coated with it; they then pass under and over brushes, by which the paste is rubbed into the fibres; then over a steam-heated copper box, by which they are dried; and, lastly, are wound on the warp-beam.

The preparation of the warp in the loom, comprising what are called the *drawing* and *mounting*, is more simple for the power-loom than for the hand-loom, but is still somewhat intricate. When, however, this is effected, steam-power does all the rest: it forms the shed or division of the warp into two parts; it throws the shuttle; it drives up the weft with the batten; it unwinds the warp from the warp-roller; and winds the woven material on the cloth-roller. Part of these operations may be illustrated by *fig.* 6, in which some of the mechanism is omitted to render the rest more clear. The warp, unwinding from the beam A, and bending round the roller B, passes through the two leaves of heddles C C, by which the shed is formed for receiving the shuttle at D; and after the action of the batten (not here shown) the finished cloth E results.

Fig. 5.



The pressing, finishing, dressing, &c., which the woven goods receive, whether woven by the power-loom or the hand-loom, depend, of course, on the nature of the fabric. One of the most important of these processes, by which the plain goods become diversified with ornament, is described under CALICO PRINTING.

Weaving, like all other parts of textile manufacture, has been marked by the introduction of many new forms of apparatus within the last few years. We will briefly mention the names of a few, as samples of the whole. Messrs. Tatton and Hodgkinson have a new small-ware loom, for weaving all kinds of narrow work, such as ribbons, galloons, chintz-lace, bed-lace, carpet-binding, tapes, &c. Mr. Somerville has introduced a new form of steam-power loom for twill, diaper, and worsted goods, especially intended for varying the effects in the same web by varying the shed-action. Mr. Macfarlane, of Comrie, introduced an arrangement in 1858 for enabling a loom to supply its own shuttle with fresh warp when exhausted or broken, and also to stop itself when any definite number of warp-threads have become broken. Mr. Ingram, of Bradford, patented in 1860 mechanism for obtaining continuous action in looms; that is, a method of supplying the loom with weft without stopping it to change the bobbin or cop; or of giving an additional supply of weft while the loom is in action, and whether the weft be all used up or only broken. Mr. Schwabe has invented an ingenious way of weaving *flounced* dresses. To effect this there is an additional warp-beam laid beside the usual one: the warp from this beam is brought into use in producing the body of the dress; but when a fringe, cording, &c., is wanted for a flounce, a portion of the other warp is brought forward by itself; or else this second warp may only be used in the flounce, and cut off at regular intervals.

Concerning the application of the arts of design to weaving, Professor Willis, in a report on the Paris Exhibition of 1855, gives an interesting account of the duties of a French functionary called the 'Professeur de la Théorie des Fabrications':—"This is a class of instruction which appears to be peculiar to Lyons, and to the want of which our deficiency in that respect may greatly be attributed. Their business is not to teach artistic drawing as a branch of fine art, but to teach the connection of design with the machinery which must be employed to realise it; to explain the entire construction and management of the looms, the mode of mounting and adjusting them, the different tissues or textures of which they are capable; the application of these to the respective parts of a given design, either as grounds or as means of bringing out details with the greatest effect, and at the same time with the necessary economy—seeing that contrast and variety of textures in the different details of a woven picture occupy the place of the painter's *handling* in works of fine art. A design may manifestly be exceedingly beautiful in itself as a work of art, but wholly inapplicable to weaving. No artist, therefore, can be qualified to make a weaver's design which shall combine in itself the beauty of art, applicable to produce effective results when translated from oil-paint or water-colours into silk or worsted, unless he be familiar with the mechanism of the looms in their infinite variety, with their practical adjustment, and with the characteristic surface-effects of the different tissues. Every designer, in short, should be able to put his own designs into the loom. Accordingly, artists, after having studied in the School of Design at Lyons, put themselves in the next place under the instruction of one of these so-called Professors of the Theory of Fabrics, for six months or more, to learn the application of the design to the machine. This is the system which has enabled the manufacturers of that city to produce the magnificent and beautiful specimens which were displayed in the galleries of the French Exhibition."

Bonelli's Electric Loom.—There is one modern invention in weaving of so remarkable a character as to deserve special notice. The theory is sound, although there may not at present be obtained a mastery over the mechanical details for carrying it out. M. Bonelli's Electric Loom has been described by Dr. Faraday at the Royal Institution, and by Mr. Le Neve Foster at the Society of Arts. The following is a slight outline of its origin and nature. In 1844 the Society of Arts prize was given to Mr. Riding for certain improvements in the Jacquard Apparatus; he employed an index-machine, something like Duncan's barrel described in an earlier paragraph, with shifting pegs for changing the patterns, the pegs acting in connection with wires in the apparatus. In later years other improvements were introduced, many of which have been noticed in JACQUARD APPARATUS. This subject attracted the attention of M. Bonelli, an Italian Civil Engineer, and Director General of the Sardinian telegraphs. He employed a long period of time in developing the theory and details of an electric apparatus which might dispense with the cards necessary in the Jacquard looms for weaving figured goods; and brought his machine to England in 1859. Bonelli's apparatus will suit any existing looms. It consists principally of an endless band of paper covered with tinfoil. The design or pattern is painted on the tinfoil with a brush and black varnish. The band passes under a series of thin metal teeth, all in connection with a galvanic battery. Whenever the foil touches a tooth a current passes through it, and thence through coils of wire surrounding small bars of soft iron, making them temporary magnets; but whenever the varnish touches a tooth, no such current is produced. Numerous small rods are placed opposite the ends of the small bar magnets; they pass horizontally to and fro, through a plate in front of a moveable frame. When any of the bars are actively magnetic, they retain or attract the rods when in contact with them. When the frame is swung or moved so as to bring the rods in contact with the bars, some are drawn a little distance through the holes in the plate, while the others are not so affected: according as the particular bars are at that moment in a magnetic state or not. The rods are like pistons, for each exactly fits one hole without tightness; and thus it happens that, when the frame recedes, some of the holes are open, while others are filled with the rods. The plate acts the part of a Jacquard card; each movement of the frame opens a distinct series of holes, and thus changes the pattern. A treadle moves the frame, at each throw of the shuttle. When the design is to be in several colours, it is in like manner painted on the tinfoil; but each separate colour, by removing a very thin strip of foil at the margin, is insulated from its neighbouring colour. All the pieces of foil thus insulated, each representing one colour or shade, are connected by small strips of tinfoil, which pierce through the paper and are fastened at the back, whence they are conducted to another strip of tinfoil which runs along the edge of the band: there being as many such strips of tinfoil as there are colours. Thus each special colour of the design, in all its parts, is connected by a conductor with its own separate strip of tinfoil. By bringing the wire from the galvanic battery successively into contact with the several strips, a current of electricity may be made to pass in succession through the several parts of the design representing the several colours. Thus, assuming four colours; there would be four strips of tinfoil running the length of the band, insulated one from another, each in connection with its own peculiar colour only. At any given moment, thin plates of metal resting on the design would touch it in a line which, as it passes over the *width* of the design, would run through all or any one of the colours; but the current would pass only through those plates which rest on the one colour represented by the strip connected at that moment with the pole of the battery. The shifting of the band does not in this case take place with every throw of the shuttle, but after an interval depending on the number of colours.

Such is Bonelli's electric loom. The inventor states, that two cells of a small Bunsen's battery will suffice, consuming one pennyworth of chemicals per day. The cost of the whole apparatus is about 20*l.* An elaborate damask design will sometimes require, on the Jacquard system 4000 cards and 400 wires, which would cost 24*l.*, and five weeks of a man's labour to set up. On the Bonelli system, we are told, the expense would be 6*l.*, and the time one week. A Jacquard design has been known to take 20,000 cards, costing 150*l.*, and an amount of labour equal to one whole year of one man's time; the figures on the Bonelli system would be 26*l.* and one month. Several advantages are claimed for the system:—1. The great facility with which, in a very short time, and with precision, reductions of the design may be obtained on the fabric by means of the varying velocity with which the design may be passed under the teeth. 2. That without damaging the mounting of the loom or the design, fabrics thinner or thicker may be produced by changing the number of the weft, and making a corresponding change in the movement of the design. 3. The loom and its mounting remaining unchanged, the design may be changed in a few minutes by the substitution of another metallised paper having a different pattern. 4. The power of getting rid of any part of the design, if required, and of modifying it. The validity of these claims remains for the future to show.