WEAVING, the art of combining threads, filaments, or strips, of various nature or material, in the way of interlacing them to form cloth, or other web or woven fabric, by means of a loom. Though the Egyptian looms, as depicted on tombs at Thebes and elsewhere, were very simple, yet the fabrics produced in them were often fine and costly. In some of them the warp extended horizontally, as now; in others it was vertical, and the weft was driven upward. In the most ancient mummy cloths the texture is close, firm, and elastic. Weaving was also practised very early in Greece and Asia Minor, both as a domestic employment and as a trade. Homer describes as the product of Creüsa's shuttle a figure-woven pattern, in which appeared a gorgon and dragons. The damasks, shawls, and tapestries woven by the later Greeks and by the Romans would rival in beauty some of the best productions of the modern art. In more modern times, the people of Italy and of the Netherlands appear first to have become famed for their textile manufactures; and from these countries the trade passed to England and France. Edward

III., and afterward Elizabeth, are said to have laid the foundation for that prominence in textile manufactures for which England is still distinguished.—In ordinary or plain weaving, two distinct series or sets of threads or yarns, that traverse the web at right angles to each other, are to be distinguished. The first is the series of threads running the whole length of the piece or web to be produced, and most commonly known as the warp; the second, generally called the weft or woof, is the series of threads crossing and interlacing with the warp, and is in effect one continuous thread passing at one throw alternately over and under the warp threads from one side of the piece to the other, and at the return throw also alternately, but on the reverse sides of the same warp threads; and so on, from the beginning until the whole length of the warp threads becomes a woven piece or cloth. In all styles of weaving, the warp threads are first affixed upon the proper parts of the loom; while the weft is wound in single threads on many small spools or bobbins, which are set one after another, as required, in a small hollowed and boat-shaped instrument, the shuttle; this, being thrown back and forth between the warp threads, parted as presently to be described, delivers the weft by its unwinding from the bobbin.—The frame of the ordinary hand loom consists of four upright posts joined by cross beams, at the middle, and at top and bottom. The centre beam, or cylinder, at the back of the loom, is the warp beam. The centre beam in front, just above the weaver's seat, is the cloth beam, on which the piece is to be wound. Just below the cloth beam, in front, is the breast beam, against which the weaver may lean in working. By a cross piece at top, with pulleys and cords, the two leaves of heddles or healds are suspended a little way back from the cloth beam; these being attached respectively to opposite ends of the same cords, and below to treadles on which the feet rest, the pressing down of either treadle depresses the leaf of heddles corresponding, and elevates the other. The leaves are light vertical frames, extending the width of the piece, each having ranged along it the heddles, or equidistant vertical twines, in number answering to half the required number of warp threads, and each twine having at the middle a loop or eye through which a warp thread is to be passed. In plain, as in all other modes of weaving, it is necessary first to lay together in the loom the number of threads requisite to form the width of the cloth; this is called warping, and was at one time done by use of a simple arrangement known as a warping frame. The more convenient "warping mill" was afterward introduced. In "beaming," the threads are wound as evenly as possible on the warp beam of the loom by passing them between the teeth of a comb, or of an instrument known as a ravel or separater. The next operation is that of "drawing," in which the warp threads are passed from the warp beam in their proper order through the loops of the respective heddles, from one side to the other, and attached forward along the cloth beam. By this arrangement, at each depression of one treadle, the corresponding half of the threads is carried down, the other half of them raised; and between the cloth beam or edge of the cloth already woven in front, and the heddles behind, the parted sets of threads thus leave a triangular space or opening, called the shed, through which the weaver throws or otherwise drives the shuttle from side to side of the piece. Just in front of the heddles, and back of the path of the shuttle, is suspended the batten, lay, or lathe, a movable frame having its axis at the top of the loom; the vertical rods forming its sides are the swords; its bottom is the shuttle race, the ends of which, just beyond the sides of the piece, are closed so as to form short troughs, in which the shuttle is arrested and started again at either side; while its middle portion is a sort of upright comb, the reed, having a tooth rising between every two consecutive threads. By seizing this batten and bringing it forward sharply after each thread or weft has been deposited, the weaver drives up the thread to its place in the cloth. However improved or complicated the loom, the principle of weaving is in all forms substantially that now described.—Before warping, the yarn is commonly sized, as by dipping sufficiently in size of starch, wringing and drying; and in weaving cotton or other yarns, these often require to be dressed as the weaver proceeds, being rubbed at intervals, as they are unrolled from the beam, with some mucilage or size, then brushed or combed, and dried by fanning; in this way the yarns are made more smooth and tenacious. For weaving broad goods, four, six, or even eight yards in width, much dexterity and precision is requisite in the throwing of the shuttle with sufficient and not too much force; while in the so-called engine loom, for weaving narrow webs, such as ribbons and galloons, several shuttles work as many webs at the same time. It is only in the simplest mode of hand weaving that the shuttle is still thrown alternately by the two hands. About 1740 John Kay invented the fly shuttle; in this mode, a continuous firm cord has a wooden handle, or "picking peg," at its middle, and placed conveniently in front of the weaver; the ends of the cord act on "pickers," one in each trough or box at the ends of the shuttle race, these pickers lying beyond or outside the shuttle, and either one impelling it by being slidden along a horizontal wire at a jerk given with the picking peg to the cord in that direction; by this means the hand weaver moves the shuttle both ways with the right hand, while he manages the batten with the left. Stripes across the piece are obtained by changing of shuttles, so as to employ the different colors or yarns as often as the proper widths of stripe are produced. This changing of shuttles

was inconvenient and wasteful of time, until Robert Kay, son of the inventor of the fly shuttle, contrived the drop box; in this, two, three, or more boxes, one over the other, at each side of the shuttle race, are so connected by a cord on which is a convenient handle, that, by moving this, one is made to slide down and the other up the swords of the batten; the boxes at one side have in them each a shuttle with one color of thread, and by moving them any required one is brought at once to the level of the shuttle race, so that its shuttle shall be next acted on by the picking peg and cord; and in this way the colors and stripes are changed at the will of the workman, or in power looms by some device changing the boxes at the proper intervals.—In the Jacquard apparatus, which can be attached to almost any kind of loom, a hollow prismatic box, extending the width of the fabric, has each of its sides perforated, in the direction of its length, with a number of straight rows of holes, corresponding, as each face is presented to the fabric, accurately with the points of as many rows of metallic bars, called needles. Each of these needles is pressed toward the box by a spiral spring, and each has passing through a loop in its length a lifting hook, which takes up, when lifted, its proper thread of the warp. These rows of lifting hooks terminate above also in hooks; and an arrangement of lifting bars is let down after each throw of the shuttle, to engage these upper hooks, raise the lifting hooks, and with them the warp threads. The prismatic box has also a reciprocating movement, by which at the same moments its sides are brought up to the ends of the needles; and it turns to present a new face at each movement. If all the needles enter the holes of the box, all the lifting hooks are in position, and are engaged by the lifting bars as they descend, and all the warp threads are raised. But the weaving of complicated figures, such as those of carpets, tapestries, or shawls, requires that, through a certain cycle of movements of the shuttle, new groups of the warp threads continually shall be elevated. To determine, then, the groups of threads that shall be elevated, a succession of stiff cards looped together to form an endless chain of any required length, and all of size and form corresponding to those of a side of the perforated box, are made to move successively over the box, one lying flat upon it at each of its movements. Now, the order and groups of threads raised are simply determined by perforating these cards beforehand, and in succession, with groups of holes that shall precisely correspond only with the threads to be lifted for that part of the pattern. When the box now advances upon the needles, those meeting the unperforated portions of the card are forced back, their lifting rods are moved out of position, and only the threads answering to the needles that enter the holes are raised. With the use of this apparatus, it is only necessary further to arrange properly the succession of colors to appear in the weft, or in both warp and weft. Some improvements of the apparatus for particular uses have been made by English manufacturers. (See JACQUARD.)—Not quite two centuries have passed since the origination of the first power loom, by M. de Gennes, a French naval officer of some distinction, who communicated his plan to the French academy of sciences in 1678. The advantages of productiveness, economy, uniformity of product, and convenience of weaving broad fabrics, which he claimed, are those practically realized and most important at the present day; but his loom was not brought into use. His account was translated in the same year for the "Philosophical Transactions;" and during a century or more several English inventors brought out power looms, none of which were generally adopted. The first successful power loom was the invention of the Rev. Edmund Cartwright (1784–'5). A principal cause which long delayed the adoption of these looms was the necessity for stopping the machine frequently, to dress the warp as unrolled from the beam; the employment for this purpose of a man for each loom prevented any saving of expense. In 1802 Mr. Radcliffe and Thomas Johnson, of Stockport, England, obviated this difficulty by producing the dressing machine in use in modern factories, by which the dressing of the warp is completed before it goes into the loom, being, during one operation, sized, brushed, dried, and distributed on the warp beam. Later, Messrs. Horrocks and Marsland, also of Stockport, further completed the adaptation of the looms for being driven by steam; and Mr. Roberts, of Manchester, brought the working parts of the looms to nearly their present perfection. The frame of the power loom is of cast iron, and of great strength. The breast beam and cloth beam are situated much as in the hand loom. The warp beam, at the back of the loom, is at the level of the breast beam, and is kept back by a weight, while above and parallel with it, at the level of the cloth beam, is a roller over which the warp threads are passed, so as to lie on the loom in a horizontal direction. The heddles, for broad or heavy cloths, are so suspended by levers and cords that the depressing of one raises the other; for light goods, a pair of rollers with cords suffices. To work the heddles, there are on a shaft running transversely across the loom two eccentric wheels on tappets differently set, the rims of which run on friction rollers fixed on levers of the third kind, pivoted at one end to the frame, while the movable end of each connects with one of the heddles. When the longer radius of either eccentric is down, the shorter of the other is so, and the lever and heddle corresponding to the former are depressed. Into the shed of the warp thus formed the shuttle is thrown by a sharp jerk communicated to it alternately from either side, by means of a single whip lever at the centre of the loom,

and moving a picking cord, or by means of two levers with short cords at the two sides; motion being in either case communicated to these at the proper moments by the mechanism. Thus, in the use of the single cord, the driving shaft in each loom, which in all cases derives its power through a band from the common shaft directly impelled by the engine, imparts motion to a second shaft running across the loom below it; while on this two rollers are so affixed, that one of them at each half turn of the shaft suddenly strikes down a roller on one side of the whip lever, and so, shortening another cord at this part, draws the lever and picking cord with a sharp jerk in the corresponding direction; the cord, acting on pickers as before explained, gives the throw to the shuttle. The stroke of the batten or lay, beating up the weft threads, is accomplished by means of cranks on the driving shaft, which so connect with arms projecting from the upright pieces of the batten (in these looms pivoted to the frame below) as to draw the batten forward after every throw of the shuttle. The connection of the shafts in the loom with each other, and with the cloth beam, to which a slow movement is imparted, is by toothed wheels, of such size as to give to each the required rate of speed. Among the late improvements in the power loom are those by which the loom is stopped when the weft thread breaks or is absent, when the driving band is shifted, and when the shuttle does not get clear of the shed; that in which the tension of the warp is obtained, not by a weight, but by springs fixed to the framing; and that of Mr. Ingram (1860) for resupplying the loom with weft as often as the bobbin or cop is exhausted, or when the thread is only broken.—The expense of material and time in preparing the cards for the Jacquard apparatus, which for the heaviest work must be of sheet iron, and for all intricate patterns very numerous, has always constituted the most serious drawback upon the desirableness of that method. Thus, an elaborate damask design has required 4,000 cards and 400 needles, at a cost of about $120, and five weeks' labor of a man in setting up; while a single design has been known to require 20,000 cards, at a cost of $600, and time equal to a year's labor of one man. With a view to reduce greatly these expenditures, M. Bonelli first constructed in 1854, and has since much improved, his "electric loom." In this, the cards of Jacquard's apparatus are superseded by an endless band of paper covered with tin foil, intended to serve as an electrical conductor; accordingly, the unperforated portions of the cards are here represented by non-conducting patches of black varnish, laid on with a brush. The band passes steadily along, under the points of rows of metallic rods or teeth. Each of these teeth connects with a small coil or helix, within which is a soft-iron bar. A frame capable of swinging slightly is situated in front of the ends of these bars, having a plate in it perforated with a corresponding number and order of holes, within and through which as many iron rods abutting at one end against the bars already named can move with a little friction, like as many piston rods through stuffing boxes. The tin foil band being put in connection with a galvanic battery, with the other pole of which the remote ends of all the helices connect, all the metal teeth at a given time resting upon the bare foil conduct portions of the current, render the bars in their helices magnets, and by their action withdraw the corresponding rods out of the plate, leaving so many holes open; while the rods answering to the teeth that are on the varnished portions of the foil remain in and close the other holes. In this way, this single plate is made to serve for the endless succession of Jacquard cards; the needles entering these holes determining as before what warp threads shall be raised. By means of insulated strips of foil running along the back of the tin foil band, and connected with certain portions only of its face, separated by narrow insulating breaks, different colors or sorts of weft can be successively worked into the piece, according to the strips of foil successively put in connection with the battery. In another improvement of the Jacquard loom, a sheet of prepared paper punched with the proper apertures is substituted for the cards of the old machine; this paper being in form of a continuous band, only three fourths of an inch wide, so that the weight of the new is to that of the old band as but 1 to 11. The arrangement is also such as permits the 400 spiral springs in connection with the needles in the old machine to be dispensed with. Thus the wear and tear due to the resistance of these is done away with, and fine and light wires are introduced in lieu of the heavy ones previously employed. Various additions have also been made to the Jacquard loom by Barlow, Taylor, Martin, and others.—American inventions in connection with the improvement of the power loom have been very numerous, but comparatively few radical changes have been introduced. In 1857 Mr. E. B. Bigelow of Boston patented a method of weaving pile fabrics double, by means of transverse intersecting pile wires woven between the two fabrics so as to keep them properly apart, with movement at the same time of two shuttles, and an arrangement connecting each shuttle with the shipper or disconnecting lever of the loom, so that, when the filling fails in either shuttle, the loom is thrown out of gear. An invention by Joseph Fish of New York was patented Oct. 26, 1875, which is especially applicable to the weaving of broad silk with figures of different colors and of various patterns. Its main object is to produce a power loom which shall not only provide for the control of the Jacquard machine or pattern-controlling device, but also "for the driving of the supplementary shuttles, and otherwise actuating them or such portions of their attachments as require to be

operated by the loom itself without the intervention of the Jacquard or pattern mechanism." The devices which control the operation of the fly shuttles are also applicable to all drop-box looms. (See also CARPET, COTTON MANUFACTURE, DAMASK, LINEN, RIBBON, SILK, TAPESTRY, VELVET, and WOOL, MANUFACTURES OF.)