WEAVING. The process of weaving consists in interlacing, at right angles, two or more series of flexible materials, of which the longitudinal are called warp and the transverse weft. Weaving, therefore, only embraces one section of the textile industry, for felted, plaited, netted, hosiery and lace fabrics lie outside this definition. Felting consists in bringing masses of loose fibres, such as wool and hair, under the combined influences of heat, moisture and friction, when they become firmly interlocked in every direction. Plaited fabrics have only one series of threads interlaced, and those at other than right angles. In nets all threads are held in their appointed places by knots, which are tied wherever one thread intersects another. Hosiery fabrics, whether made from one or many threads, are held together by intersecting a series of loops; while lace fabrics are formed by passing one set of threads between and round small groups of a second set of threads, instead of moving them from side to side. Notwithstanding the foregoing limitations, woven fabrics are varied in texture and have an enormous range of application. The demands made by prehistoric man for fabrics designed for clothing and shelter were few and simple, and these were fashioned by interlacing strips of fibrous material and grasses, which in their natural condition were long enough for the purpose in hand. But, as he passed from a state of savagery into a civilized being, his needs developed with his culture, and those needs are still extending. It no longer suffices to minister to individual necessities; luxury, commerce and numerous industries must also be considered.

The invention of spinning (*q.v.*) gave a great impetus to the introduction of varied effects previously; the use of multicoloured threads provided ornament for simple structures, but the demand for variety extended far beyond the limits of colour, and different materials were employed either separately or conjointly, together with different schemes of interlacing. Eventually the weaver was called upon to furnish articles possessing lustre, softness and delicacy; or those that combine strength and durability with diverse colourings, with a snowy whiteness, or with elaborate ornamentation. In cold countries a demand arose for warm clothing, and in hot ones for cooler materials; while commerce and industry have requisitioned fabrics that vary from normal characteristics to those that exceed an inch in thickness. In order to meet these and other requirements the world has been searched for suitable raw materials. From the animal kingdom, wool, hair, fur, feathers, silk and the pinna fibre have long been procured. From the vegetable kingdom, cotton, flax, hemp, jute, ramie and a host of other less known but almost equally valuable materials are derived. Amongst minerals there are gold, silver, copper, brass, iron, glass and asbestos. In addition, strips of paper, or skin, in the plain, gilt, silvered and painted conditions are available as well as artificial fibres. All of the foregoing may be used alone or in combination.

From such varied raw materials it is not surprising that woven fabrics should present an almost endless variety of effects; yet these differences are only in part due to the method of weaving. The processes of bleaching (*q.v.*), mercerizing (*q.v.*), dyeing (*q.v.*), printing (see TEXTILE PRINTING) and finishing (*q.v.*) contribute almost as much to the character and effect of the resultant product as do the incorporation in one fabric of threads spun in different ways, and from fibres of different origin, with paper, metal, beads or even precious stones.

[1] Both these species seem to have been first described and figured in 1600 by Aldrovandus (lib. xv. cap. 22, 23) from pictures sent to him by Ferdinando de' Medici, duke of Tuscany.

INDUSTRIAL TECHNICOLOGY

All weaving schemes are reducible to a few elementary principles, but no attempted classification has been quite successful, for fabrics are constantly met with that possess characteristics supposed to be peculiar to one class, but lack others which are deemed equally typical. Nevertheless, since some classification is essential, the following will be adopted, namely: Group 1, to include all fabrics made from one warp and one weft, provided both sets of threads remain parallel in the finished article and are intersected to give the requisite feel and appearance. Group 2, to include (*a*) fabrics constructed from two warps and one weft, or two wefts and one warp, as in those that are backed, reversible and figured with extra material; (*b*) two or more distinct fabrics built simultaneously from two or more warps and wefts, as in two, three and other ply cloths; (*c*) fabrics built by so intersecting two or more warps and wefts that only one texture results, as in loom-made tapestries and figured repps. Group 3, to include fabrics in which a portion of the weft or warp rises vertically from the groundwork of a finished piece, as in velveteens, velvets, plushes and piled carpets. Groups 4, to embrace all fabrics in which one portion of the warp is twisted partially, or wholly, round another portion, as in gauzes and lappet cloths. Although some fabrics do not appear to fall into any of the above divisions, and in others the essential features of two or more groups are combined, yet the grouping enumerated above is sufficiently inclusive for most purposes.

The fabrics included in Group 1 are affected by the nature and closeness of the yarns employed in their construction, by colour, or by the scheme of intersecting the threads. The most important section of this group is *Plain Cloth*, in which the warp and weft threads are approximately equal in thickness and closeness, and pass over and under each other alternately, as in fig. 1, which shows a design, plan and two sections of plain cloth. Such a fabric would, therefore, appear to admit of but slight ornamentation, yet this is by no means the case, for if thick and thin threads of warp and weft alternate, the resultant fabric may be made to assume a corrugated appearance on the face, while beneath it remains flat, as in poplins, repps and cords. A plan and a longitudinal section of a repp cloth is shown at fig. 2. Colour may also be employed to ornament plain fabrics, and its simplest application produces stripes and checks. But colour may convert these fabrics into the most artistic and costly productions of the loom, as is the case with tapestries, which

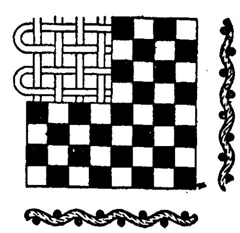


FIG. 1.—Plain Cloth.

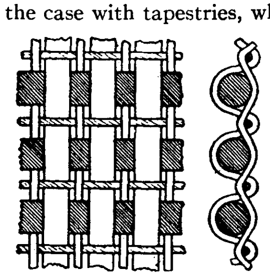


FIG. 2.—Repp Cloth.

are at once the oldest and most widely diffused of ornamented textiles. Tapestries only differ from simple plain cloth in having each horizontal line of weft made up of numerous short lengths of parti-coloured thread. Many fine specimens of this art have been recovered from ancient Egyptian and Peruvian tombs, and many are still produced in the Gobelins and other celebrated manufactories of Europe.

Twills are next in importance to plain cloth on account of their wide range of application and great variety of effects; in elaborately figured goods their use is as extensive as where they provide the only ornament. Twills invariably form diagonal ribs in fabrics, and these are due to the intervals at which the warp and weft are intersected; thus two or more warp threads are passed over or under one or more than one weft thread in regular succession. Twills are said to be equal when similar quantities of warp and weft are upon the face of a fabric, unequal when one set of threads greatly preponderates over the other set, as in figs. 3, 4, which require four warp and weft threads to complete the scheme of intersections. If the ribs form angles of 45 degrees, the warp and weft threads per inch are about equal in number, but for an unequal twill the material most in evidence should be closest and finest. The angle formed may be greater or less than 45 degrees, as in figs. 5, 6; if greater, the warp preponderates, if less, the weft preponderates. Twills are *simple* and *fancy*; both terms refer to the schemes of intersecting. In the former the same number of warp threads are placed successively above or below each weft thread, and the ribs are of uniform width, as in figs. 3, 4. In the latter more warp threads may be above one

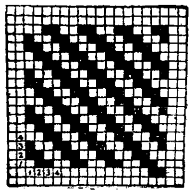


FIG. 3.—Four-thread $\frac{2}{2}$ Twill.

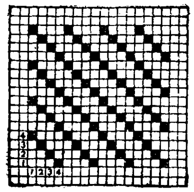


FIG. 4.—Four-thread $\frac{1}{3}$ Twill.

pick than another, the ribs may vary in width and small ornament may be introduced between the ribs, as in figs. 5, 6 and 7, where the dark squares represent warp upon the surface. Twills may be broken up into zigzags, lozenges, squares and other geometrical designs; all of which may be produced by reversings in the diagonal lines, or by reversing the weave of an unequal twill. Fig. 8 is a zigzag, namely, a twill reversed in one direction. Fig. 9 is a diamond,

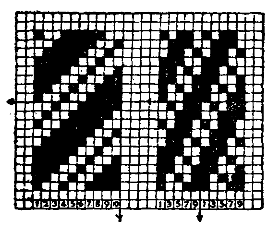


FIG. 5.—Upright Twill.

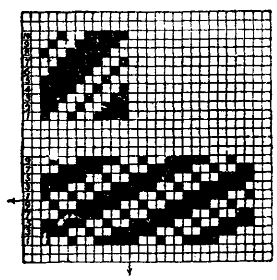


FIG. 6.—Reclining Twill.

or a twill reversed in two directions, and fig. 10 is a diaper, or an unequal twill which gives a warp face in one place and a weft face in another. *Satins* and *satteens* form another important section of Group 1. In a satin the bulk of the warp, and in a satteen the bulk of the weft, is on the face of a fabric. If perfect in construction both present a smooth, patternless appearance, which is due in part to the scheme of intersections, in part to using fine material for the

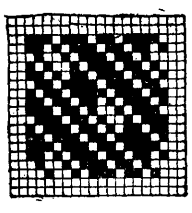


FIG. 7.—Fancy Twill.

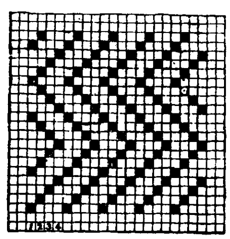


FIG. 8.—Zigzag.

surface threads and placing it close enough together to render the points of intersection invisible; the threads of the other set being coarser and fewer in number. Satins differ from twills in having each warp thread lifted, or depressed, separately, but not successively. From five to upwards of thirty threads of warp and weft are required to complete the various schemes of intersecting. If the intervals between the intersections are equal the weave is said to be perfect,

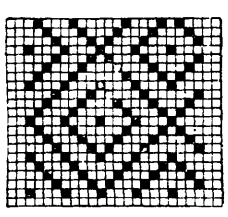


FIG. 9.—Diamond.

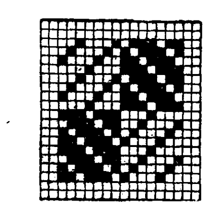


FIG. 10.—Diaper.

as in fig. 11, but if the intervals are irregular it is said to be imperfect, as in fig. 12. In *Damasks* a satin is combined with a satteen weave, and since any desired size and shape of either weave may be produced, great facilities are offered for the development of all kinds of ornamentation. But in combination neither the satin nor the satteen can be perfect in construction, for one requires a preponderance of warp, the other a preponderance of weft; as a sequence every point of intersection is distinctly visible on both surfaces. *Brocades* are fabrics in which both sets of threads may be floated irregularly upon the surface to produce ornamental effects, and they may be taken as typical of all one warp and one weft fabrics that are figured by irregularly floated materials, whether the threads are uniformly or irregularly distributed, and whether one weave or several weaves be employed.

Group 2 includes all backed and reversible fabrics, as well as those ornamented with extra material and compounded. Cloths intended for men's wear are often *backed*, the object of which is to give weight and bulk to a thin texture without interfering with the

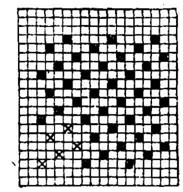


FIG. 11.—Five-thread Satteen.

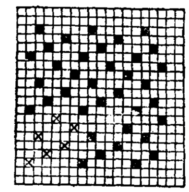


FIG. 12.—Six-thread Satteen.

face effects. Either warp or weft may be used as backing; if the former there are two series of warp to one series of weft threads, while in the latter there are two series of weft to one series of warp threads. The face material is superposed upon that of the back, but the ratio of face threads may be one or two to one of back. In order to avoid disturbing the face weave, only those threads are used to bind the backing that are hidden on the face, as in fig. 13, which gives the design and a transverse section of a backed fabric; A is face weft; B back weft, and the circles are warp threads; of the latter C, D, are beneath both B and A. This diagram will serve equally as a longitudinal section of a warp-backed fabric, if A represents a thread of face warp, B a thread of back warp and the circles are weft threads. Weft backing is capable of giving a more spongy feel to a fabric than warp, because softer materials may be used, but in these fabrics the length output of loom is reduced by reason of the wefts being superposed. Warp-backed fabrics, whether uniformly coloured or striped, do not materially reduce the output of a loom, for every weft thread adds to the cloth length. *Reversible* fabrics may have either two series of differently coloured wefts or warps to one of the other series, in which event they may be similarly figured on both sides by causing the threads of the double series to change places, as in the design and transverse section, fig. 14; or, by allowing one series to remain constantly above the other, as in backed cloths, both sides may be similar or dissimilar in colour and pattern. *Fabrics figured with extra material* may have two series of warp or weft threads to one series of the other set, and they may yield reversible or one-sided cloths. A ground texture may have extra material placed above or below it, as in fig. 15, where a design and transverse section of the cloth are given; the waved lines and circles represent a cross-section of plain cloth and A is a thread of extra material; or ordinary and extra material may be used conjointly for figuring. *Compound cloths* must have at least two textures, and be as distinct in character as if woven in separate looms; they have many advantages over backed cloths, thus: the same design and colouring may be produced on both sides; where bulk and weight are required a fine surface texture may be formed over a ground of inferior material, and soft weft be passed between the upper and lower textures. The fabric is more perfect and admits of either simple or elaborate patterns being wrought upon the surface, with simple ones beneath, as in piqués and matelassés. One texture may be constantly above the other and connected at the selvages only, as in hose pipes and pillow slips; or at intervals a thread may pass from one texture into the other, in which event both are united, as in many styles of bed-covers and vestings. If differently coloured,

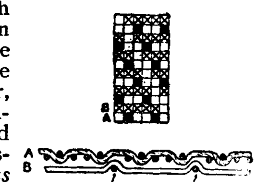


FIG. 13.—Weft-backed Fabric.

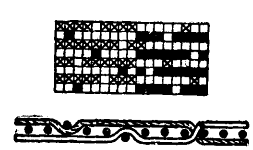


FIG. 14.—Weft Reversible Fabric.

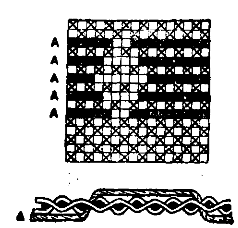


FIG. 15.—Figuring with Extra Weft.

the textures may change places at pleasure, as in Kidderminster carpets; or, from three to twelve textures may be woven simultaneously, and united, as in belting cloth. There may be from one to three threads of face warp to one of back, and the wefting may or may not correspond with the warping. Fig. 16 shows the face and back weaves, the design, and a transverse section of a compound cloth with two threads of face warp and weft to one of back, and both are stitched together. The circles in the upper and lower lines represent face and back warps respectively, and A, B, C are weft threads placed in the upper and lower textures. *Loom-made tapestries and figured repps* form another section of Group 2. As compared with true tapestries, the loom-made articles have more limited colour schemes, and their figured effects may be obtained from warp as well as weft, whether interlaced to form a plain face, or left floating more or less loosely. Every weft thread, in passing from selvage to selvage, is taken to the surface where required, the other portions being bound at the back. Some specimens are reversible, others are one-sided, but, however numerous the warps and wefts, only one texture is produced. When an extra warp of fine material is used to bind the wefts firmly together a plain or twill weave shows on both sides. If a single warp is employed, two or more wefts form the figure, and the warp seldom floats upon the surface. Where warps do assist to form figure it rarely happens that more than three can be used without overcrowding the reed.

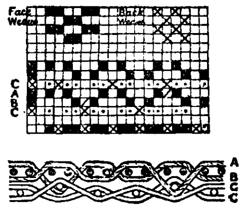


FIG. 16.—Compound Fabric.

Fig. 17 gives the design, and a transverse section of a reversible tapestry in four colours, two of which are warps and two wefts. If either warp or weft is on the surface, corresponding threads are beneath. The bent lines represent weft and the circles warp. *Figured repps* differ from plain ones in having threads of one, or more than one, thick warp floated over thick and thin weft alike; or, in having several differently coloured warps from which a fixed number of threads are lifted over each thick weft thread; the face of the texture is then uniform, and the figure is due to colour.

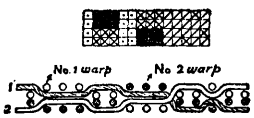


FIG. 17.—Tapestry with Two Warps and Two Wefts.

Group 3. *Piled Fabrics.*—In all methods of weaving hitherto dealt with the warp and weft threads have been laid in longitudinal and transverse parallel lines. In piled fabrics, however, portions of the weft or warp assume a vertical position. If the former there are two series of weft threads, one being intersected with the warp to form a firm ground texture, the other being bound into the ground at regular intervals, as in the design and transverse section of a velveteen, fig. 18; the circles and waved lines form plain cloth, and the loose thread A is a pile pick. After leaving the loom all threads A are cut by pushing a knife lengthwise between the plain cloth and the pile. As each pick is severed both pieces rise vertically and the fibres open out as at B. Since the pile threads are from two to six times as numerous as those of the ground, and rise from an immense number of places, a uniform brush-like surface is formed. Raised figures are produced by carrying the threads A beneath the ground cloth, where no figure is required, so that the knife shall only cut those portions of the pile weft that remain on the surface. The effect upon the face varies with the distribution of the binding points, and the length of pile is determined by the distance separating one point from another.

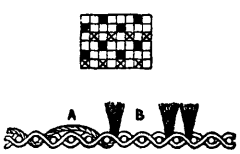


FIG. 18.—Velveteen.

Chenille.—When chenille is used in the construction of figured weft-pile fabrics, it is necessary to employ two weaving operations, namely, one to furnish the chenille, the other to place it in the final fabric. Chenille is made from groups of warp threads that are separated from each other by considerable intervals; then, multi-coloured wefts are passed from side to side in accordance with a predetermined scheme. This fabric is next cut midway between the groups of warp into longitudinal strips, and, if reversible fabrics such as table-covers and curtains are required, each strip is twisted axially until the protruding ends of weft radiate from the core of warp, and form a cylinder of pile. In the second weaving this chenille is folded backward and forward in a second warp to lay the colours in their appointed places and pile projects on both sides of the fabric. If chenille is intended for carpets, the ends of pile weft are bent in one direction, and then woven into the upper surface of a strong ground texture.

Warp-piled Fabrics have at least two series of warp threads to one of weft, and are more varied in structure than weft-piled fabrics, because they may be either plain or figured, and have their surfaces cut, looped or both.

Velvets and Plushes are woven single and double. In the former case both ground and pile warps are intersected with the weft, but at intervals of two or three picks the pile threads are lifted over a wire, which is subsequently withdrawn; if the wire is furnished with a knife at its outer extremity, in withdrawing it the pile threads are cut, but if the wire is pointed a line of loops remains, as in terry velvet. Fig. 19 is the design, and two longitudinal sections of a Utrecht velvet. The circles at A are weft threads, and the bent line is a pile thread, part of which is shown cut, another part being looped over a wire. At B the circles are repeated to show how the ground warp intersects the weft.

Double Plushes consist of two distinct ground textures which are kept far enough apart to ensure the requisite length of pile. As weaving proceeds the pile threads are interlaced with each series of weft threads, and passed from one to the other. The uniting pile material is next severed midway between the upper and lower textures, and two equal fabrics result. Fig. 20 gives three longitudinal sections of a double pile fabric. The circles A, B are weft threads in the upper and lower fabrics respectively; the lines that interlace with these wefts are pile warp threads which pass vertically from one fabric to the other. At C, D the circles are repeated to show how the ground warps intersect the wefts, and at E the arrows indicate the cutting point.

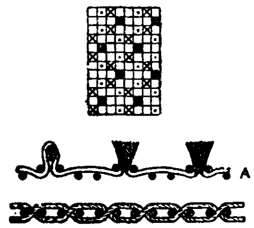


FIG. 19.—Utrecht Velvet.

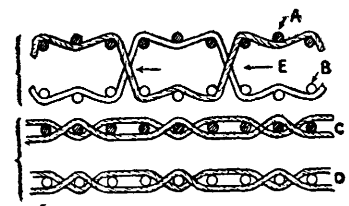


FIG. 20.—Double Plush.

Figured Warp-pile Fabrics are made with regular and irregular cut and looped surfaces. If regular, the effect is due to colour, and this again may be accomplished in various ways, such as (*a*) by knotting tufts of coloured threads upon a warp, as in Eastern carpets; (*b*) by printing a fabric after it leaves the loom; (*c*) by printing each pile thread before placing it in a loom, so that a pattern shall be formed simultaneously with a pile surface, as in tapestry carpets; (*d*) by providing several sets of pile threads, no two of which are similar in colour; then, if five sets are available, one-fifth of all the pile warp must be lifted over each wire, but any one of five colours may be selected at any place, as in Brussels and Wilton carpets. Fig. 21 is the design, and a longitudinal section of a Brussels carpet. The circles represent two tiers of weft, and the lines of pile threads, when not lifted over a wire to form loops, are laid between the wefts; the ground warp interlaces with the weft to bind the whole together. When the surface of a piled fabric is irregular, also when cut and looped pile are used in combination, design is no longer dependent upon colour, for in the former case pile threads are only lifted over wires where required, at other places a flat texture is formed. In the latter case the entire surface of a fabric is covered with pile, but if the figure is cut and the ground looped the pattern will be distinct.

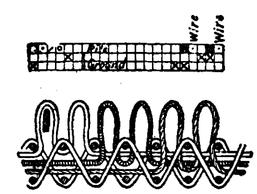


FIG. 21.—Brussels Carpet.

Group 4. *Crossed Weaving.*—This group includes all fabrics in which the warp threads intertwist amongst themselves to give intermediate effects between ordinary weaving and lace, as in gauzes. Also those in which some warp threads are laid transversely in a piece to imitate embroidery, as in lappets.

Plain Gauze embodies the principles that underlie the construction of all crossed woven textiles. In these fabrics the twisting of two warp threads together leaves large interstices between both warp and weft. But although light and open in texture, gauze fabrics are the firmest that can be made from a given quantity and quality of material. One warp thread from each pair is made to cross the other at every pick, to the right and to the left alternately, therefore the same threads are above every pick, but since in crossing from side to side they pass below the remaining threads, all are bound securely together, as in fig. 22, where A is a longitudinal section and B a plan of gauze.

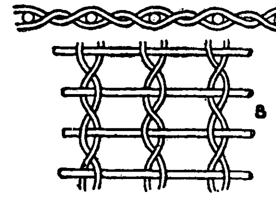


FIG. 22.—Plain Gauze.

Leno is a muslin composed of an odd number of picks of a plain weave followed by one pick of gauze. In texture it is heavier than gauze, and the cracks are farther apart transversely.

Fancy Gauze may be made in many ways, such as (*a*) by using crossing threads that differ in colour or count from the remaining threads, provided they are subjected to slight tensile strain; (*b*) by causing some to twist to the right, others to the left simultaneously; (*c*) by combining gauze with another weave, as plain, twill, satin, brocade or pile; (*d*) by varying the number of threads that cross, and by causing those threads to entwine several ordinary threads; (*e*) by passing two or more weft threads into each crossing, and operating any assortment of crossing threads at pleasure.

Lappet weaving consists in diapering the surface of a plain or gauze fabric with simple figures. This is done by drawing certain warp threads into a transverse position and then lifting them over a thread of weft to fix them in the texture; after which they are moved in the opposite direction and lifted over the following pick. The material between one binding point and another must float loosely, and this limits the usefulness of lappet figuring. In fig. 23, the thick lines show a lappet spot upon a plain texture. Notwithstanding diverse structure, intricate mechanisms are not essential to the production of either simple or complex textures; the most elaborate and beautiful specimens of the weaver's art have been manufactured upon simple machinery.

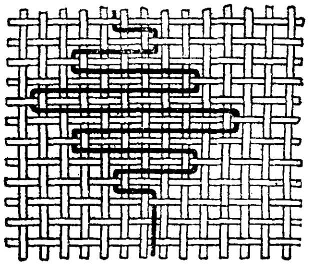


FIG. 23.—Lappet Fabric.

Weaving Machinery.

The longitudinal threads of a fabric are called warp, caine, twist and organzine, and the transverse threads are weft, shoot, woof, filling and tram. A loom for intersecting these several threads must provide for: (1) Shedding; namely, raising and lowering the warp threads in a predetermined sequence so as to form two lines between which the weft may be passed. (2) Picking, or placing lines of weft between the divided warp. (3) Beating-up, or striking each weft thread into its appointed position in the fabric. (4) Letting-off, or holding the warp tense and delivering it as weaving proceeds. (5) Taking-up, or drawing away the cloth as manufactured. (6) Temples, for stretching the fabric widthwise in order to prevent the edge threads of a warp from injuring the reed, and from breaking. Power looms require the above-named contrivances to act automatically, and in addition: (7) A weft-fork, to stop a loom when the weft becomes exhausted or breaks. (8) Mechanism for stopping a loom when the shuttle fails to reach its appointed box. (9) For weaving cross stripes, multiple shuttle boxes are needed to bring different colours, or counts of weft, into use at the proper time. (10) In some looms a device for automatically ejecting a spent cop, pirn or shuttle, and inserting a full one, is requisite. (11) If a weaver has to attend to a greater number of looms than usual, a device for stopping a loom when a warp thread fails is essential.

The Hand-Loom.—During the 17th and the first half of the 18th centuries it was observed that wherever any branch of the textile industry had been carried to a high state of excellence the looms

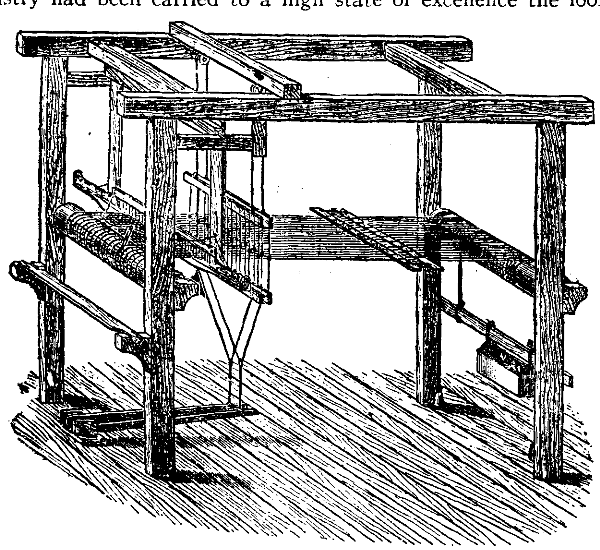


FIG. 24.—Diagram of Hand-Loom.

used to manufacture a given fabric were similar in essentials, although in structural details they differed greatly. Prior to the invention of the fly shuttle by John Kay, in 1733, no far-reaching invention had for generations been applied to the hand-loom, and subsequently the Jacquard machine and multiple shuttle boxes represent the chief changes. A hand-loom as used in Europe at the present time (see fig. 24) has the warp coiled evenly upon a beam whose gudgeons are laid in open steps formed in the loom framing. Two ropes are coiled round this beam, and weighted to prevent the warp from being given off too freely. From the beam the threads pass alternately over and under two lease rods, then separately through the eyes of the shedding harness, in pairs between the dents of a reed, and finally they are attached to a cloth roller. For small patterns healds are used to form sheds, but for large ones a Jacquard machine is required. Healds may be made of twine, of wire or of twine loops into which metal eyes, called mails, are threaded. But they usually consist of a number of strings which are secured above and below upon wooden laths called shafts, and each string is knotted near the middle to form a small eye. From two to twenty-four pairs of shafts may be employed, but the healds they carry must collectively equal the number of threads in the warp. These healds will be equally or unequally distributed upon the shafts according to the nature of the pattern to be woven, and the threads will be drawn through the eyes in a predetermined order. The upper shafts are suspended from pulleys or levers, and the lower ones are attached directly or indirectly to treadles placed near the floor. The weaver depresses these treadles with his feet in a sequence suited to the pattern, and the scheme of drawing the warp through the healds. When a treadle is pressed down, at least one pair of shafts will be lifted above the others, and the warp threads will ascend or descend with the healds to form a shed for a shuttle, containing weft, to be passed through (see SHUTTLE). The reed (fig. 25) is the instrument

FIG. 25.—Weaver's Reed.

by which weft is beaten into position in the cloth; it also determines the closeness of the warp threads, and guides a moving shuttle from side to side. It is made by placing strips of flattened wire between two half round ribs of wood, and binding the whole together by passing tarred twine between the wires and round the ribs. Such a reed is placed in the lower portion of a batten, which is suspended from the upper framework of the loom. In front of the reed, and immediately below the warp, the projecting batten forms a race for the shuttle to travel upon from side to side. Before Kay's invention a shuttle was thrown between the divided warp and caught at the opposite selvage, but Kay continued the projecting batten on both sides of the warp space, and constructed boxes at each end. Over each box he mounted a spindle, and upon it a driver, or picker. Bands connected both pickers to a stick which the weaver held in his right hand, while with the left hand he controlled the batten. Thus: a treadle is pressed down by one foot to form a shed; the batten is pushed back till a sufficient portion of the shed is brought in front of the reed, and the depressed threads lie upon the shuttle race; a clear way is thus provided for the shuttle. A quick movement of the stick tightens the cord attached to a picker and projects the shuttle from one box to the other. The batten is now drawn forward, and the reed beats up the weft left by the shuttle. As the next treadle is depressed to form another division of the warp for the return movement of the shuttle, the last length of weft is enwrapped between intersecting warp threads, and the remaining movements follow in regular succession (see fig. 26).

In cases where the weft forms parti-coloured stripes across a fabric, also where different counts of weft are used, shuttles, equal in number

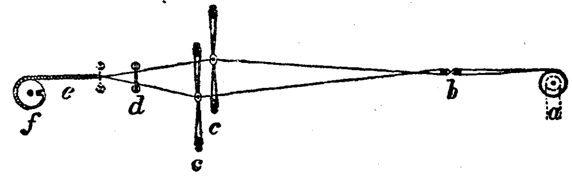


FIG. 26.—Section of Plain Web in Process of Weaving on the Loom.

a, The warp beam.
b, The lease rods by which the warp is divided and crossed.
c, *c*, Two pairs of shafts containing healds.
d, The reed in position for picking, and also for beating-up.
e, Woven cloth.
f, The cloth beam.

to the colours, counts or materials, must be provided. By Robert Kay's invention of multiple shuttle boxes, in 1760, much of the time lost through changing shuttles by hand was prevented. His drop boxes consist of trays formed in tiers and fitted into the ordinary shuttle boxes. Each tray is capable of holding a shuttle, and by operating a lever and plug with the forefinger and thumb of the left hand, the trays may be raised and lowered at pleasure to bring that shuttle containing the colour next needed into line with the picker.

The Draw Loom.—Large figured effects were formerly produced in draw looms, where the warp threads were so controlled by separate strings that any assortment could be lifted when required. Thus: to the lower end of each string a dead weight, called a lingoe, was attached, and a few inches above the lingoe a mail was fixed for the control of a warp thread. The strings passed through a drilled board which held the mails and warp threads facing the proper reed dents. Still higher up, groups of strings were connected to neck cords; each group consisted of all strings required to rise and fall together constantly. If, for example, in the breadth of a fabric there were twelve repeats of a design, twelve strings would be tied to the same neck cord, but taken to their respective places in the comber board. The foregoing parts of a draw loom harness are clearly shown in fig. 27: A are lingoes, and the dots represent mails. B is the comber board; between B and C are mounting strings and neck cords, two strings being attached to each cord; and C is the bottom board. Each neck cord, after being led through a perforated bottom board C, and over a grooved pulley, was threaded through a ring on the top of a vertical cord called the simple, and passed horizontally to, and tied upon a bar rigidly fixed near the ceiling of the weaving room. The simple cords were similarly attached to a bar placed near the floor. From one hundred to several thousands of neck and simple cords could be used in one harness. The design to be reproduced in cloth was read into the parallel lines of the simple by looping a piece of string round each cord that governed warp threads to be lifted for a given shed; after which all the loops were bunched together. By pulling at a bunch of loops the simple cords were deflected and they caused all warp threads controlled by them to be lifted above the level of those undisturbed. Similar bunches of loops were formed for every shed required for one repeat of a design, and they were pulled in succession by the draw-boy, while the weaver attended to the batten and picking.

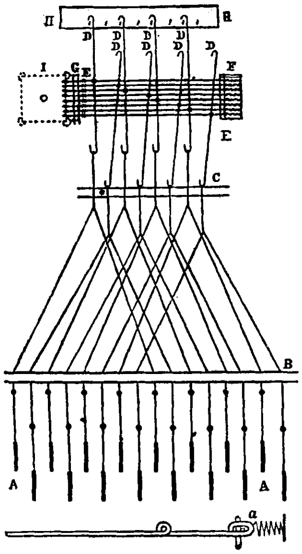


Fig. 27.—Diagram of Jacquard Machine and Harness.

The *Jacquard machine* is the most important invention ever applied to the hand-loom, but it is not the work of one man; it represents the efforts of several inventors whose labours extended over three-quarters of a century. This apparatus has taken the places of the simple, the loops, the pulleys and the draw-boy of the older shedding motion, but other parts of the harness remain unchanged. In 1725 Basile Bouchon substituted for the bunches of looped string an endless band of perforated paper by which the simples for any shed could be selected. In 1728 M. Falcon constructed the machine since known as the Jacquard and operated it through the medium of perforated cards, but it was attached to the simple cords and required a draw-boy to manipulate it. In 1745 Jacques de Vaucanson united in one machine Bouchon's band of paper and the mechanism of Falcon. He placed this machine where the pulley box previously stood, and invented mechanism for operating it from one centre.

It is said that about the year 1801 J. M. Jacquard was called upon to correct the defects of a certain loom belonging to the state, in doing which he asserted that he could produce the desired effects by simpler means, and this he undoubtedly accomplished. In or about 1804 he discarded the simple and all but a few inches of the vertical neck cords; he placed Falcon's apparatus immediately over the centre of the loom and severally attached the upper portions of the neck cords to the hooks; all of which Vaucanson had previously done. He then perforated each face of a quadrangular frame—used by Falcon to guide the cards to the draw-boy, and since known as the cylinder—and invented means whereby the cylinder could be made to slide horizontally to and fro, and at each outward journey make one-quarter of a revolution. Cards were so held upon this cylinder by pegs that at each rotatory movement one was brought into action and another moved away. By means of two treadles placed beneath the warp one weaver could operate the entire loom. The cylinder was controlled with one foot, the selecting parts with the other, and both hands were free to attend to picking and beating-up.

In a Jacquard machine the warp threads are raised by rows of upright wires called hooks. See D, fig. 27. These are bent at both extremities and are normally supported upon a bottom board C, which is perforated to permit the neck cords from the harness beneath to be attached to the hooks. Each of a series of horizontal needles E—one of which is shown enlarged and detached at the foot of the drawing—is provided with a loop and a coiled eye; the former to permit of a to-and-fro movement, the latter to receive a hook. The straight ends of the needles protrude about one-quarter of an inch through a perforated needle board G, but the looped ends rest upon bars placed in tiers. A wire passed through all the loops of the needles which form one vertical line limits the extent of their lateral movement, and small helical springs, *a*, enclosed in a box F, impinge upon the loops of the needles with sufficient force to press them and their hooks forward. A frame H, called a griffe, is made to rise and fall vertically by a treadle which the weaver actuates with one foot. This frame contains a blade for each line of hooks, and when the blades are in their lowest position the hooks are free and vertical with their heads immediately over the blades, hence, an upward movement given to the griffe would lift all the hooks and thereby all the warp threads. Only certain hooks, however, must be lifted with the griffe, and the selection is made by a quadrangular block of wood, I, called a cylinder, and cards which are placed upon it. Thus, each face of the cylinder has a perforation opposite each needle, so that if the cylinder be pressed close to the needle board the needle points will enter the holes in the cylinder and remain undisturbed. But if a card, which is not perforated in every possible place, is interposed between the cylinder and the needles, the unpunctured parts of the card close up some of the holes in the cylinder, and prevent corresponding needles from entering them. Each needle so arrested is thrust back by the advancing card; its spiral spring *a* is contracted and its hook D is tilted as shown in the figure. If at this instant the griffe H ascends, its blades will engage the heads of all vertical hooks and lift them, but those dislocated by being tilted will remain unlifted So soon as the pressing force of a card is removed from the needles the elasticity of the springs restores both needles and hooks to their normal positions. Cards are perforated by special machinery from a painted design, after which they are laced into a chain and passed over conical pegs upon the cylinder; the number required to weave any pattern equals the number of weft threads in that pattern. The cylinder is generally drawn out and turned by each upward movement of the griffe, and restored to the needles by each downward movement, so that each face in succession is presented to the needles, and each rotatory movement brings forward a fresh card. As the griffe rises with vertical hooks a shed is formed, and a thread of weft is passed across the warp. The griffe then descends and the operation is repeated but with a new combination of lifted threads for each card. A Jacquard may contain from 100 to 1200 hooks and needles, and two or more machines may be mounted upon the same loom.

Since Jacquard's time attempts have been made to dispense with hooks, needles, springs, cards, the cylinder and several other parts; machines have also been specially designed for effecting economies in the manufacture of certain fabrics; but although some of these devices are used in different sections of the industry, the single lift Jacquard remains unchanged, except in its details, which have been modified to give greater certainty of action to the moving parts. The most far-reaching changes are directly due to efforts made to adapt the Jacquard to fast running power looms. Alfred Barlow, John and William Crossley, and others, devised means whereby two hooks could control the same warp thread, and they provided the machine with two griffes, each capable of actuating alternate rows of hooks. One griffe was caused to ascend as the other descended, therefore, if one of the two hooks that operate a warp thread is lifted for the first shed, the other hook can begin to rise for a second shed immediately the first begins to fall. About half the time originally needed for shedding is thus saved, and as a result Jacquards can now be run at 210 to 220 picks per minute.

Preparing Warp and Weft for Weaving.—The power loom is only one of a series of machines which revolutionized weaving. Although early inventors of the power loom did much to perfect its various movements, the commercial results were disappointing, chiefly because means had not been devised for preparing warp and weft in a suitable manner for such a machine. William Radcliffe, of Stockport, perceived these shortcomings, and concluded that, by division of labour, weaving could be brought into line with, the then recently invented, spinning machinery. He, therefore, set himself the task of solving the problems involved, and by inventing the beam warper, the dressing sizing machine, the shuttle tongue, and the pin cop, he enabled the power loom to become a factor in the textile industry. The term preparation embraces winding, warping, sizing, Yorkshire dressing, drawing-in, twisting and occasionally other operations.

Weft Winding.—Weft yarns invariably receive simpler treatment than warp yarns; in many cases none at all. Cops and ring spools pass direct to the loom unless their dimensions are unsuited to the shuttles, in which case they, together with wefts bleached or dyed in hanks or used in a saturated condition, require winding upon pirns, or into cops of suitable sizes. Pirn winders differ greatly in construction, but the majority are furnished with conical shapers, consisting either of slip cups, or of cone rollers mounted upon studs. A pirn, whose head is coned to fit inside a shaper, is slipped over a spindle, and both are passed, either vertically or horizontally, through a shaper; the basal end of the spindle being flattened to enter a rectangular hole in a wharve which is driven from a central tin drum. A thread is attached to a rotating pirn, and a vibrating guider leads it to and fro inside the shaper. Both spindle and pirn recede from the shaper until the pirn is full, when they become stationary. Hanks are carried by ryces, and cops and ring spools by skewers. Cop winders are chiefly used for coarse yarns, which they coil upon bare spindles. By this means a greater length of weft can be placed in a shuttle than when pirns are used.

Warp winding consists in transferring yarn from cops, ring spools or hanks, either to warpers, bobbins or cheeses (see COTTON-SPINNING MACHINERY). Machines for this purpose are of two kinds, which are known respectively as spindle and drum. In the former each bobbin is placed upon a vertical spindle and rotated by frictional contact; a yarn guider meanwhile rises and falls far enough to lay the threads in even coils between the bobbin flanges. In the latter each bobbin, or tube, is laid upon a rotating drum and a thread guide moves laterally to and fro; slowly for a bobbin, but quickly for a tube.

Warping.—The number of longitudinal threads in a web vary according to their closeness and its breadth. It is the function of a warper to provide a sufficient number of parallel threads for a web, all of equal length, and to retain their parallelism. Warpers are of three types, viz. mill, beam and sectional.

Mill warping is the oldest type now in extensive use. A mill warper has a creel in which from 50 to upwards of 300 bobbins or cheeses, are supported horizontally upon pegs, and the mill has a vertical axis which carries three wheels, upon whose rims vertical staves are fixed about 1 ft. apart to form a reel, from 5 to upwards of 20 yds. in circumference. The threads from the creel are threaded in succession through leasing needles, then passed in groups of four to twenty threads between runners, and, finally, fastened by a peg to the mill staves. The needles are mounted alternately in two frames which may be moved up inclined planes; one to elevate odd threads, the other even ones, and both separations thus formed are retained upon separate pegs; this is the lease which enables a weaver to readily fix the position of a broken thread. As the mill rotates the threads form a tape about 1 in. wide, and the leasing apparatus slides down a post to coil the threads spirally upon the reel. When the full length of warp has been made the mill is stopped, a half beer lease is picked by hand from the divisions formed by the runners, and also retained upon pegs. The mill next reverses its direction of rotation, and as the leasing apparatus ascends the threads are folded back upon themselves. Hence, if a reel is 20 yds. in circumference, and 200 threads are in use to make a warp 600 yds. long, and containing 2000 threads, the reel will make 30 revolutions ($600 \div 20 = 30$) also 10 reversals, for at each reversal 200 additional threads will be added ($2000 \div 200 = 10$). When a warp is complete, strings are passed through the leases, and it is coiled into a ball, loosely linked into a chain, or dropped into a sheet. If a mill has its axis horizontal the leasing apparatus must slide horizontally.

Winding on Frame.—After a ball warp has been bleached, dyed or sized, the half beers are laid amongst the teeth of a coarse comb to open out the threads to the necessary breadth, in which condition they are coiled upon a loom beam.

Beam warping is the system most extensively used in the cotton trade. The creels for these machines have an average capacity of about 600 bobbins, and are often V-shaped in plan. In each leg of the V the bobbins are arranged in tiers of 16 to 20, and row behind row. The threads are drawn separately between the dents of an adjustable reed, then under and over a series of rollers; from here they are dropped amongst the teeth of an adjustable comb and led down to a warpers beam, which rests upon the surface of a drum. As the drum rotates the threads are drawn from the bobbins and wrapped in even coils upon the beam. On most of these machines mechanism is attached for arresting motion on the fracture of a thread, and also for accurately measuring and recording the lengths of warp made. When full, a warpers beam holds threads of much greater length than are needed for any warp, but they are insufficient in number. Thus: If 500 threads are in use, and warps of the above-named particulars are required, four similar beams must be filled ($2000 \div 500 = 4$) and the threads from all are subsequently united. The chief parts of a beam warper may be used as a substitute for a mill warper, provided that mechanism be employed to contract the threads to the form of a loose rope and coil them into a cylindrical ball, which will be subsequently treated as a mill warp. Or, one of these warpers may be furnished with parts which, when the threads are roped, links them loosely into a chain.

Sectional warping is chiefly employed for coloured threads and its outstanding features consist in contracting the threads to form a ribbon of from 3 in. to 12 in. wide. This ribbon is coiled upon a block placed between flanges, and when completed is set aside until a sufficient number of similar sections have been made; after which they are slipped upon a shaft and by endlong pressure converted into a compact mass. All the threads are then collected and transferred in the form of a sheet to a loom beam; each section contributing its own width to that of the warp. Sectional warps are also made upon horizontal mills by superposing the coils of a ribbon of yarn upon a portion of the staves. When the first section is formed a second is wound against it, and the operation continued until all the sections have been made; after which the yarn is run upon a loom beam.

Yorkshire dressing is used to make striped warps from balled warps which have been dyed in different colours. The operation is as follows: The requisite number of threads of any colour is split from a uniformly dyed ball and set aside until warps of the remaining colours have been similarly treated. The split sections from the several balls collectively contain as many threads as are needed for a warp, but those threads have still to be placed in their proper sequence. This is done by drawing them in groups of two or four between the dents of a reed to a predetermined colour scheme, then all are attached to a loom beam which is supported in a frame. The beam is rotated by stepped cones and gearing, and winds the threads upon itself. But in order to hold the threads taut they are passed between weighted rollers and deflected by bars arranged ladder-wise; in passing from one part of the machine to another they are gradually opened out to the width of the beam.

Sizing.—In cases where single yarns are made from short fibrous materials, smooth surfaces are obtained by laying the outstanding ends of fibres upon the thread, and fastening the fibres together to impart sufficient strength to resist the strains of weaving. This is accomplished either by coating a thread or by saturating it with an adhesive paste. In hand-loom days the paste was applied by brushes to successive stretches of warp while in a loom. But with the advent of mechanical weaving it was found necessary to size a warp before placing it in a loom. Two systems were evolved, the one invented by William Radcliffe sizes, dries and beams a warp in one operation, the yarn is made to pass in the form of a sheet between a pair of rollers, the lower one being partly immersed in warm size. In rotating this roller carries upon its surface a film of size which it deposits upon the threads, while, by pressure, the upper roller distributes the size evenly. Brushes acting automatically smooth down the loose fibres and complete the distribution of size. As the yarn advances it is separated by reeds and lease rods, so that in passing over steam chests and fans the moisture contained in the threads may be quickly evaporated. This machine is a duplex one, for the warpers beams are divided into two sets and placed at opposite ends of the machine. Both halves receive similar treatment as they move to the centre, where the loom beam is placed.

The Ball Warp Sizer.—While efforts were being made to perfect Radcliffe's dressing machine a system of sizing ball warps was being gradually evolved and this system is still largely employed. The machine consists of a long trough, inside which a series of rollers are fitted, either in one horizontal plane or alternately in two horizontal planes; but over the front end of the trough a pair of squeezing rollers are mounted. The trough contains size, which is maintained at a boiling temperature and in sufficient quantity to submerge the rollers. Two warps, in the form of loose tapes, may be simultaneously led over, under and between the rollers. As the warps advance the threads become saturated with size, and the squeezing rollers press out all but a predetermined percentage, the latter being regulated by varying the pressure of the upper roller upon the lower one. If more size be required than can be put into the threads during one passage through the machine, they may be similarly treated a second time. This process does not lay all the loose fibres, but the threads remain elastic. After sizing, the warps are passed backward and forward, and over and under, a set of steam-heated cylinders by which the moisture contained in the threads is evaporated; they are next either reballed, or wound upon a loom beam.

Slasher Sizing.—For sizing cotton yarns Radcliffe's dressing machine has to a large extent been displaced by the slasher, but in some branches of the textile industry it is still retained under various modifications. In a slasher the threads from a number of warping beams are first combined into one sheet, then plunged into a trough filled with size which is kept at a boiling temperature by perforated steam pipes; and next squeezed between two pairs of rollers mounted in the trough. The under surfaces of the sizing rollers are in the size, but the upper squeezing rollers are covered with flannel, and rest by gravitation upon the lower ones. On leaving the size trough the sheet of yarn almost encircles two steam-heated cylinders whose diameters are respectively about 6 ft. and 4 ft.; these quickly expel moisture from the yarn, but so much heat is generated that fans have to be employed to throw cool air amongst the threads. The yarn is next measured, passed above and below rods which separate threads that have been fastened together by size, smeared with piece marks, and coiled upon a loom beam by means of a slipping friction gear. The last-named is employed so that the surface speed of winding shall not be affected by the increasing diameter of the loom beam. By means of mechanism which greatly reduces the velocities of the moving parts, much necessary labour may be performed without actually stopping the machine; this relieves the yarn of strain, and gives better sizing, yet slashed warps are less elastic than dressed, or balled sized ones, and they lack the smoothness of dressed warps.

Hank sizing is chiefly, but not exclusively, employed for bleached and coloured yarns. Machines for doing this work consist of a tank which contains size, flanged revolving rollers and two hooks. One hook is made to rotate a definite number of times in one direction, then an equal number the reverse way; the other has a weight suspended from its outer end and can be made to slide in and out. Size in the tank is kept at the required temperature by steam pipes, and " doles " of hanks are suspended from the rollers with about one-third their length immersed in size. As the hanks rotate all parts of the yarn enter the size, and when sufficiently treated they are removed from the rollers to the hooks where they are twisted to wring out excess, and force in required size. If sufficient size has not been added by one treatment, when untwisted, the wrung-out hanks are passed to a similar machine containing paste of greater density than the first there to be again treated; if necessary this may be followed by a third passage. On the completion of sizing the hanks are removed either to a drying stove or a drying machine. If to the former, they are suspended from fixed, horizontal poles in a specially heated and ventilated chamber. If to the latter, loose poles containing hanks are dropped into recesses in endless chains, and slowly carried through a large, heated and ventilated box, being partially rotated the while. On reaching the front of the box they are removed, brushed and made up into bundles. After which the yarn is wound, warped and transferred to a loom beam.

Drawing-in, or entering, is the operation of passing warp threads through the eyes of a shedding harness, in a sequence determined by the nature of the pattern to be produced, and the order of lifting the several parts. It is effected by passing a hook through each harness eye in succession, and each time a thread is placed in the hook by an attendant, it is drawn into an eye by the withdrawal of the hook.

Twisting or looming consists in twisting, between the finger and thumb, the ends of a new warp separately upon those of an old one, the remains of which are still in the eyes of the shedding harness. The twisted portions adhere sufficiently to permit of all being drawn through the eyes simultaneously.

The Power Loom.—Little is known of the attempts made before the beginning of the 17th century to control all parts of a loom from one centre, but it is certain the practical outcome was inconsiderable. In the year 1661, a loom was set up in Danzig, for which a claim was made that it could weave four or six webs at a time without human aid, and be worked night and day; this was probably a ribbon loom. In order to prevent such a machine from injuring the poor people, the authorities in Poland suppressed it, and privately strangled or drowned the inventor. M. de Gennes, a French naval officer, in 1678 invented a machine whose chief features consisted in controlling the healds by cams, the batten by cams and springs and the shuttle by a carrier. From 1678 to 1745 little of importance appears to have been done for the mechanical weaving of broadcloth. But in the last-named year M. Vaucanson constructed a very ingenious, self-acting loom, on which the forerunner of the Jacquard machine was mounted; he also adopted de Gennes's shuttle carrier. All early attempts to employ mechanical motive power for weaving failed, largely because inventors did not realize that success could only be reached through revolution. Mechanical preparing and spinning machinery had first to be invented, steam was needed for motive power, and the industry required reorganization, which included the abolition of home labour and the introduction of the factory system.

During the last quarter of the 18th century it was generally believed that, on the expiry of Arkwright's patents, so many spinning mills would be erected as to render it impossible to consume at home the yarns thus produced, and to export them would destroy the weaving industry. Many manufacturers also maintained it to be impossible to devise machinery which would bring the production of cloth up to that of yarn. It was as a protest against the last-named assertions that Dr Edmund Cartwright, a clergyman of the church of England, turned his attention to mechanical weaving. More fortunate than his predecessors, he attacked the problem after much initial work had been done, especially that relating to mechanical spinning and the factory system, for without these no power loom could succeed. In 1785 Dr Cartwright patented his first power loom, but it proved to be valueless. In the following year, however, he patented another loom which has served as the model for later inventors to work upon. He was conscious that for a mechanically driven loom to become a commercial success, either one person would have to attend several machines, or each machine must have a greater productive capacity than one manually controlled. The thought and ingenuity bestowed by Dr Cartwright upon the realization of his ideal were remarkable. He added parts which no loom, whether worked manually or mechanically, had previously been provided with, namely, a positive let-off motion, warp and weft stop motions, and sizing the warp while the loom was in action. With this machine he commenced, at Doncaster, to manufacture fabrics, and by so doing discovered many of its shortcomings, and these he attempted to remedy: by introducing a crank and eccentrical wheels to actuate the batten differentially; by improving the picking mechanism; by a device for stopping the loom when a shuttle failed to enter a shuttle box; by preventing a shuttle from rebounding when in a box; and by stretching the cloth with temples that acted automatically. In 1792 Dr Cartwright obtained his last patent for weaving machinery; this provided the loom with multiple shuttle boxes for weaving checks and cross stripes. But all his efforts were unavailing; it became apparent that no mechanism, however perfect, could succeed so long as warps continued to be sized while a loom was stationary. His plans for sizing them while a loom was in operation, and also before being placed in a loom, both failed. Still, provided continuity of action could be attained, the position of the power loom was assured, and means for the attainment of this end were supplied in 1803, by William Radcliffe, and his assistant Thomas Johnson, by their inventions of the beam warper, and the dressing sizing machine.

For upwards of thirty years the power loom was worked under numerous difficulties; the mechanism was imperfect, as were also organization, and the preparatory processes. Textile workers were unused to automatic machinery, and many who had been accustomed to labour in their own homes refused employment in mills, owing to dislike of the factory system and the long hours of toil which it entailed, that spinners and manufacturers were compelled to procure assistants from workhouses; this rendered mill life more distasteful than it otherwise would have been to hand spinners and weavers. Their resentment led them to destroy machinery, to burn down mills, to ill-use mill workers and to blame the power loom for the distress occasioned by war and political disturbances. Yet improvements in every branch of the textile industry followed each other in quick successions, and the loom slowly assumed its present shape. By using iron instead of wood in its construction, and centring the batten, or slay, below instead of above the warp line, the power loom became more compact than the hand-loom.

Motion is communicated to all the working parts from a main shaft A (fig. 28), upon which two cranks are bent to cause the slay B to oscillate; by toothed wheels this shaft, drives a second shaft, C, at half its own speed. For plain weaving four tappets are fixed upon the second shaft, two, D, for moving the shuttle to and fro, and two others, E, for moving the healds, L, up and down through the medium of treadles M, M. For other schemes of weaving shedding tappets are more numerous, and are either loosely mounted upon the second shaft, or fixed upon a separate one. In either event

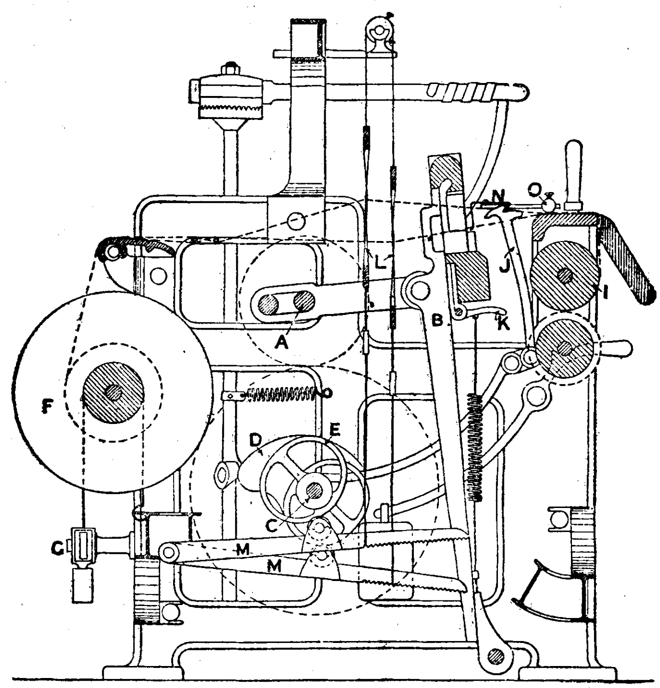


Fig. 28.—Vertical Section of a Power Loom.

they are driven by additional gearing, for the revolutions of the tappets to those of the crank shaft must be as one is to the number of picks in the repeat of the pattern to be woven. Also, when two or more shuttles are driven successively from the same side of a loom, if the picking tappets rotate with the second shaft, those tappets must be free to slide axially in order to keep one out of action so long as the other is required to act. The warp beam F is often put under the control of chains instead of ropes, as used in hand looms, and the chains are attached to adjustably weighted levers, G, whereby the effectiveness of the weights may be varied at pleasure. In the manufacture of heavy fabrics, however, it may be necessary to deliver the warp by positive gearing, which is either connected, or otherwise, to the taking-up motion. The cloth is drawn forward regularly as it is manufactured by passing it over the rough surface of a roller, I, and imparting to the roller an intermittent motion each time a pick of weft is beaten home. This motion is derived from the oscillating slay, and is communicated through a train of wheels. The loom is stopped when the weft fails by a fork-and-grid stop motion, which depends for its action on the lightly balanced prongs of a fork, N. These prongs come in contact with the weft, between the selvage of the web and the shuttle box each time the shuttle is shot to the side at which the apparatus is fixed. If the prongs meet no thread they are not depressed, and being unmoved a connexion is formed with a vibrating lever, J; the latter draws the fork forward, and with it a second lever O, by which the loom is stopped. On the other hand, if the prongs are tilted, the loom continues in action. If more than one shuttle is used it may be necessary to feel for each, instead of alternate threads of weft. In such cases a fork is placed beneath the centre of the cloth and lifted above a moving shuttle; if in falling it meets with weft it is arrested, and the loom continues in motion, but if the weft is absent the prongs fall far enough beneath the shuttle race for a stop to act upon a lever and bring the loom to a stand. To prevent a complete wreck of the warp it is essential to arrest the loom when a shuttle fails to reach its appointed box. For this purpose there are two devices, which are known respectively as fast and loose reed stop motions. The first was invented in 1796 by Robert Miller, and its action depends upon the shuttle, as it enters a box, raising two blades, K, which if left down would strike against stops, and so disengage the driving gear. The second was invented in 1834 by W. H. Hornby and William Kenworthy; it is an appliance for liberating the lower part of a reed when a shuttle remains in the warp, thus relieving it, for the time being, of its function of beating up the weft. On the release of a reed from the motion of the slay, a dagger stops the loom. Temples must keep a fabric distended to the breadth of the warp in the reed, and be self-adjusting. This is usually accomplished by small rollers whose surfaces are covered with fine, closely set points. The rollers are placed near the selvages of a web which is prevented from contracting widthwise by being drawn tightly over the points.

Looms are varied in details to suit different kinds of work, but as a rule fabrics figured with small patterns are provided with healds for shedding as at L, while those with large patterns are provided with the Jacquard and its harness. Healds may be operated either by tappets or dobbies, but the range of usefulness in tappets is generally reached with twelve shafts of healds and with patterns having sixteen picks to a repeat; where they are unsuitable for heald shedding a dobby is used. A dobby may resemble, in construction and action, a small Jacquard; if so the selection of healds that rise and fall for any pick is made by cards. In other types of dobbies the selection is frequently made by lags, into which pegs are inserted to pattern in the same manner that cards are perforated. By acting upon levers the pegs bring corresponding hooks into contact with oscillating griffe bars, and these lift the required heald shafts. Such machines are made single and double acting, and some have rollers in place of pegs to form a pattern. When multiple shuttles are required for power looms one of two types is selected, namely, drop or rotating boxes; the former are applicable to either light or heavy looms, but the latter are chiefly confined to light looms. As previously stated, Robert Kay invented drop boxes in 1760, but they were not successfully applied to the power loom until 1845, when Squire Diggle patented a simple device for operating them automatically. Since his time many other methods have been introduced, the most successful of these being operated indirectly from the shedding motion. Revolving boxes were patented in 1843 by Luke Smith. They consist in mounting a series of shuttles in chambers formed in the periphery of a cylinder, and in moving the cylinder far enough, in each direction, to bring the required shuttle in line with the picker.

Automatic Weft Supply.—Many devices have been added to power looms with a view to reduce stoppages, amongst which those for the automatic supply of weft are probably the most important. These efforts originated with Charles Parker, who, in 1840, obtained the first patent, but no marked success was achieved until 1894, when J. H. Northrop patented a cop changer. By his plan a cylindrical hopper, placed over one shuttle box, is charged with cops or pirns. At the instant fresh weft becomes necessary the lowest cop in the hopper is pressed into a shuttle from above, the spent one is pressed out from beneath, and the new weft is led into the shuttle eye, while the loom is moving at its normal speed. The mechanism is controlled by the weft fork, or by a feeler which acts when only a predetermined quantity of weft remains inside a shuttle. Many inventions are designed to eject an empty shuttle and introduce a full one; others change a cop, but differ in construction and action from the Northrop, yet, at the time of writing, they have not been so successful as the last-named. By relieving a weaver of the labour of withdrawing, filling, threading and inserting shuttles it was seen that a large increase might be made in the number of looms allotted to one weaver, provided suitable mechanism could be devised for stopping a loom on the failure of a warp thread.

Warp Stopping Motions date from 1786, when Dr Cartwright suspended an independent detector from each warp thread until a fracture occurred, at which time a detector fell into the path of a vibrator and the loom was arrested. The demand for warp stop motions was, however, small until automatic weft supply mechanisms were adopted. The majority of those devices now in use are constructed upon Dr Cartwright's lines, but some are so attached to wire healds that, at one position in every shed, an unbroken thread supports both heald and detector until a thread fails, when a detector is engaged by a vibrator, and the driving mechanism is dislocated. In other warp stop motions pairs of threads are crossed between the lease rods, and a wire passed between them is held forward by the crossed threads until one breaks; the wire then springs back, makes contact with a metal bar, and electro-mechanical connexions stop the loom.

Smallware Looms.—A loom, which was for a long period operated manually, but to which mechanical power could be applied, was brought into use more than a century before Dr Cartwright's invention. It was known as the Dutch engine loom, and was designed to weave from eight to upwards of forty tapes or ribbons simultaneously. This machine may be regarded as a series of looms mounted in one frame, each having a complete set of parts, and as the first practical effort to connect and control all the motions of weaving from one centre. The place and date of its invention are uncertain; but it is known that in some districts its use was entirely prohibited, in others it was strictly limited, and that it was worked in Holland about 1620. In England the first patent was obtained by John Kay and John Snell, in 1745, for additions which enabled it to be worked by hand, by water, or other force, and in 1760 John Snell appears to have added the draw harness for weaving flowered ribbons. In 1765 a factory in Manchester was filled with ribbon looms which were either invented by M. Vaucanson, or Kay and Snell, but one weaver could only attend to one machine. When worked by hand it was known as the bar loom, because the weaver oscillated by hand a horizontal bar that set in motion all parts of the machine. The shuttles and reeds are actuated from the batten, the former originally by pegs, but later by a rack and pinion arrangement, which in action shoot the shuttles simultaneously across a web, to the right and left alternately, each into the place vacated by its next neighbour. One small warp beam is required for each web, but tappets, dobbies, or Jacquards are available for dividing the threads. Where differently coloured wefts are needed in one web the shuttles are mounted in tiers and all raised or lowered at once to bring the proper colour in line with the shed.

In *Swivel Weaving* similar shuttles are added to the battens of broad looms in order to diaper small figure effects, in different colours or materials, over the surface of broad webs.

Pile Weaving.—Looms for weaving piled fabrics differ in certain important respects from those employed for ordinary weaving; they are also made to differ from each other to suit the type of fabric to be manufactured, as, for example, double and single, plain and figured, textures.

In *Double Pile Looms* the special features are those that control the pile threads, and those that sever the vertical lines of pile. Two ground warps are requisite, and unless they are kept a uniform distance apart the piled effects will be irregular. For plain goods the pile threads are wound upon two or more beams, and, as they move from web to web, cloth-covered rollers deliver them in fixed lengths. Meanwhile, a shuttle passes twice in succession through each ground warp, and the pile threads in moving above or beneath the wefts are bound securely. Both fabrics are furnished with taking-up rollers which draw the pieces apart and so stretch the uniting pile in front of a knife, which severs it, thus forming two pieces at once. A knife may consist of a short blade that merely moves to and fro across the webs, or of a disk mounted upon a spindle, which, in moving from side to side, revolves; in either case it is automatically sharpened. But if a knife is longer than the breadth of a fabric it receives only a slight lateral movement, and must be periodically removed for sharpening. In plain and printed goods healds control all the warps; but in figured goods, other than those made from printed warps, a Jacquard is needed to lift, and a creel to hold, the pile threads.

Single Pile Looms.—The chief feature which renders most single pile looms dissimilar from others is the mechanism by which wires are woven upon, and withdrawn automatically from, a ground texture. Wires are of two kinds, namely, without and with knives; the former, being flattened and somewhat pointed, are woven above the weft of a ground texture, but beneath the pile, hence, by withdrawing them, looped pile is formed. A wire terminating in a knife with a sloping blade, on being withdrawn, cuts the pile and produces a brush-like surface. The mechanism for operating the wires is placed at one end of a loom and consists of an arm which moves in and out; at each inward movement a wire is inserted, and at each outward movement one is withdrawn. In weaving tapestry carpets, and certain other fabrics, a wire and a shuttle move simultaneously, but a shuttle passes through the ground warp, while a wire passes beneath the pile. After several wires have been woven upon the ground texture the one first inserted is withdrawn by the vibrating arm, and at the next inward movement the same wire enters the warp near the reed, where it is beaten up with the weft, and, from this point, the operation is continuous. Tapestry carpets require three warps, one for the ground texture, a second, or stuffing warp, to give bulk and elasticity to the tread, and a third to form the pile. The last named is printed upon a large drum, thread by thread to the colour scheme of the design, then, when the colours have been fixed, and the threads accurately placed, they are wound upon a beam, and all the warps are operated by healds. For figured velvets, and Brussels and Wilton carpets, the pile warp beam is replaced by a creel, in order that each thread of pile may be wound upon a bobbin and separately tensioned. This is essential, because, in the weaving of a design, it is probable that no two threads of pile will be required in equal lengths. Creels are made in sections called frames, each of which usually carries as many bobbins as there are loops of pile across a web, and the number of sections equal the number of colours. In weaving these fabrics healds are used to govern the ground warp, but a Jacquard is needed for the pile. It must form two sheds, the lower one to receive a shuttle, the upper one to make a selection of threads beneath which the wire is to pass.

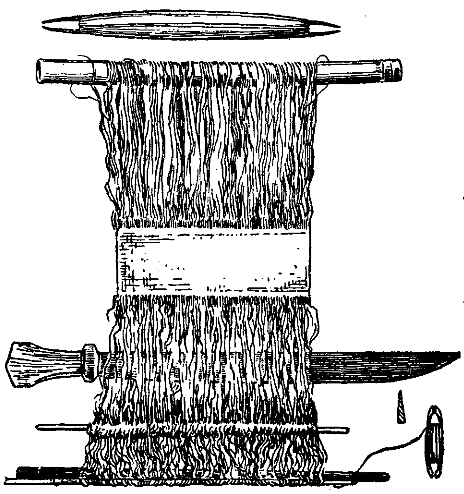
Terry Looms.—Looms for weaving piled textures, of the Turkish towel type, have the reed placed under the control of parts that prevent it from advancing its full distance for two picks out of every series that separate one line of loops from another. At such times the weft is not beaten home, but a broad crack is formed. So soon as the reed again moves through its normal space three picks of weft are simultaneously driven home, thus closing the gap, and causing part of the pile to loop upward, the remainder downward. The system is available for plain and figured effects.

Gauze Textures are woven in looms having a modified shedding harness, which, at predetermined intervals, draws certain warp threads crosswise beneath others, and lifts them while crossed. Also, a tensioning device to slacken the crossed threads and thus prevent breakages due to excessive strain. At other times the shedding is normal.

Lappet Looms have a series of needles fixed upright in laths, and placed in a groove cut in the slay, in front of the reed. Each needle carries a thread which does not pass through the reed, hence, by giving the laths an endlong movement of varying extent, and lifting the needles for each pick, their threads are laid crosswise in the web to pattern. (T. W. F.)

Archaeology and Art

The archaeology of shuttle-weaving shows that for ages the use of a loom for weaving plain, as distinct from ornamental or figured textiles, whether of fibres or of spun threads, has been practically universal, whilst the essential points of its construction have been almost uniform in character. An early stage in its development, anterior probably to that when the spinning of threads had been invented, is represented by the loom or frame (see fig. 29) used by a native of Sarawak to make a textile with shreds of grass. As will be seen, the shreds of grass for the warp are divided into groups by a flat sword-shaped implement which serves as the batten (Latin *spatha*). The shuttle is passed above it, leaving a weft of grass in between the warp; the batten is then moved upwards and compresses the weft into the warp; this method of pressing the weft upwards was usually employed by Egyptian and Greek weavers for their linen textiles of beautiful quality. Fig. 30 gives us an Indian



From Roth's *Natives of Sarawak*, by permission of Truslove and Hanson.

Fig. 29.—Loom from Sarawak.

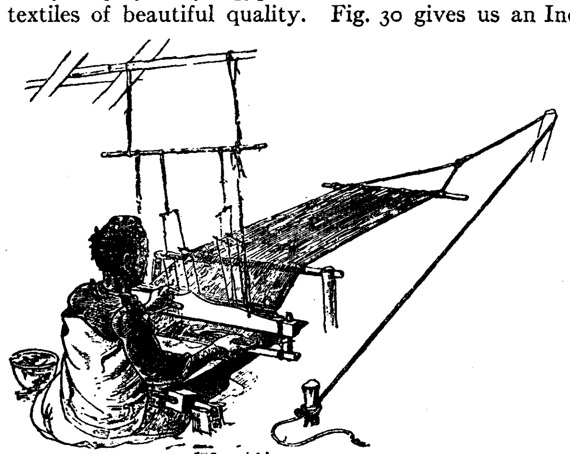


Fig. 30.—Indian Hill Tribesman's Loom.

Hill tribesman weaving with spun threads; but here we find the loom fitted with rudely constructed headles, by which the weaver lifts and lowers alternate ranks of warp threads so that he may throw his shuttle-carried weft across and between them. Besides the headles there is a hanging reed or comb, and between the reeds of it the warp threads are passed and fastened to a roller or cylinder. After throwing his shuttle once or twice backwards and forwards, the weaver pulls the comb towards himself, thereby pressing his weft and warp together, thus making the textile which he gradually winds from time to time on to the roller. This advance in the construction of the loom is also virtually of undateable age; and except for more substantial construction, there is little difference in main principles between it and the medieval loom of fig. 31. With such looms, and by arranging coloured warp threads in a given order and then weaving into them coloured shuttle or weft threads, simple textiles with stripes and chequer patterns could be, and were, produced; but textiles of complex patterns and textures necessitated the more complicated apparatus that belongs to a later stage in the evolution of the loom. Fig. 32 is from a Chinese drawing, illustrating the description given in a Chinese book published in 1210 on the art of weaving intricate designs. The traditions and records of such figured weavings are far older than the date of this book. As spun silken threads were brought into use, so the development of looms with increasing numbers of headles and other mechanical facilities for this sort of weaving seems to have started. But as far back as 2690 B.C. the Chinese were the only cultivators of silk,[1] the delicacy and fineness of which must have postulated possibilities in weaving far beyond those of looms in which grasses, wools and flax were used. It therefore is probably correct to credit the Chinese with being the earlier inventors of looms for weaving figured silks, which in course of time other nations (acquainted only with wool and flax textiles) saw with wonder. At the comparatively modern period of 300 B.C. Chinese dexterity in fine-figured weaving had become matured and was apparently in advance of any other elsewhere. Designs were being woven by the Chinese of the earlier Han Dynasty 206 B.C. as elaborate almost

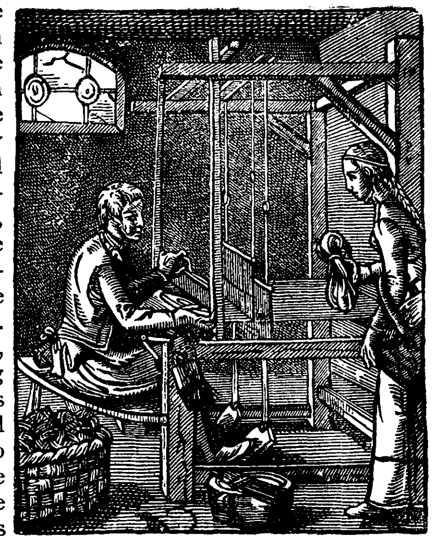


Fig. 31.—Medieval Loom, from a Cut by Jost Amman; middle of the 16th century.

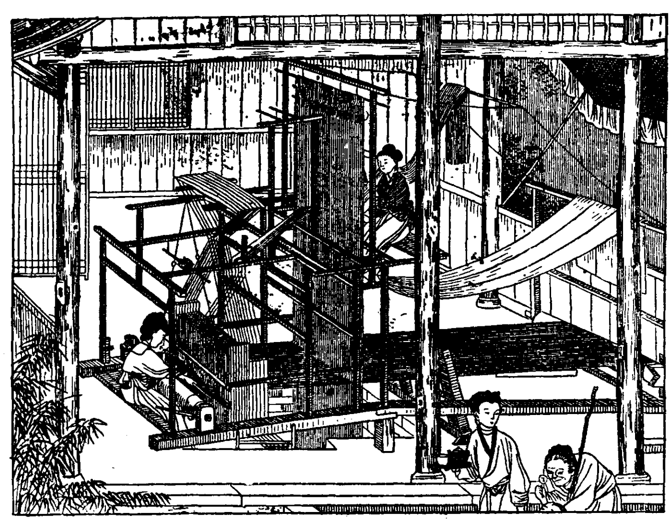


Fig. 32.—Chinese Loom for Figured Weaving (Photo).

[1] E. Pariset, *Histoire de la soie* (Paris, 1862).

as those of the present day, with dragons, phoenixes, mystical bird forms, flowers and fruits.[1] At that time even Egypt, Assyria or Babylonia, Greece and Rome, seem to have been only learning of the fact that there was such a material as silk.[2] Their shuttle-weaving had been and was then concerned with spun wool and flax and possibly some cotton, whilst the ornamentation of their textiles, although sparkling on occasion with golden threads, was done apparently not by shuttle-weaving but by either embroidery or a sort of compromise between darning and weaving from which tapestry weaving descended (see TAPESTRY). The range of their colours was limited, reds, purples and yellows being the chief; and their shuttle-weaving was principally concerned with plain stuffs, and in a much smaller degree with striped, spotted and chequered fabrics. Remains of these, whether made by Egyptians thousands of years B.C., by Scandinavians of the early Bronze Age, by lake dwellers, by Aztecs or Peruvians long before the Spanish Conquest, display little if any technical difference when compared with those woven by nomads in Asia, hill tribes in India and natives in Central Africa and islands of the Pacific. Such ornamental effect as is seen in them depends upon the repetition of stripes or very simple crossing forms, still this principle of repetition is a prominent factor in more intricate designs which are shuttle-woven in broad looms and lengths of stuff.

The world's apparent indebtedness to the Chinese for knowledge of figured shuttle-weaving leads to some consideration of their early overland commerce westwards. About 200 B.C. during the Han Dynasty Chinese trade had extended beyond inner Asia to the confines of the Graeco-Parthian empire, then at its zenith, and the protection of the route by which the Seres (Chinese) sent their merchandise was fully recognized as a matter of importance. Seventy years later the emperor of China sent a certain Chang Kien on a mission to the Indo-Scythians; and according to his records the people as far west as Bactria (adjacent to the Graeco-Parthian territory) were knowing traders, and amongst other things understood the preparation of silk. Chinese weavings had for some time been coming into Persia, and doubtless instigated the more skilled weavers there to adapt their shuttle looms in course of time to the weaving of stuffs with greater variety of effects than had been hitherto obtained by them; and into Persian designs were introduced details taken not only from Chinese textiles, but also from sculptured, embroidered and other ornament of Graeco-Parthian and earlier Babylonian styles. In A.D. 97 Chinese enterprise in still furthering their trade relations with the Far West is at least suggested by the fact that envoys from the emperor of China to Rome actually reached the eastern shores of the Mediterranean, but turned back frightened by the Parthian accounts of the terrors of the sea voyage.

Early in the 3rd century A.D. Heliogabalus is reputed to have been amongst the first of the Roman emperors to wear garments entirely of silk (holosericum), which, if figured (as is not unlikely), were probably of Syrian or Persian manufacture. Sidonius Apollinaris (5th century) writes of Persian patterned stuffs,—"Bring forth brilliant cushions and stuffs on which, produced by a miracle of art, we behold the fierce Parthian with his head turned back on a prancing steed; now escaping, now returning to hurl his spear, by turns fleeing from and putting to flight wild animals whom he pursues"—a description quite appropriate to such silk weaving as that in fig. 33. A number of kindred pieces have been recovered of late years from Egyptian burial-places of the Roman period. The Persians of the Sassanian dynasty (3rd to 7th century) traded in silks with Romans and Byzantines; King Chosroes (about 570) encouraged the trade, and ornamental weaving seems to have been an industry of some standing at Bagdad and other towns north, east and south, *e.g.* Hamadan, Kazvin Kashan, Yezd Persepolis, &c. To the north-west of Persia and north of Syria lay the Byzantine region of Anatolia (now Asia Minor), some towns in which became noted for their fine weavings: the mass of the population there was well off in the 6th century, the country highly cultivated and prosperous, 'and justice fairly administered,[3] thus affording favourable conditions for an industry like ornamental weaving, which had been and was prospering in neighbouring Syrian districts.

[1] See *Chinese Art*, by Stephen W. Bushell, C.M.G., B.Sc., M.D. (London, 1906), vol. ii. p. 95.

[2] Aristotle describes the silk-worm and its cocoon. Virgil-Martial and late Roman writers (including Pliny) throw scarcely more light upon the use of silken stuffs than that they were of rarity and greatly prized by opulent Romans. Propertius (19 B.C.) writes of "silken garments of varied tissue," and of Cynthia that "perchance she glistens in Arabian Silk."

[3] W. M. Ramsay, *Studies in the History and Art of the Roman Empire* (University of Aberdeen, 1906).

Between the 1st and 6th centuries A.D., then, knowledge of silk and its value in fine weaving was spreading itself, not only in the further western regions of Southern Asia, but also in Egypt, where Greek and Roman taste influenced the works of Copts or those

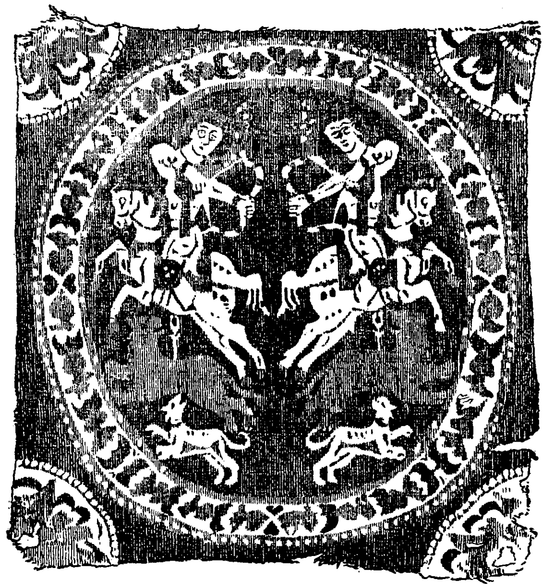


FIG. 33.—Syrian or Persian Silk Weaving of the 5th Century.

natives who maintained old Egyptian traditions in technical handicrafts. Of peculiar interest in this connexion are fragments of flax (yellow and brown) woven with a comparatively elaborate texture, as well as in patterns (see fig. 34) which suggest an ordinary type of Roman pavement designs (3rd century and earlier), the basis of which is roundels linked together. Stuffs in which the style of

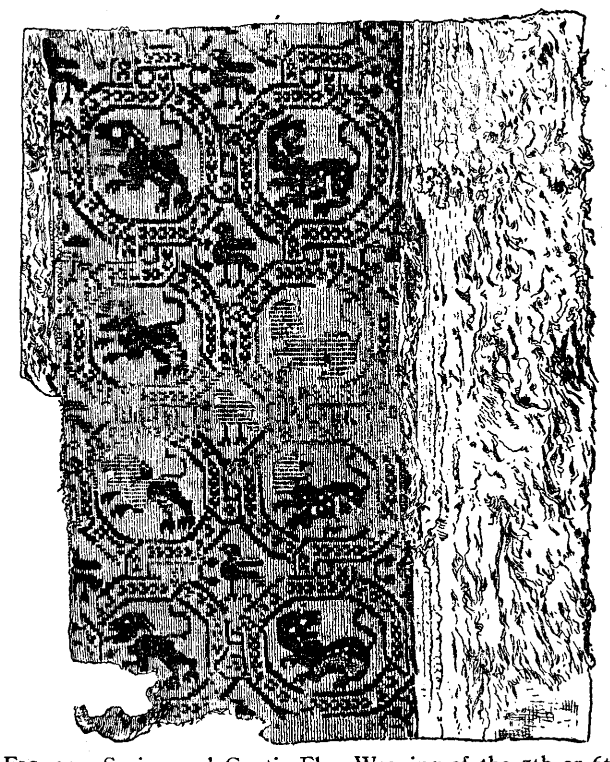


FIG. 34.—Syrian and Coptic Flax Weaving of the 5th or 6th Century.

patterns, though comparatively simple, is rather more Oriental, are of flax and wool, and the official robes of Roman consuls seem to have been of this character, and amongst other goods may have been made with small technical difference at Rome[4] or at Fostat (Cairo)

[4] In 369 by order of the emperors Valens and Valentinian the making of textiles in which gold and silken threads were introduced was limited to women's workrooms or gynecia (see Codex of Theodosius, lib. x. tit. 21, lex 1). In the 5th century the weaving of silken tunics and mantles was prohibited (Codex Theodosius, lib. x. tit. 21, lex 3).

or Alexandria or other towns in Lower Egypt as well as in Syria. Contemporaneously the development of similar weaving appears to

FIG. 35.—Syrian or Anatolian Silk Weaving of the 5th Century. with Samson and the Lion (repeated).

have been proceeding in Byzantine provinces, though perhaps not in so marked a way as when Justinian systematized sericulture[1] and still further stimulated shuttle-weaving in the town of Byzantium (Constantinople) itself in A.D. 552.

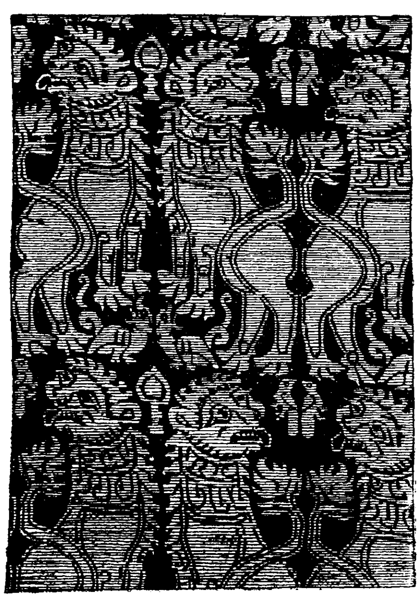


FIG. 36.—Byzantine Red Silk and Gold Thread Weaving of the 11th Century. Pairs of lions and pairs of small birds.

For examples of the elaborate figure weavings at that time we have to rely upon such as have been rescued in the service of archaeology from the oblivion of tombs and burial-places. The dates of some specimens can be fixed with almost certainty, by means of nearly contemporary records, *e.g.* those of Sidonius Apollinaris and later Anastasius the Librarian; comparison and classification lead to almost conclusive inferences as to the dates of other examples. Broadly speaking, the earlier of these remains (*i.e.* from about the 4th to the 7th century) seem to be either of Persian (Sassanian) manufacture and design, or of Syrian and possibly Alexandrian make. Christian subjects were occasionally introduced into the designs. Between the 7th and the 13th centuries Byzantine manufactures come to the fore, and it is difficult if not impossible now to draw a clear line between those of Roman-Byzantine, Perso-Byzantine and Moslem-Byzantine styles, though one may do so in respect of certain Moslem (Moorish and Saracenic) weavings, which have distinctive features

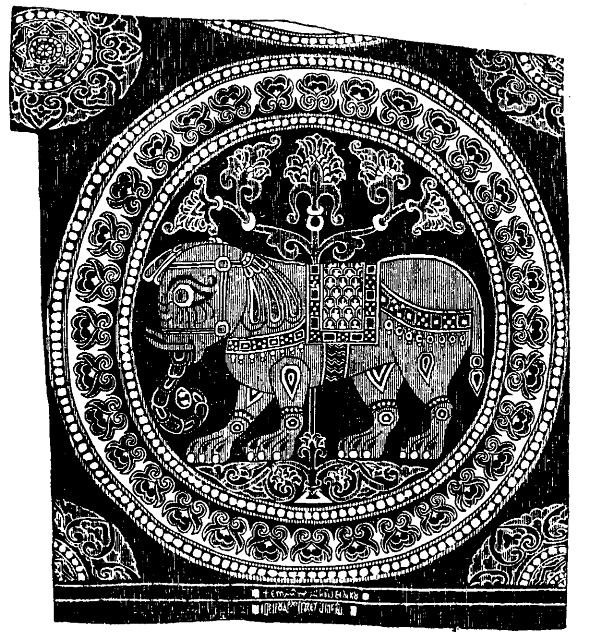


FIG. 37.—Part of Silk Wrapping of the Emperor Charlemagne, possibly of Bagdad manufacture, 9th Century, with Fanciful Elephant and Sacred Tree device in a Roundel.

of design, and were produced in the south of Spain and in Sicily about a period from the 10th century to the 13th.

Fig. 35, from a piece of sarcenet with repeated parallel series of Samsons and lions (or gladiators?), is probably 5th-century Syrian or

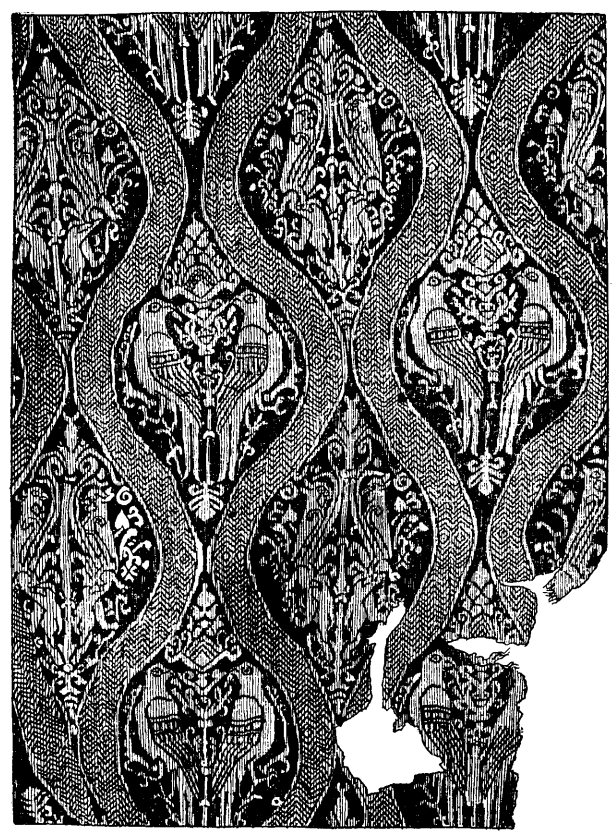


FIG. 38.—Fragment of Byzantine Silk, 12th Century, with Ogival Framing about pairs of Birds, &c.

Anatolian; of the same date are pieces with scenes of the Annunciation repeated in roundels, and with artistic birds and lions, in the treasury of the Sancta Sanctorum of the Chapel of St Lawrence in

[1] This virtually was the starting of sericulture in Europe.

the old Lateran Palace, Rome. Scriptural subjects[1] seem to be typical of those which were condemned by Anatolian and Syrian fathers of the Christian church as early as in the late 4th century, and Asterius, bishop of Amasus, in denouncing the luxury of the rich in flaunting themselves in such inappropriately decorated silks, has left a most useful description of the subjects decorating them. A scheme long maintained in Syrian and Byzantine patterns was that of repeated roundels, within which other than scriptural subjects were wrought, *e.g.* hunters on horseback (as in fig. 33), fantastic animals and birds, singly or in pairs, confronting one another or back to back, frequently with a sacred tree device[2] between them. A piece of Sassanian silk, probably of the 6th century, shows a gryphon practically identical with that sculptured on the patterned saddle-cloth of a king (Chosroes II.?) in the archway to the garden of the king's palace at Kermchah.

Less common perhaps are patterns, without roundel or other framing, composed of animals, birds and the like, formally treated and repeated vertically and horizontally, as in fig. 36, which is from a silk and gold thread shuttle-weaving classified as Byzantine of the 11th century manufacture. But this style of composition also occurs in a Sassanian or Syrian silk of the 5th century at Le Mans,[3] and again in the Cope of St Maxim at Chinon, which is powdered with panthers. Conventional eagles (reminiscent perhaps of the Roman Eagle), with scale patterns on their breasts and wings, are woven in the wrappings reputed to have been given by the Empress Placidia for the corpse of St Germain (448) preserved at the church of St Eusebius at Auxerre. Some likeness in style may be detected between these latter and a fragment of one of the wrappings of St Cuthbert (d. 688) at Durham, though in this case the elaborate ornamentation is set within a roundel. Prior to the discovery of woven silks in the Akhmin cemeteries, the periods to which tradition and association had ascribed the Auxerre and Durham specimens were considered too early; but there now seems to be far less reason to question that ascription. Fig. 37 is from part of a silken wrapping of Charlemagne (early 9th century) now at Aix-la-Chapelle. It bears a Greek inscription of the names of Peter, governor of Negropont, and Michael, chamberlain of the Imperial Chambers, and this is taken by some authorities as evidence that the weaving was made at Byzantium. On the other hand, Eginhard, Charlemagne's secretary, has written of gifts, including rich textiles presented in his day by Haroun al Raschid to the emperor,[4] and a fabric like that in question might have been made quite possibly even at Baghdad in the 9th century or earlier. In the 11th century amongst the handicraftsmen in the city of Byzantium were many skilled native and foreign weavers; and their designs generally appear to reflect the style of earlier Persianesque and Syrian taste.

About the 12th century the well-used pattern scheme of roundels became more or less superseded by one of continuous ovals, of ogival framings (see fig. 38), contemporary with which are Saracenic patterns based on hexagonal and star-shape frames. Within these new varieties of pattern framings recur the Byzantine and Persianesque pairs of birds, animals, &c. But distinct from these is the more restricted style which has been mentioned. It had arisen under the influence for the most part of the Fatimy Khalifs, not only in Syria and Alexandria but also in Sicily and southern Spain. Patterns of this Moslem or Saracenic type are usually composed of a succession of parallel bands—narrow and wide—containing Kufic inscriptions, groups of small intricate geometrical devices, and occasionally conventional animals and birds. A 12th-century example of this class of pattern has been given elsewhere (see BROCADE, fig. 1).

Almeria, Malaga, Grenada and Seville were notable Moorish weaving places in Spain for such patterned silks and stuffs as these; and even after the Christian conquest of Grenada at the end of the 15th century this city retained its celebrity for silks woven "à la Moresque."

In Sicily no similar survival of Saracenic influence seems to have been as strongly maintained, notwithstanding the numerous Saracen weavers at work in the island for years before the Royal factory for silk weaving came to be organized at Palermo under Norman supremacy. According to the usual story, Roger of Sicily, or Roger Guiscard, who in 1147 made a successful raid on the shores of Attica, and took Athens, Thebes and Corinth, carried off as prisoners a number of Greek (Byzantine) weavers and settled them at Palermo in the factory known as the Hôtel des Tiraz. A mixture of Byzantine

FIG. 39.—Specimens of various Small Loom Weavings between the 7th and 15th centuries.

A. Part of a narrow band or orphrey woven in gold and silk threads with a Latin inscription along the edges. German work of the 13th century.
B. Part of a broad band or orphrey woven in gold and silk threads with figures of the Crucifixion and the Annunciation (?). It bears an inscription, Odilia me fecit. It is probably German work of the 13th century.
C and D. Specimens of Cologne orphreys woven in silk and gold threads; C bears a Latin inscription, and the faces of the Virgin and Child are embroidered.
E. Part of a narrow band woven in gold and silk threads with chevron spaces filled with delicate scroll ornament, among which are occasional animal and bird devices. Possibly English or French work of the 13th century.
F. Part of a narrow band or clavus from a Coptic tunic of the 9th or 10th century.

[1] The silken wrappings of St Wilibald (700–786), a founder of the church at Eichstätt, where they are still preserved, are woven with repeated roundels, each enclosing a Daniel between two lions, and are perhaps Byzantine of the 8th century.

[2] See Sir George Birdwood's chapter on Knop and Flower pattern in his *Industrial Arts of India*, in which this device of ancient Assyrian art is discussed as well as its relation and that of the hom, a fanlike symbol, to cognate ornament in Greek, Roman and even Renaissance art.

[3] See *Abécédaire d'archéologie* (June 1854).

[4] *Recherches*, &c., by Francisque Michel, i. 40.

and Saracenic styles of textile patterns ensued; and this peculiarity is demonstrated in many of the rich fabrics attributed to south and north Italian weavers from the 12th century onwards. From Palermo the art of ornamental weaving in this style soon extended into the mainland, and from Apulia a bishop of St Evroul in Normandy is mentioned as having obtained a number of silken goods in the 12th century. From the 13th century onwards Lucca, Florence, Milan, Genoa and Venice became important centres, using not only imported silk, but also such as was being then cultivated in Italy, for sericulture had become an Italian industry early in the 13th century. Wandering Saracenic and Byzantine weavers even before that time had strayed or been taken to work at places in Germany, France and Britain, but the output of their productions in northern countries was almost infinitesimal as compared with that of the far greater Italian output, nevertheless they were sowing the seeds of a harvest to be reaped centuries later by these more northerly European countries.

To the influence of these early sporadic weavings we seem to trace a distinctive class of work, which was done by inmates of monasteries and convents as well as by devout ladies, in little looms, for use as stoles, maniples, orphreys and similar narrow bands. A rhyming chronicler of the 13th century paraphrases the older record by Eginhard of the skill of Charlemagne's daughters in silk weaving, "ouvrer en soie en taulieles" or small looms.[1] The illustrations in fig. 39 give varieties of this class of work between the 7th and 15th centuries, for which Cologne especially seems to have become famous in the 15th century. Venice also made work of corresponding character: and the designs were evidently furnished by or directly adapted from the compositions of such artists as those who produced the notable German and Venetian woodcuts of the 15th century (fig. 40).

Whilst the bulk of the Italian patterned stuffs issuing in great lengths from large looms were of silk, a good many also were woven in wools, or wools intermixed with silks. The earlier of the silk textiles—Persian, Syrian and Byzantine—were of the nature of sarcenet and taffetas; later in development are satins, damask satins, brocades, and still later (*i.e.* about the end of the 14th century) come Italian velvets and cloths of gold, which quite transcended the ancient and less substantial attalic cloths of the early Roman period. Medieval inventories and records contain many names of textiles, but the exact technical meaning of several of them is uncertain. *Cendal, Sandal, Syndonus* seem to relate to such materials as sarcenet or taffeta: *zetani*, from low Latin, is held by some writers to be of the same class as *samit* or *examite*, so called because the weft threads were only caught at every sixth thread of the warp; *damask*, now regarded as a special class of textile, the ornamentation of which depends upon contrasting sheens in the surface of the stuff, whether of silk or linen, got its name from Damascus, much in the same way as *Baudekin* comes from Baldak, or Baghdad. *Baudekin*, and an apparently somewhat earlier word *ciclatoun*, seem to have been general terms for rich-looking textiles, in which gold thread played an important part, and possibly was applicable to early brocades. *Carmoca* or *Carmuk* (Arab *Kamkla*, from the Chinese *Kimka*—also brocade) was another handsome stuff corresponding in a way with Indian *Kincobs*. Velvet (Italian *velluto*—shaggy) is *veluiau* in French documents of the 14th century, and is a finely piled material of silk, and on that account may have been called *Samit*, as the German word

A

Apparel of a Dalmatic woven in Venice late in the 15th century, with the Virgin in glory.

B

Part of Orphrey with the Virgin and Child (Siena weaving, 1425–1450).

C

Part of Orphrey, with the Annunciation (Florentine weaving, late 15th century).

Fig. 40.

Fig. 41.—Piece of North Italian Silk Weaving of the 14th century, with pattern planned on an ogival basis with fantastic birds, some of which are of a Chinese type, and Persianesque cone forms containing sham Arabic inscriptions.

Sammet implies velvet, as does the Russian *Axamitt*. Diaper (Italian *diaspro*, meaning patterned) was used not only to denote a regular and geometric patterning but in some cases a special sort of linen or silk. Muslin from Mosul, and gauze from Gaza, are two

[1] See *Recherches*, &c., by Francisque Michel, i. 93-94.

well-known and kindred textiles. Frequently one meets with odd phrases such as "silk of Brydges" (Bruges), "silk dornex" (from Dorneck), "sheets of raynes" (Rheims), and "fuschan in Appules" (Naples fustian).

Many of the foregoing stuffs are identifiable by textures peculiar to them; this is, however, not so as regards their ornamental patterns, for these are frequently interchanged, the same class of patterns appearing in satin damasks, velvets and brocades. This is particularly the case with 13th- and 14th-century Italian stuffs. In the patterns of these, as previously suggested, are strong traces of Saracenic and Byzantine motives, intermingled with badges, heraldic devices, human figures, eagles, falcons, hounds, lions, harts, boards, leopards, rays of light, Persianesque pine cone and cloud forms, and even Chinese mystical birds, symmetrically distributed, without framings, as a rule, though elaborations of the ogival frame or scheme are also met with, but less frequently (see fig. 41). Such fabrics, made in the main by Lucchese weavers, appear to have been traded in with other European countries. But besides trade records, there are others relating to Lucchese weavers who left their own town under stress of circumstances, civil wars and the like, to settle and work elsewhere, as in France and Flanders, during the 15th century. Nevertheless the northern parts of Italy were the fertile places for producing fine types of patterned textiles used by Italian and other

FIG. 42.—Damask and Brocade Silk Fabric. Italian manufacture of the 15th century.

European courts and nobles: and if the art seriously dwindled in the town of Lucca, it flourished conspicuously, from the end of the 14th century and up to the beginning of the 16th century, in Venice, Bologna, Genoa, Florence and Milan. There was nothing similar to compete with it in France, Germany or England. The identification of its splendid varieties is made possible upon referring to contemporary paintings by Orcagna, Crivelli, Spinello Aretino and later Italian masters, as well as to those of the Flemish School, Gheraet David, Mabuse, &c.

Of a specially distinct class, very dignified in effect, are patterns of the 15th century based upon the repetition of conventional pentagonally constructed leaf panels, clearly defined in outline, each encircling a pomegranate or cone form around which radiate small leaves or blossoms; though they were more richly developed in superb velvets and cloths of gold, for which Florence, Venice and Genoa were famed, this type of design is also woven in less costly materials. A composite unusual and beautiful design of another kind is given in fig. 42. Repeated large leaf shapes can just be detected in it, but more remarkable are the bunches of radiating stalks of wheat-ears and cornflowers within them; whilst about them, arranged in hexagonal trellising, are leafy bars, small birds, crowns, pomegranates and other daintily depicted plant forms. This piece of damask combined with brocade weaving is of late 15th century manufacture: and after the opening of the next century the freedom towards realistic treatment, which we find here, enters into many of the Italian patterns. In some of them, however, an Ottoman or Anatolian feeling is apparent, as in fig. 43 from a figured silk which is considered to have been made in Venice. The chained dogs and birds in this design recall the rather more formal ones in Lucchese patterns of a hundred and fifty years earlier, whereas the lengthy serrated leaves and elongated flower devices charged with carnations and hyacinths depicted on a smaller scale are unmistakably Ottoman. Persian fabrics of rather thin silk material or taffetas like that of the original of this were also being woven with varieties of floral designs, as well as others portraying Persian stories. At this period there was considerable activity in weaving sumptuous stuffs at Broussa and Constantinople (fig. 44). Arabic and Turkish weavers often came over to be employed in Venice, blending Italian and Oriental characteristics into their designs.

FIG. 43.—Piece of Venetian Silk Weaving showing Ottoman influence in the design (16th century).

In Spain during the early 16th century we have traces of Hispano-Moresque influence in the overlapping and interlocking nondescript forms; but Spanish weavings are hardly comparable in quality with the Italian of the same time. In the middle of this century cloths of gold or of silver, with the pattern details raised in velvet and brocatelles of similar formal design were made in greater quantities in Italy for costumes of men and women. The frequent basis of most of the designs is the ogival framework already referred to, but it is much elaborated with detail and combined with the cone device of a previous century. The ornamentation of this style is purely conventional throughout, the various devices having little of the appearance of actual objects like fruit, leaves, &c.

The time, however, was close at hand when a more general reaction was to set in, in the direction of designs representing forms very nearly as they actually look, an example of which occurs in fig. 45, with its leaf forms and crowns. This from a class of silk damask or lampas, which is kindred to brocatelle; a feature in lampas is that its ground is different in colour from that of the ornament on it, and as in the case of portions of brocatelles its texture is of taffeta or sarcenet quality.[1] At the end of the 16th century a peculiar type of pattern consists of repetitions in different positions of the same detail treated realistically or purely ornamentally, little if anything of quite the same character having been previously designed. Of such fig. 46, with its repeated realistic leafy logs variously placed, is an example. The principle in the composition of these patterns, but with a greater variety of conventional detail, is followed in French 17th century examples. However, as soon as figured weaving became well organized in France at this time, a school of designers arose in that country who adopted a realism that predominated in French patterns during the succeeding 150 years, that is, from Louis XIV. to the end of the 18th century. Throughout this period French figured stuffs seem to surpass those of other countries. "If," writes Monsieur Pariset, "any account is to be taken of the weavers during the 14th and 15th centuries who made cloths and velvets of silk at Paris, Rouen, Lyons, Nimes and Avignon, it must be remembered that they were almost solely Italian emigrants from Lucca and Florence, who had fled their towns during troublous times." By a charter granted by Francis I. to Lyons, foreign and native workmen were encouraged to promote the city's interests in trade and manufacture; still, it is not until the 17th century that Lyons really asserts herself in producing fabrics possessing French taste and ornamentation. The more important designs were supplied by trained artists of whom Reval, a pupil of Le Brun, the first principal of the Academie des Beaux Arts founded by Colbert in Paris (1648), Pillement and Philippe de la Salle in the 18th century, may be

[1] See *Ornament in European Silks* (London, 1899), p. 15.

named. Their influence in the domain of fanciful, and at times extravagant realistic, floral patterns was widespread. Soon after the revocation of the Edict of Nantes, in consequence of which thousands of Protestant weavers left France, factories for weaving silks and mixed materials with patterns imitating the successive French phases became organized at Spitalfields, in Cheshire, Yorkshire, Norfolk and elsewhere in England, as well as in Germany at Crefeld, Elberfeld, Barmen and Weissen.

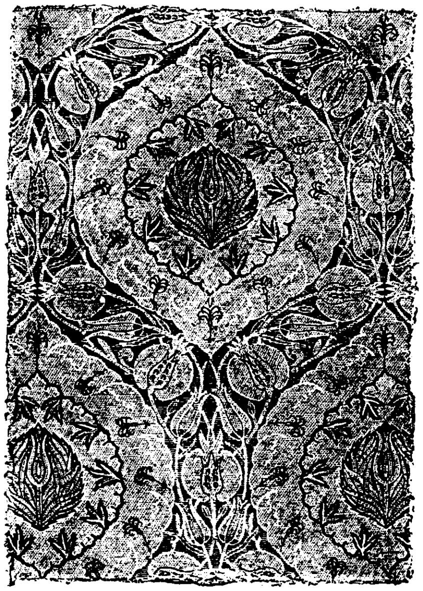


FIG. 44.—Ottoman (Anatolian) Silk and Gold Thread Weaving of the 16th century, with ogival framed ornament. The original is stated to have come from a sultana's tomb at Broussa or Constantinople.

Entirely distinct from what has already been discussed is a branch of artistic weaving concerned with the decoration of linens, that flourished notably in Italy towards the end of the 15th century and in the 16th century. From early times long and narrow Italian tablecloths were enriched with ornament of linen or cotton threads of a single colour, and Signora Isabella Erera has written at some length about them,[1] illustrating the result of her investigations with several examples culled from paintings by Pietro Lorenzetto of Siena (1340), by Ghirlandaja (1447–1490), &c. In Leonardo da Vinci's painting of the Last Supper, now in the Louvre, the border of the tablecloth is very like many examples of this sort of textile in the Victoria and Albert Museum, South Kensington. Their characteristic ornament, in rather heavy blue thread, consists of quaint animals and birds in pairs, which are evident derivations of those so often seen in Italo-Byzantine and Lucchese silks and brocades. Besides animals and birds, reversed names and words were sometimes introduced, *e.g.* "Amor" for "Roma," "Asoizarg" for "Graziosa" and "Eroma" for "Amore," &c. The simpler of these table-cloth patterns probably date from before the 14th century, whilst the fuller ones were certainly made in considerable quantities in the 15th century. An inventory dated 1842 has an entry of two napkins or cloths woven in cotton with bands of dragons and lions *à la Pérugina*, which is suggestive that this type of weaving was associated particularly with Perugia. In the 16th century, work of similar style was produced, but it was lighter and flatter in texture and often done with red or yellow silk, and embroidery was sometimes added to the weaving.

FIG. 45.—Italian Silk Damask or Lampas, with purple ground and pattern of late 16th century.

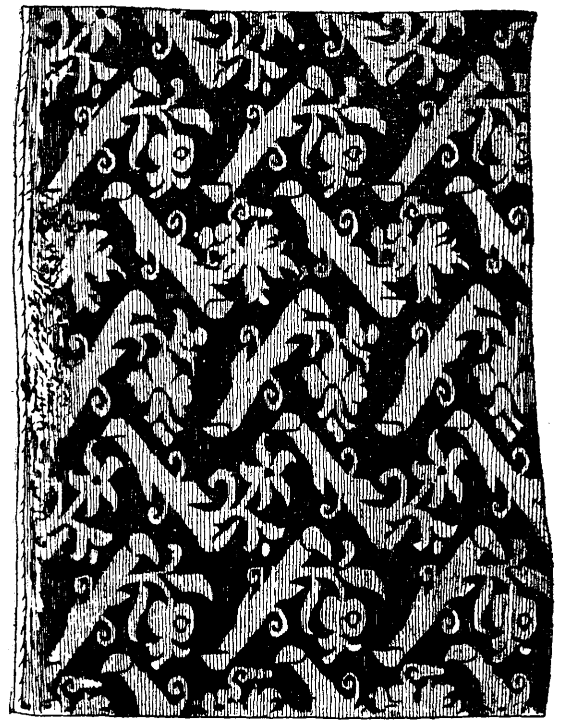


FIG. 46.—Italian Silk Damask or Lampas of late 16th century, with pattern of repeated leafy logs.

The most important and probably the best known class of later ornamental linen weaving is that of damask household napery, which, as a reflection of satin damask, was developed in the flax-growing regions of Saxony, Flanders and North France, during the late 15th or early 16th century; it was then rare and acquired for use by wealthy persons only.[2] The style of design in the better of the old linen damasks has some kinship with that of bold 15th- and 16th-century woodcuts of the Flemish or German schools. To some extent these damask figure subjects recall those of the coloured Cologne and Venetian orphreys for copes and apparels for dalmatics. The early history of linen damask is obscure, but a great many of its results are preserved in England. A napkin with the royal shield of Henry VII., the supporters within the garter surmounted by the crown, is in the Victoria and Albert Museum where it is called Flemish. On the other hand it is possibly the work of Flemings in England, since from the time of Edward I. and for a hundred years "a constant stream of emigrants passed from Flanders to England."[3] The Victoria and Albert Museum contains an early 16th-century tablecloth in damask linen of German or Flemish manufacture with various subjects, chiefly religious and moral: Gideon being shown as a kneeling knight, the fleece of wool on the ground being near him, while from above the dew falls on it; below Gideon is the Virgin Mary and the unicorn, and lower down an angel with seven dogs' heads typifying different virtues as shown in the lettering—*fides, spes, charitas,* &c. In another which was probably made in England (at Norwich?) by Flemings during the second half of the 16th century, we find St George and the Dragon, the royal arms of Queen Anne Boleyn, the badges of Queen Anne Boleyn and Queen Elizabeth, the crowned Tudor Rose, and repeated portraits of Queen Elizabeth, with the legend below, "God save the Queene." This specimen is also in the Victoria and Albert Museum. A hundred years later in date is a tablecloth on which is a view of old St Paul's (burnt in 1666), while above and below occurs the wreathed shield of the City of London. A different class of linen, with the design done in blue, was evidently, from the inscriptions on it, the work of a German or Fleming, and probably woven in Germany about 1730. Here we find the wreathed arms of the City of London, a view of "London," and "George der II. König in Engelland" mounted on horseback. In this specimen the design is repeated, and

[1] See the Italian monthly art review, *Emporium*, vol. xxiii. (1906).

[2] The earl of Northumberland (1512) is said to have had but eight linen cloths for his personal use, while his large retinue of servants had but one, which was washed once a month. (See notes by Rev. C. H. Evelyn White on damask linen. *Proceedings of Society of Antiquaries*, second series, vol. xx. p. 132.)

[3] See Rev. C. H. Evelyn White's paper on damask linen, *Proceedings of Society of Antiquaries*, second series, vol. xx. pp. 130-140.

not reversed, as is the case with the earlier pieces. A large collection of this German damask weaving with coloured thread was formed under the auspices of the Royal Kunstgewerbe Museum at Dresden.[1] The north-eastern Irish industry of damask weaving owes much to French Protestant refugees, who settled there towards the close of the 17th century, though linen manufacture had been established in the district by a colony of Scots in 1634. Dunfermline in Scotland is said to produce as much damask as the rest of Europe, but there are important manufactories of it at Courtrai and Liége in Belgium, in Silesia, Austria and elsewhere.

LITERATURE.—The following are titles of a few works on weaving, from which much important information on the subject may be derived:—J. Bezon, *Dictionnaire des tissus* (8 vols., Paris, 1859–1863), more or less technical only, *Dictionnaire des sciences* (Paris, 1751–1780), technical; Michel Francisque, *Recherches sur le commerce, la fabrication et l'usage des étoffes de soie, d'or et d'argent* (2 vols., Paris, 1852–1854), a well-known work full of erudition in respect of the archaeology of woven fabrics, their technical characteristics, &c.; James Yates, *Textrinum antiquorum: an Account of the Art of Weaving among the Ancients* (London, 1843), a very valuable and learned work of reference; Very Rev. Daniel Rock, D.D., *Textile Fabrics* (London, 1870), with some few good illustrations; Pariset, *Histoire de la soie* (Paris, 1862); Raymond Cax, *L'Art de décorer les tissus*, &c. (Paris, 1900); Alan Cole, *Ornament in European Silks* (London, 1899), well illustrated; J. Lessing, *Berlin königliche Museen, Die Gewebe-Sammlung des k. Kunstgewerbe-Museums* (Berlin, 1900), a very fine series of phototype facsimiles of all kinds of textiles; A. Riegl, *Die ägyptischen Textil-Funde* (Wien, 1889); R. Forrer, *Römische und byzantinische Seiden-Textilien* (Strassburg, 1891); A. Dupont Auberville, *L'Ornament des tissus* (Paris, 1877), admirable illustrations; F. Fischbach, *Die wichtigsten Webe-Ornamente* (3 vols., Wiesbaden, 1901), admirable illustrations; Raymond Cax, *Le Musée historique des tissus . . . de Lyon* (Lyon, 1902); Nuremberg: Germanisches Museum, *Katalog der Gewebesammlung des germanischen National-Museums* (Nuremberg, 1896).

(A. S. C.)