III. TEXTILE MACHINERY.

Among the utilitarian arts which mark man's progress from a state of barbarism, there are none of greater antiquity than that of spinning and weaving. It appears, indeed, to have come into existence with the first dawnings of civilization. In the remains of the Lake-dwellers there have been found shuttles and plaited stuff made of flax (*pl.* 34, *fig.* 3), which took the place of woven goods. The Mound-builders of the Ohio Valley manufactured from some vegetable fibre a coarse cloth woven with a warp and filling whose threads were uniform in size and regularly spun. The ancient Egyptians prepared "vestments of fine linen" (Gen. xli. 42), as also of cotton, and in their production, as their native monuments show (*fig.* 2), men and women were alike employed. In Exodus (xxxv. 30) there is mention "of the weaver," and Isaiah (xix. 9) in his prophecy concerning the Egyptians says, "They that work in combed flax and they that weave cotton shall be ashamed." The staff of Goliath's spear was like "a weaver's beam" (1 Sam. xxii. 7), and Job (vii. 6) says, "My days are swifter than a weaver's shuttle." "Penelope's web" (*fig.* 1) was woven by a Grecian princess; the Latin *filia* (daughter) signifies "the spinner," and the German *Weib* (wife), "the weaver." In the Middle Ages these handicrafts were ennobled in the eyes of all the people, and a golden spindle was placed upon the grave of Luitgard, the daughter of Otto the Great, as a testimony of her diligence.

Everywhere for long centuries practically the same methods and appliances were employed in working textile fibres; the distaff, the spindle, with or without the wheel, and the hand-loom were busy the world over. The poet's idealistic description of one of the phases of home-life in Acadie might, with variations to suit different conditions and customs, have been appropriately applied to every community:

> "Matrons and maidens sat in snow-white caps and in kirtles
> Scarlet and blue and green, with distaffs spinning the golden
> Flax for the gossiping looms, whose noisy shuttles within doors
> Mingled their sound with the whir of the wheels and the songs of the maidens."

These slow and laborious processes continued until near the close of the eighteenth century. Previous to that time the materials employed in the manufacture of textile fabrics were mainly linen and wool, neither of which admitted, upon the wheel (*fig.* 5) and the hand-loom (*fig.* 8), of any great complexity of structure. Between the years 1767 and 1800 three inventions—namely, the spinning-frame, the cotton-gin, and the Jacquard machine—brought into being an extended list of fabrics infinite in variety of pattern and texture.

The Spinning-jenny (*fig.* 9), invented by Hargreaves in 1767, was capable of spinning from twenty to thirty threads at once with no more labor than had previously been required to spin a single thread. But the thread spun by the jenny did not possess the firmness required for the warp; this latter was made of linen until Arkwright, in 1768, produced the cotton-spinning frame (*pl.* 34, *fig.* 11), by which there could be spun a vast number of threads of any required firmness and hardness, and with such rapidity that the work of one man sufficed to produce what before had required the labor of more than one hundred. Crompton's "mule-jenny" (*fig.* 10), invented in 1775, is a combination of Hargreaves's jenny and of Arkwright's spinning-frame.

The Cotton-gin.—The invention of the spinning-frame greatly increased the demand for the supply of the cotton fibre, but this demand could never have been met had there not been invented a machine for expeditiously separating the fibre from the seeds, which, contained in every boll of cotton, cling to the fibre with such tenacity that the process of separating them by hand is very slow and tedious, a pound of green seed-cotton being all that one person can clean in a day. Though a rude machine called the "churka" had long been in use by the Chinese and the Hindus, and a similar one called the "manganello" had been employed by the Italians, no satisfactory results were attained until the invention of the cotton-gin by Eli Whitney in 1793. This machine (*pl.* 35, *fig.* 2) had a wonderful effect on the cultivation and manufacture of cotton, and rapidly increased its production and consumption. Though not suited to the long-stapled Sea-Island cotton, the ordinary Whitney gin is employed for cleaning the greater portion of the cotton grown in the Southern States. Its average daily capacity is about thirty-two hundred pounds.

Jacquard Machine.—Previous to the invention of the draw-loom and the Jacquard apparatus mechanical weaving of figured stuffs was confined to simple patterns. The Jacquard machine (*pl.* 44, *fig.* 13) takes its name from its inventor, Joseph Marie Jacquard (1752–1834), who in 1801 perfected the machine left by Jacques de Vaucanson (1709–1782). The principle of the Jacquard apparatus was first employed in 1725 by Bouchon, who used a band of pierced paper pressed by a hand-bar against a row of horizontal wires, so as to push forward those that happened to lie opposite the blank spaces, thus forming loops at the lower extremity of vertical wires in connection with a comb-like rack below. In 1728, Falcon substituted a chain of card-boards in place of the band of paper of Bouchon, and employed a square prism, known as the "cylinder." In 1745, Vaucanson dispensed with the cumbrous tail-cards of the draw-loom, and made the loom self-acting by placing the pierced paper or card-board upon the surface of a large perforated cylinder, which travelled backward and forward at each stroke and revolved through a small angle by ratchet-work. He also devised the rising and falling griffe, and thus produced a machine closely resembling the actual Jacquard. His machine, however, remained incomplete and lacked the simplicity requisite for general use. In 1801, Jacquard, who after many vicissitudes had attracted public attention by gaining a medal for an invention in textile machinery at the industrial exhibition in Paris, was called by Napoleon and his minister, Carnot, to a position in the Conservatoire des Arts et Métiers, where he found the Vaucanson machine whose mechanism suggested the improvements which finally were developed by Jacquard to their present form (p. 153). The opposition to the introduction of the Jacquard machine was so violent that the inventor was several times attacked by a mob and barely escaped with his life. The Conseil des Prudhommes, who were appointed to watch over the interests of the Lyonnese trade, so completely entered into the feeling which prompted this opposition that they broke up his model in the public square. The invention, however, was not lost; the machine was constructed elsewhere, and gradually made its way into England and France. After some years had passed it proved of great practical value, and in 1840, on the spot where the model was destroyed, a statue of Jacquard was erected.

1. Machines for Preparing Cotton for Spinning.

It is a characteristic feature of spinning by machinery that the process does not, as in spinning by hand, proceed in one operation from the simple fibres to the perfected thread, but that it first produces a strong ribbon-like semi-fabric, technically known as a "sliver," in which the fibres, freed from foreign substances, are arranged together in regular straight and parallel order. This semi-fabric is then gradually drawn out to the desired degree of fineness, and the requisite firmness is finally imparted to it by twisting. Hence, in considering the subject of spinning by machinery, the entire process may be divided into two operations: (1) the preparation of the sliver (ginning, opening, and carding) and (2) the conversion of the sliver by drawing and spinning into threads. The principal machines used for the first process are represented on Plates 35 and 36, and those employed for the second process are shown on Plates 37 and 38.

Ginning: Whitney Saw-gin.—The primary operation in spinning cotton by machinery is "ginning"—that is, the separating of the fibre from the seed. Figures 1 and 2 (*pl.* 35) show in vertical section two machines, termed "cotton-gins," which are used for this purpose. The principal feature of the so-called "saw-gin" (*fig.* 2) invented by Eli Whitney is a cylinder (*a*) armed with circular saws, a roller-brush (*b*), and a grate (*c*, *c*) composed of iron rods. This grate serves for the removal of the seeds, and is fastened below to the plate *d*, and, together with the plate, can be set in a suitable position in relation to the teeth of the saw-blades by means of the screw *e*, which enters into the cross-piece *f*. To permit the varying arrangements of the grate the rods of the latter are also connected above with a plate, which is secured by hinge-joints (*g*) to the upper cross-piece *h*. The hopper for the reception of the cotton is made up on the two sides by the walls of the frame, in front by the adjustable plate *i*, below by the grate, and in rear by the curved plate *l*. The plate *i* can be set backward and forward or higher and lower and screwed to the side walls by the screw-bolt *n*. The object of this is to set the comb *k*, placed below at *i*, in such a position regarding the cylinder which carries the saw-blades that the seed can pass with the requisite velocity through the opening between *k* and *c*. The curved plate *l* can be turned at *o* and secured by a screw (m) in a more or less inclined position, whereby the material to be worked is correspondingly pressed against the saw-blades.

If a more forcible action is requisite to gin the cotton properly, the plate d is depressed, whereby the teeth are projected farther over the grate, the curved plate l being at the same time moved forward. By giving the plate d the opposite position the fibres are less forcibly acted upon and the work proceeds more slowly. In case the seed does not fall freely enough from the machine, the plate i must be placed higher and farther forward; if the seed runs out too rapidly and is not sufficiently cleaned, the plate is to be set in the opposite position. At the rear of the cylinder, between the saw-blades, is placed a second or cleansing grate in a vertical position. It is secured to the plate p, which beneath the cross-piece h can be pushed up or down in grooves in the side frames of the machine. It consists of separate rods (q), which are connected with p only by a screw (r), and if desired may receive a slightly lateral motion between the saw-blades. Between the lower end of the rods q and a screen covered with tin plate (s) is a slit, through which the coarsest particles of dirt pass out in the direction of the arrow 1, the finer particles passing round and falling on the other side, as indicated by the arrow 2, while the cotton fibres themselves ascend in the direction of the arrow 3 on the plane t, also covered with tin plate, underneath which the space for the accumulation of the impurities is shut off by the screen u.

Comb-gin.—Though the saw-gin is very effective, it somewhat injures the quality of the cotton by tearing the fibres; to prevent this the comb-gin has been introduced (perspective, *pl.* 35, *fig.* 3; vertical section, *fig.* 1). In Figure 1, A represents a cylinder covered with rough leather which rotates in the direction of the arrow and carries with it the fibres of raw cotton fed to it. The blades a placed close to the periphery of the cylinder retain the seeds, which, liberated from the bundles of fibres by two blades (b b') oscillating rapidly up and down, fall between the rods of the grate (i). The blades b b' are fastened to the ends of the levers c, and from a shaft placed in the lower portion of the frame (B) receive their motion by means of two eccentrics and two eccentric-rods (D d). The raw cotton is spread out upon an endless rotating apron running over two rolls and receiving from them a forward motion, which carries the cotton under the grooved roll h, after which it is thrown into the trough H I by a toothed roll (s), and is finally pushed against the leather-covered roll A by means of the oscillating comb J. The rail a is secured to the frame F j by the screw e. The cylinder A is revolved from the driving-shaft by means of a belt and a pulley (L'). The ginned cotton is finally removed from the cylinder A by a rapidly revolving fluted roll (G).

Willow.—The cotton is always ginned on the plantations where it is produced, and for transportation is packed in bales with the assistance of powerful presses: it therefore requires subsequent loosening at the factories by special machines, one of which, the so-called "willow," is shown in Figure 4. This consists of a wooden casing in which rapidly revolve two horizontal shafts provided with beating arms. These arms are so placed that those on the one shaft pass between those on the other, and, besides, a number of stationary rods arranged in two rows in the interior of the casing correspond to the interspaces between the shafts. By introducing the cotton taken from the bales into the interior of the casing by means of an endless feeding-apron and two feeding-rolls, the firmly compressed masses are loosened and reduced to small bunches.

Opener.—A still more effective machine, the "opener" (*pl.* 35, *fig.* 5), performs the work by means of four drums provided with thumb-like elevations, which receive the cotton also from a feeding-apparatus and throw it repeatedly against rows of similar but stationary teeth. Below the drums is arranged a grate, composed of thin iron rods, through which fall all foreign bodies (sand, seed, pieces of leaves, etc.). The cotton thus loosened and freed from the coarser contaminations passes through two sieve-drums with fine meshes, from the interior of which air is constantly drawn by an exhaust-fan. The cotton, thus drawn against the periphery of these sieve-drums, is freed from dust and very short fibres by the powerful current of air. The prepared cotton is removed by an endless apron.

Batting-and-lapping Machine.—The most important preparatory machine, and one closely allied in its action to those described above, is the batting-machine (scutcher, beater, or opener), which is generally combined with an apparatus for the formation of the laps, and is known as the "lapper" (section, *fig.* 6). The cotton is spread upon an endless feeding-apron and conveyed by two pairs of fluted rolls to a beater in the interior of the casing *a*. This beater consists of two or three steel rails connected by several cross-arms with a shaft revolving at high speed. The rails beat in rapid succession and with great velocity upon the cotton coming from the feeding-rolls, thus further reducing any bunches still present. Below the beater is a grate, for the escape of coarser detritus. The loosened cotton next passes to the so-called "flying-space" *b*, and consolidates to a flor on the periphery of the sieve-drum *c*, from which the air is constantly drawn. The flor is detached by the pair of rolls *d*; and, being further compacted between the rolls *e*, *f*, *g*, *h*, is finally rolled together upon a large wooden bobbin to a lap. To facilitate the detachment of the flor from the sieve-drum (*c*) the current of air is cut off at the appropriate place by a shield firmly connected with the shaft of the sieve by means of the lever *m* loaded with the weight *n*.

Figure 8 shows a modified form of the batting-and-lapping machine: *a* designates the beater; *c*, *d*, the grate; *b*, the flying-space; *e* and *f*, two endless sieve-cloths, replacing the sieve-drum; and *g*, the compressing-rollers, back of which is the attachment producing the laps and known as the "lapper." At *h* and *i* enter the suction-channels *l* and *m*, which lead to a fan, and by means of which the dust is removed from the cotton. *k* is a receptacle for the coarser contaminations, and serves at the same time for shutting off the air from below. To be enabled, when working short cotton, to bring the effective edge of the beater as close as possible to the place where the fleece is held, the feeding-rolls are frequently replaced, as in Figure 7 (*pl.* 35), by a tray (*a*) and a roll (*b*) set with sharp points, which can be brought close to the beater carried by the arms *g*. This arrangement is called "tray-feeding." The external appearance of an opener and lapper is shown in perspective views in Figure 9 (*pl.* 35) and Figure 1 (*pl.* 36).

Carding.—From the previously explained machines the cotton is delivered in the form of a very clean downy fleece, known as a "lap," having its constituent fibres thoroughly disentangled, yet not parallel. As the parallel condition is necessary before forming the roving from which the yarn is to be wrought, the lap must be subjected to the process known as "carding." As a regular and perfect roving is one of the first requisites for producing a perfect cloth, the carding is an important operation, as is evidenced by the constant efforts made by builders to produce carding-machines of increased capacity and higher quality of result. The carder of to-day has many advantages not possessed by his predecessors of the last generation, his card-clothing and auxiliary machines being so much advanced and so superior that he cannot fail to obtain better results from the same quality of cotton. The object of the carding-engine is further to separate the bunches of fibres composing the lap by means of the very fine wires of the card-clothing, and then to re-form the fibres into a roll (the roving) in which the fibres are uniformly parallel.

Carding is one of the most important processes required in manufacturing raw cotton-fibre into thread. That the work may be well done two conditions are requisite: first, in order to allow a "true" setting and to prevent unequal pressure of the working parts on the bearings and framework, the carding-engine should be placed on a solid level floor where there will be no vibration: the ground-floor of the mill-building furnishes the most suitable location; and secondly, for the different parts of the carding-engine there should be selected proper card-clothing, upon which good carding mainly depends. The principle of the card-clothing will be understood from the following explanation.

Card-clothing consists of strips of leather in which are inserted fine wires, called "needles" or "teeth" (dents), having their projecting ends slightly bent in one direction. The teeth, which vary in size according to the quality of cotton to be worked, must be equally distributed and equally inclined over the surface of the leather. The card-clothing is fastened to flat or cylindrical surfaces of wood or metal, and the cotton is passed between two or more such clothed surfaces. It will be readily seen that the card-clothing is a very important factor in carding cotton, as it performs the peculiar function of separating the fibres and again combining them.

Figure 6 (*pl.* 36) shows a section of card-clothing for a "licker-in" roller. As this is the card-clothing with which the cotton first comes in contact, it must be strong, so as to remain uninjured by any impurities adhering to the cotton. Figure 7 illustrates the card-clothing used for covering the main cylinder of a carding-engine when working a good staple cotton; Figure 8 (*pl.* 36) is the card-clothing required for the "dirt-roller." The latter clothing is not so close set as the former, the purpose being to receive in its interstices the seed, leaves, and other impurities in the cotton, taken from the surface of the close-set card-clothing which covers the main cylinder. Card-clothing is designated by numerals, which indicate the number of wires to the square inch. The wires are either flattened or round, coarse or fine, according to their required purpose.

Figures 4 and 5 represent two pairs of card-clothing bands of different modes of action. In Figure 4 the needles are set opposite one another in the direction of their points. Supposing the lower card-clothing covered (in any manner) with cotton and the upper (*b*) moved over it to the right, hence in the direction opposite that of the arrow, the dents or teeth of the upper card-clothing will remove a portion of the cotton from all places of the lower where it is in excess and deposit it on those places which are empty or not sufficiently filled, the result of this simple operation being the separation of the fibres and their uniform distribution between the two surfaces. Figure 5 shows two strips of card-clothing with dents bent in the same direction. If the upper card (*a*) be filled with cotton and drawn over the lower in the direction of the arrow, the entire material will be transferred to the lower.

Carding-machine.—Upon the latter two modes of application is based the action of the carding-machine, also termed "carding-engine." Around a large cylinder or drum covered with card-clothing and revolving at great speed are placed a number of small rollers, called "workers" and "strippers," or a number of stationary top-cards, or both combined, so arranged that the cotton introduced by a feeding-apparatus is separated into filaments and wrought into a flat, narrow strip or ribbon, termed a "sliver." This latter is then further drawn out, and thus reduced to a yet thinner and more attenuated state. The carding-engine shown in Figure 3 contains workers and clearers as well as top-cards and an automatic cleaning-apparatus for the latter, thus representing this kind of machine in its most advanced form. Figure 2 shows a revolving flat carding-engine.

2. PREPARATORY MACHINES AND SPINNING-MACHINES.

Drawing.—The cotton, having been wrought by the carding-engine or other preparatory machine so as to form a continuous sliver or ribbon of some consistency, must next be converted into drawings. To obtain the utmost uniformity as regards thickness, several ribbons or slivers are combined by "doubling" and the fibres straightened out by stretching these ribbons. It is then made gradually thinner by continued stretching or "drawing," being at the same time slightly twisted, which gives it the requisite consistency of "roving." This, which may be considered as a preparatory yarn, is finally reduced to the fineness and firmness required by more forcible twisting or fine spinning.

Mule-jenny.—Hence, for soft yarns, such as are used in the production of many woven articles, and which require a slighter twist, the water-frame is not available and is replaced by the mule-jenny, shown in various arrangements in Figure 9 (*pl.* 37) and Figures 1 and 2 (*pl.* 38). Though the stretching and twisting of the thread are simultaneously effected by this machine, the winding up is done intermittently each time after the completion of a certain length of thread (about 6 feet), the actual spinning being interrupted in the mean while. The yarn is not wound on wooden bobbins such as are shown in Figures 6 and 7 (*pl.* 37), but on slender conical iron or steel spindles whose shape is represented in Figure 8.

There is a remarkable difference between the mule used for the production of smooth yarn from cotton, long sheep's wool (worsted), etc., and that for rough carded yarns from short wool. In the first, where there is already a roving of great uniformity, the stretching is effected by means of an ordinary drawing-frame, but in the latter between a pair of feeding-rollers and the spindle which serves for twisting as well as for winding, and which continues to recede from the feeding-rollers after the latter have come to a stand-still. The spindles, on whose periphery the thread is fastened, stand slightly inclined toward the vertical and revolve at great speed during the entire spinning process, thus imparting a permanent twist to the thread. If, now, the twisting and drawing be effected at the same time, as by the mule for carded wool, the twists affect the threads first upon the thin places, which oppose the least resistance to the twisting, whereby they obtain such a solidity that in the drawing they oppose a greater resistance than the remaining thicker but less twisted places, the drawing thus chiefly affecting the latter. The equalizing required on account of the uneven thickness of the rovings is in the process of fine spinning thus attained at the same time. This also explains the somewhat different arrangement of the mechanism of the mule for carded wool.

Self-acting Mules.—A large number of threads (from two hundred to one thousand) are produced by a mule at the same time. A number of spindles corresponding to the number of threads to be spun stand in a row on a carriage, which runs on iron rails, alternately receding from and approaching the drawing-frame during the spinning and winding periods respectively. With the so-called "hand-mules" the motion of the carriage as well as the rotation of the spindles and the distribution of the windings on the spindle by a workman takes place during the latter period, while with the self-acting mules, which are chiefly used, all motions, without exception, are derived from the driving-shaft. Figure 9 (*pl.* 37) and Figures 3 and 5 (*pl.* 38) show the external appearance of different self-acting mules.

3. MACHINES FOR PREPARING WOOL, ETC. FOR SPINNING.

Wool-burring Machine.—If we now turn our attention to the machines for the preparation of wool fibre, we have first to consider the apparatus for cleaning the wool. Figures 2 and 3 (*pl.* 39) represent what are known as burring-machines, which serve to free the wool without loss from the burrs that frequently adhere to it. The effective part of such machines is a cylinder provided with fine steel combs set tangentially, upon whose periphery the wool is so brushed that the burrs lie free upon the outside and are knocked off by a quickly revolving knife-roller.

Wool-washing Machine.—After the locks of wool have been opened and cleaned of impurities in the burring-machine, the wool is transferred to the washing-apparatus, which serves for the removal of the oily substances adhering to the wool. To dissolve the adhering fat or "suint" the wool is treated with warm soapy water.

The wool-washing machine (*fig.* 4) consists of a series of stationary rakes or racks, alternating with movable ones, which are actuated by a crank-motion and arranged in a long box partly filled with scouring-liquor. Such machines are built with one, two, or three bowls. The liquor in the first bowl soon becomes dirty and must be drawn off. When this is done, the liquor from the second bowl is drawn, by means of an injector attached to the side of the machine, into the first bowl, and a new liquor is prepared for the second bowl. In a three-bowl machine this process is used between the second and third bowls. In some instances the wool is first scoured, and, if making wool-dyed fabrics, colored, before it is burr-picked. In most instances the wool is colored before being carded and spun. If colored after scouring, it is submitted to the action of the hydro-extractor (*pl.* 38, *figs.* 6, 7). Figure 6 represents one of these machines operated by belt and friction cones, and Figure 7 a similar one operated by a direct-acting steam-engine. After the wool is colored and repeatedly washed, or only scoured—in which condition it would be used either for piece-dyed goods or white flannels, etc.—it is submitted to the wool-drying machine.

Wool-picker.—After being thoroughly dried the wool is subjected to the common picker or opening-machine (*pl.* 39, *fig.* 1), by which it is loosened or opened. In a semi-cylindrical casing there revolves a large cylinder having strong iron spikes, to which the wool is supplied by means of a feeding-apparatus consisting of an endless apron of wooden slats and fluted rollers, the loosened wool being thrown out through an aperture opposite the feeding-apparatus. When used for working wool moistened with oil for the carding process, this machine is technically known as the "wool-picker."

Wool-carding Machine.—Entirely unlike the method of cotton-roving is the process of producing rovings from the sliver of the last carding in spinning wool, the latter being effected by an apparatus attached to the carding-engine itself. While in spinning cotton, flax, and worsted yarn the object is to produce smooth, even rovings with the separate fibres drawn straight, in spinning wool the object is to obtain a rough thread of fibres lying cross-wise and with their upper ends projecting from the surface, so that the tissue (cloth) spun from such threads will be capable of being "fulled"—that is, so that the threads lying alongside one another may readily "felt" under the influence of moisture, heat, and kneading. For this reason the doubling and drawing processes are dispensed with, and the object is attained in one operation by pulling the sliver coming from the carding-engine cross-wise into roving-threads, which are then converted into roundish threads by the apparatus referred to above. This pulling apart of the fibres is effected on the periphery of the "doffing"-cylinders, following immediately behind the carding-cylinder. The cylinders are covered with narrow strips of card-clothing separated from one another by short intervals, being thus arranged to receive the wool from alternate zones on the main cylinder.

To prevent these strips from coming in contact with one another their detachment is effected by two combs, the first of which is provided with teeth for the first, third, fifth strip, etc., and the other for the second, fourth, sixth strip, etc., two rubbing and two winding attachments being also used. Such a carding-engine is shown in Figure 1 (*pl.* 40), while a carding-engine with only one comb is represented in Figure 2. Both machines are of German construction. Figure 5 (*pl.* 39) represents the "finisher" of an American carding-machine.

The complete carding-machine consists of three individual machines, known as the "first breaker," the "second breaker," and the "finisher" (*pl.* 41, *figs.* 2–4), which constitute what is termed "one set." Figures 2 and 5 illustrate the first breaker, which is that part of the "set" with which the wool first comes in contact. In Figure 5, at the left of the machine, extends the feed-apron, upon which the wool is spread; this apron is similar to the one used on the wool-picker and brings the wool in contact with the first pair of rollers, which are known as the "dirt-rollers." This spreading of the wool upon the apron is also now done automatically by means of the Bramwell feed (*fig.* 2). Figure 3 illustrates what is known as the "second breaker," through which the drawing passes before reaching the finisher (*fig.* 4). Figure 1 illustrates a similar finisher with the Apperly feed attached. This feed is used to make automatic connection between the second breaker and the finisher. Figure 6 shows a Garnett machine and card combined. This machine is for opening, for reworking, the "hard waste"—that is, the yarn waste—from the weave-room.

Quite different from wool-carding is wool-combing, known as "worsted-combing." In the latter process the object is to produce as smooth a thread as possible, since fabrics made of this yarn require very little if any felting or fulling. From the worsted-card (*pl.* 40, *fig.* 3) the drawing goes to the comb, and thence to the spinning-frame.

Figures 1, 2, and 4 (*pl.* 38) illustrate a mule for spinning woollen yarn from the roving as it leaves the finisher-card, where, by means of rubbing, it has received sufficient solidity to be put on roving-spools, which are so inserted in a frame in the mule as to allow rewinding of the roving for drawing it to the required size, as well as for imparting the necessary twist.

Flax is a term employed to denote both the fibre of the flax-plant and the plant itself. There is abundant evidence that this important plant has been cultivated from remote antiquity (see Gen. xli. 42) for the strong fibres of the bark, which are manufactured into linen. To prepare it for spinning and weaving the following preliminary processes are requisite.

The Rippling Process, which has for its object the removal of the seed-capsules, is the first to which the flax-plant is subjected after being pulled up by the root. It consists in drawing by hand successive bundles of flax straw through the upright prongs of large fixed iron combs, or "ripples." If the plant, after having been pulled, has been dried, the removal of the seeds is effected by means of the "seeding-machine," which consists of a pair of iron rollers, between which the flax is passed.

Retting is an important operation which is performed for the purpose of separating the fibre from the woody "shive" or core, and also for decomposing and removing certain adherent glutinous substances. Two processes—namely, cold-water retting and dew-retting—have been practised from the earliest times. Warm-water retting was adopted in England in 1846.

Cold-water Retting, which is the usual process, requires a pond of pure soft water not more than 4 feet in depth, and for retting an acre of flax it is calculated that it should be 50 feet long and 9 feet broad. In the pond are placed the rippled stalks, which, tied in bundles and covered with straw or sods, have placed above them stones of sufficient weight to keep the flax submerged. Under favorable circumstances a fermentation is immediately induced through the influence of heat and moisture. The process is generally completed in about two weeks, when the flax is spread out and allowed to remain for several days in the open air; it is then ready for breaking and scutching.

Dew-retting, which dispenses with fermentation, is accomplished by subjecting the spread-out flax to the influence of air, sunlight, dews, and rain.

Warm-water Retting employs tanks, in which water is raised to a temperature of from 75° to 95° Fahr. during the time the flax is kept in the tanks, which is from fifty to sixty hours. The different colors in flax are due to the different systems of retting.

Flax-breaking Machines.—Of the auxiliary machines for the treatment of flax the two brakes shown in Figures 7 and 8 (*pl.* 41) are especially characteristic. After the destruction by the retting process of the gummy matter uniting the fibres with the stem these brakes serve to crack, at short intervals, the woody portions of the flax-stem, so that their complete removal can be readily accomplished by the beating- or scutching-machine. In Figure 7 the breaker consists of two rows or groups of cast-iron levers, which move toward each other with an oscillating motion, so that their edges slightly pass over one another and the flax-stems held between them are broken. Figure 8 represents Guild's breaking-machine, whose effective portion consists of two pairs of fluted rollers, between which the flax-stems, spread out upon a table, have to pass.

Scutching.—A scutch is an implement employed for dressing flax or hemp. By its use the fibre is entirely freed from the woody core. Scutching is done by hand or by scutching-mills driven by water or by steam-power. A variety of machines and processes has been introduced for the purpose of economizing labor and of improving the fibre of the flax, both with reference to cleanliness and to the production of the least amount of scutching-tow.

Flax-hackling.—The flax fibres, thus freed from the woody portions, are subsequently subjected to the so-called "hackling" process, by which the long fibres ("line") are separated from the short fibres ("tow"). By piecing together separate lengths the long flax is converted in a very simple manner into an endless tape or ribbon, while for working the tow there is used the carding-engine, which is the universal machine for converting all short-fibred material (requiring spinning) into a uniform roving, which can then be readily twisted into a thread.

Silk.—In producing the silk-thread neither roving nor carding machines are necessary, since the thread is spun by the silkworm around itself when it enters the pupa or chrysalis state, and for textile purposes needs only to be unwound from the cocoon.

Reeling.—The cocoons, after the chrysalides they contain have been killed either by dry heat, exposure to steam, or in water heated to about 200° Fahr., are sorted and submitted to the reeling process, in preparation for which a number are thrown into a basin of warm water, in order to soften the gummy envelope of the fibres and to permit their ready separation from the cocoon. During the reeling process two threads, composed of an equal number of fibres, are passed separately through two perforated agate guides. After being crossed at a given point they are again separated and passed through a second pair of guides, and next through the distributing guides to the reel, from which they are taken off in hanks ready for market.

Silk-throwing.—Before using reeled silk for textile purposes two or more of the threads are "thrown" together and slightly twisted. In this manner are produced the various kinds of silks known as "organzine," "tram," "embroidery," "sewing," etc.

The next process is what is known as "shaking out," whose object is to beat out or open out the hanks that they may present a uniform appearance. Following is the "stringing" process, which is performed either by hand or by machine, and whose object is to complete the separation of the double silk fibre into its constituent fibres and to impart to them an additional lustre. Some silks which require a special lustre are subsequently subjected to a special process, known as "silk lustring." This is effected by submitting the hanks to a gentle stretching between two polished steel rollers enclosed in a cast-iron box. During the rotation of the cylinders steam is admitted at a moderate temperature.

4. Preparatory Machines for Weaving, and Looms.

The various machines represented on Plates 42 to 47 serve for the production of woven textile fabrics—that is to say, of fabrics composed of two distinct systems of threads which interlace at right angles. The threads which run lengthwise in the fabric are technically known as the "warp;" those which run crosswise are termed the "filling." The raw materials usually employed in the production of woven fabrics are cotton, wool, silk, flax, jute, etc.

The Warp: Chain Warping.—The warp consists of numerous individual threads, which before the actual weaving operation must be placed parallel and near one another by a special manipulation known as "warping" or "dressing;" and by an operation termed "beaming" these threads are wound tightly upon a wooden roller, called the "warp-beam." There are two methods of warping—namely, chain warping and section warping. Chain warping (*pl.* 42, *fig.* 1) derives its name from the manner in which the warp is taken from the reel. After the warp has been made it is drawn from the reel by hand and looped up in a succession of links like a chain. It then goes to the dyehouse, to be dyed or sized, as may be required. Reels—or, as they are generally called, "warping-mills"—vary in height and circumference according to the grade and quantity of work. After the warp has been linked in a chain it is put on the beaming-machine. Figure 2 is an illustration of a good form of beaming-machine, showing the rolls, etc. For warping cotton a different machine is frequently used (*fig.* 3), the thread being passed directly from the bobbins and wound upon a beam. This machine is generally provided with an attachment which, should any thread break or the bobbin run out of yarn, immediately stops the machine until the thread is tied or replaced.

Section Warping, mainly practised in the manufacture of woollen and worsted fabrics, is clearly illustrated in Figures 1, 4, and 5 (*pl.* 43). Figure 1 represents the sizing-machine, and Figure 4 the section reel used in connection with the former. Section reels are made about 4 yards in circumference and from 40 to 120 inches long, according to the work to be done. Most reels have twelve long rails, called "pin-rails," provided with numerous small holes from $\frac{3}{16}$ to $\frac{1}{4}$ of an inch in diameter, systematically arranged, into which the operative puts pins from 3 to 4 inches in length, to act as "builders" and to limit the width of the section. For woollen and worsted fabrics the warp-yarn is generally wound on long spools, each containing from twenty-five to fifty ends. Figure 5 shows a machine for winding these long spools.

The Filling consists of single threads running in straight layers to and fro across the entire width of the tissue, returning at the edges and imparting to the web the requisite firmness. The combination of the warp with the filling for the formation of a web can be effected in an endless variety of ways, technically known as the different "weaves." These are generally divided into three distinct classes, termed "foundation weaves"—namely, the plain, the twills, and the satins—which form the basis of further subdivisions, classified as "derivative weaves."

Cotton Weave.—Figure 3 (*pl.* 43) represents a fabric produced by what is technically known as the plain or "cotton weave." In this diagram two distinct sets of threads crossing each other at right angles and interlacing alternately are visible. The threads (*W*) which run lengthwise in the fabric are the warp-threads; the transverse threads (*F*) are the filling. Figure 6 shows the design or pattern, executed to correspond with the fabric sample, Figure 2, the shaded squares indicating warp up and the empty squares representing filling up. Figure 6 is a section of a fabric woven on "plain" weave, showing one warp-thread light (1), the other shaded (2). The filling is represented in full black. Figure 2 shows that this weave produces a very firm interlacing of the two systems of threads employed; in fact, it is the most frequent interchange of warp and filling possible. This weave produces a strong fabric, as, by reason of the interlacing, each thread supports the other to the fullest extent.

Harness.—The portion of the loom which effects the regular separation of the warp-threads (technically known as the "opening of the shed") is called the harness, its arrangement for weaving "plain" being shown in Figure 8, in which *a*, *b* is the horizontally stretched warp, *c* the so-called "reed," a light wooden frame as long as the width of the fabric and provided with a large number of parallel vertical strips of metal (dents, *fig.* 11), between which are passed the warp-threads, either separately or by twos, threes, etc. By this means the warp-threads are kept uniformly distributed over the width of the loom, and the pushing together of the introduced filling ("beating up of the filling") is readily effected by pushing the reed toward the breast-beam of the loom.

Harness-frame and Heddles.—Figure 9 shows the so-called "harness-frame" and "heddles," consisting of two horizontal laths with a number of twines with small wire loops ("mails"), through which the warp-threads are drawn. Figure 12 is another shape of a harness or harness-shaft more frequently in use than the one previously shown. It consists of a frame *A* and the iron rod *B* for holding the heddles *C*. Through the eyes (*D*) of the heddles the warp-threads are drawn, as illustrated by *E*. For drawing a warp into its set of harness two persons are required. The "drawer in" inserts his "drawing-in hook" through the eye of the heddle toward the second person, called the "hander in." The latter inserts one of the warp-threads in the eye of the hook, which in turn is pulled out of the heddle-eye by the first drawer in.

The Shuttle for the introduction of the filling is shown in Figures 13 to 15. It is a boat-shaped piece of wood with metal-pointed ends, and is hollowed out for the reception of the bobbin, which is wound with the filling and placed upon a spindle in the shuttle. From this bobbin the filling is unwound either in a direction normal to the axis or parallel to it. In the first case (*fig.* 14), the bobbin *g* revolving around the spindle, cylindrical convolutions are formed; but in the second (*pl.* 43, *fig.* 15), the bobbin *s* being fixed upon the spindle, conical layers are produced. The filling passes out through a hole in the side of the shuttle, which, passing through the shed, is drawn across the width formed by the warp. Figure 13 is a shuttle used in weaving cloth in power-looms. Figure 7 shows the lay or batten and reed as used in hand-looms; *H* represents the shuttle-race supported by the arms *E* attached to the cross-bar *B*, which is suspended by means of two steel prisms or points, so that it can be turned to the frame of the loom, and which is given pendulum-like oscillations by the left hand of the weaver. The reed sits between the shuttle-race *H* and its cover *P*.

Temples.—To prevent a too forcible and irregular contraction of the warp by the tension of the filling, which in the beating up is forced to assume an undulatory shape, the weaver uses special appliances, called "temples" (*fig.* 10), consisting of two pieces of hard wood connected by threads and provided at the ends with pins. The two pieces of wood form an obtuse angle, and by inserting these pins near the edge of the fabric and adjusting the whole upon the cloth in the manner of a joint-lever there is produced in the direction of the width of the cloth a suitable tension, which resists the pull of the filling. The temples are shifted as the formation of the cloth progresses. In the same manner, that the play of the batten may be constantly continued in one place, the cloth itself must move in the direction of the arrow (*fig.* 8). For this purpose it is adjusted to wrap upon a roller (the cloth-beam), which from time to time is turned by the weaver or at short intervals by a mechanism driven by the batten.

Looms.—The art of weaving antedates all authentic records. References to woven goods occur at an early period of Scripture history and they are numerous in the Mosaic period. Pliny accords to the Egyptians the invention of the loom, in which, as shown by the temple-paintings, the web was either horizontal or perpendicular. The finest of the Egyptian mummy-cloths have about sixty-four threads to the inch in the warp, and about one hundred and forty threads in the filling. In the looms of the Greeks and Romans the warp also ran either horizontally or vertically. Their shuttles, made of box-wood, were pointed at each end, and in a cavity made in each shuttle there was placed either a quill (*pira*) or a bobbin, on which the filling was wound, and which revolved as the yarn unwound and passed through a hole in the side of the shuttle.

Hand-loom.—Figure 8 (*pl.* 34) exhibits a simple form of horizontal hand-loom employed in Europe during the Middle Ages, and Figure 7 is a representation of a loom now in use among the peasants of India. With the latter loom the richest gold-and-silk fabrics and the most elaborate patterns are woven, frequently by travelling weavers who carry with them their apparatus, whose parts they can quickly adjust. Figure 12 (*pl.* 44) illustrates a hand-loom, *A*, *A*, *A*, *A* being the frame, *t* the treadles for operating the harness *b*, *d*, actuating around rollers *a*, *I* the lay, and *h* the breast-beam, around which the woven cloth passes to the cloth-beam. In the rear of the loom is the warp-beam, around which the warp-threads are wrapped before passing into the harness.

In plain cloth, the threads which run lengthwise constitute the "warp," while those which run crosswise are variously termed the "weft" or the "filling." The warp is divided into two parts, one of which is raised while the other is lowered to allow the filling to pass between them, the space thus formed being termed the "shed." The principal working parts of the hand- and power-loom are practically the same, as will be apparent from the succeeding description.

For plain weaving two harness-shafts are united by two cords passing over pulleys (*e; pl.* 43, *fig.* 8), and below by two other cords with the treadles F^1, F^2, which are pivoted on the axis g, and which the weaver alternately depresses with the feet. Suppose, now, the odd-numbered warp-threads (first, third, fifth, etc.) to be drawn through the heddle-eyes of the heddle d^1 and the even-numbered through those of d^2; it is evident that by depressing the treadle F^2 the heddle d^2 will be drawn down from its central position and d^1 will be drawn up, and that as such separation of the warp-threads (formation of a shed) takes place all the odd-numbered warp-threads will be carried above and all the even-numbered ones below the original central position. In the angular shed formed by the heddles d^1, d^2 between the already finished cloth a and the reed c, the filling is introduced by means of the shuttle, which is hollowed out, to contain the "cop" or bobbin. By a vigorous movement (beating up) of the reed the filling is driven close to the already finished web. The opposite position of the heddles is then brought about by depressing the treadle F^1, the odd-numbered warp-threads being thus brought into the lower shed and the even-numbered into the upper. A second pick of filling is then introduced and beaten home with the batten, thus completing a round of all the movements, which are regularly repeated.

The Couper.—While in the production of fabrics interlaced with the plain weave only two different positions of the warp-threads occur, requiring only two harness-shafts, in all other fabrics there are a larger number of different positions of the warp-threads, requiring a correspondingly larger number of harness-shafts; consequently, the arrangement shown in Figure 8 (*pl.* 43) cannot be used, it being replaced by the couper, illustrated in Figure 1 (*pl.* 44). Each harness (a) is connected by a cord with a lever (b, b), which is pivoted on the pin c. A cord passing outside the heddle connects this lever with another (d), twice as long, which is pivoted on the pin e. At f there is secured to the latter lever a cord leading to the treadle g. The same heddle is directly connected by cords and the intermediate lever (h, i) with a second treadle (k). It will be seen that by pressing down the treadle g the heddle a can be raised from the central position, and lowered by pressing upon the treadle k. Now, in the harness as many heddles have to be arranged as there are different positions of warp-threads in the cloth, and as many treadles as there are different positions of filling, each treadle being connected with all those harness-shafts which are to be raised by its depression by the parts *b*, *d*, *f*, *g*; all the rest, which are to come into the lower shed, directly by the parts *h*, *i*, *k*. By varying the "cording" of the treadles a harness of this kind can be so arranged as to be applicable for the production of a large number of different points of intersection and kinds of fabrics. The couper is in general use for weaving twills, satin, and many small figured fabrics, its application being limited only where the number of heddles is too great to be accommodated by the loom and the number of treadles too large to be conveniently accessible to the feet of the weaver. Such is the case in the production of all large figured stuffs—for example, damask, etc.—in which the same position of the warp-thread and of the filling-thread recurs only at long intervals. For this purpose the couper is replaced by the Jacquard apparatus (*pl.* 44, *figs.* 2, 3).

The Jacquard Apparatus consists of the following principal parts: the frame and the perforated board fastened horizontally to the base of the machine, through which are passed the neck-cords of the harness; the hooks and the griffe, with the necessary attachments for lifting the same; the needles, needle-board, springs, and spring-frame; the cylinder, hammer, batten, and catches; and the cards and harness.

Hooks and Needles.—The hooks (*fig.* 5) are made of polished spring wire. The upper ends of the hooks engage with the griffe-bars, and to the crook of their lower ends are fastened the neck-cords of the harness, the small catch serving to keep the hooks in their required position by means of the rest-bar. The needles (*fig.* 4) are also of wire, with a loop on one end and an eye (made by a turn of the wire in the straight part of the needle) between the loop and the point or head. The eye through which the hook is passed is about ⅜ of an inch in diameter, and allows sufficient play for the up-and-down movement of the hook. The point at which the eye is made upon the needle is determined according to the position of the hook which it embraces (comp. *fig.* 3). The needles are adjusted in rows of different heights; the arrangement most used is four, eight (*fig.* 3), or twelve rows high.

The Griffe (*fig.* 9) is a gridiron-shaped cast-iron plate. Each bar (knife) of the griffe accommodates a row of hooks, which when the griffe is down or the machine is at rest stand about ½ inch above the bars. The hooks are controlled by the needles, which run horizontally and are kept in position by the needle-springs in the spring-frame (*d; fig.* 3). It will be seen that when the hooks are in their natural positions the lifting of the griffe will raise all the hooks; but should any of the needles be thrust back, thus moving the hooks from their vertical positions, they will not be disturbed by the rising griffe (*fig.* 2).

The Cylinder.—The so-called "cylinder" (*fig.* 7) is a hollow four-sided prism. Each side of the prism is perforated with small regularly disposed holes corresponding to the number of the needles, and is also provided with protruding pegs about ½ an inch in length, which serve to steady the cards when in contact with the cylinder. The cylinder alone does not affect the needles, its function being simply to carry on its rotating faces a series of pasteboard cards, which are presented and pressed against the points of the needles by the motion of the cylinder.

The Needle-board (*pl.* 44, *fig.* 8) is a perforated board in which the points (heads) of the needles rest, and by which they are guided to the holes in the cylinder.

The Cards (*fig.* 10) are of pasteboard of sufficient thickness not only to resist the wear caused by the pressure of the needles on those parts not perforated for the pattern, but also to give steadiness to the cards when resting on the pegs of the cylinder. The cards are laced together in an endless arrangement; hence one card follows another in regular rotation toward the needles by the revolution of the cylinder. Figure 1 (*pl.* 45) is a belt-power card-stamper and Figure 2 is a foot-power card-stamper which are used for stamping the Jacquard cards. Figure 3 shows the machine for lacing these stamped cards into an endless arrangement.

The Harness (*pl.* 44, *fig.* 11).—To the lower end of the above-mentioned hooks are adjusted the neck-cords, which are passed separately through one of the holes of the perforated bottom board (*a*). To the neck-cords are fastened the harness-cords (leashes), which pass through holes in the comber-board *b* (a perforated board which guides and keeps the harness-cords in the required positions) and are attached to the heddles. To the heddles are fastened weights (lingoes) and through the eyes (mails) of the heddles the warp-threads are drawn.

Operation of the Jacquard Machine.—In ordinary weaving, as explained on page 152, the warp is divided into two sets of threads, the predetermined alternate division of which is raised and lowered, to enable the weaver to throw the shuttle from his right to his left hand, and *vice versâ.* If, however, a pattern is to be produced either in plain materials or of varied colors, it is necessary, instead of raising and depressing the entire series of threads of the warp in two sets, to raise only such as are required to develop the various parts of the figure; and this must be effected with great exactness, as the formation of the pattern depends upon the position of each thread. The Jacquard apparatus is for the purpose of regulating these movements.

Figure 3, which illustrates one cross-row (containing eight hooks) of a Jacquard machine, gives a clear understanding of the arrangement of hooks (*a*), needles (*b*), griffe (*c*), springs (*d*), with frame for holding the latter, the needle-board (*e*), and the cylinder (*f*). When the machine is at rest, the needle-board (*e*) supports the heads of the needles, which project about ½ an inch toward the cylinder (*f*). The loops of the needles are passed between two bars of the spring-frame (*d*), and are firmly held by the latter, but with sufficient play for the lateral pressure against the springs (*d*). The pin (*o*) is inserted for holding the springs in their places, a pin being required for each vertical row of needles. The hooks embraced by the loops (eyes) of the needles stand vertically, with the small crook of their upper part directly over the griffe-bars. From a study of the illustration it will be evident that when the heads of the needles are pushed laterally, in the direction of the arrow, the hooks will also be moved; hence such of the hooks as are moved out of contact with the bars of the griffe will remain stationary (*pl.* 44, *fig.* 2). From the foregoing explanation it is apparent that by raising the hooks the leashes are lifted, and the latter raise every warp-thread throughout the fabric, forming the shed for interlacing the filling regulated by the design of the cards.

The raising of the hooks in the weave of any given pattern of fabric is actuated by the cards (*fig.* 10). For the warp-threads to be raised holes are punched in the cards which are presented to the needles by the cylinder. This cylinder performs, in addition to its rotary motion, a movement similar to that of a pendulum toward the points of the needles. Any of the needles for which a hole has been punched in the card will penetrate the cylinder; hence the corresponding hooks will remain in their natural positions, and the rising griffe will carry with it the undisturbed hooks, making a shed of the warp-threads attached to their cords. Needles for which no holes have been punched in the cards will be thrust back by the pressure of the cylinder, which forces the corresponding hook back and away from the griffe-bars above, whereupon in raising the griffe they will remain stationary. The thrusting back of the needles compresses the springs, which will again expand as soon as the cylinder leaves the needle-board.

Jacquard Machines.—In Figure 2 (*pl.* 47) there is given the perspective view of a complete single-lift Jacquard machine, while Figure 4 (*pl.* 45) represents the same machine adjusted to the loom. On the longer arm of the lever is a series of holes which regulate the height of the lift by the vertical rod which provides the required movement. The nearer this rod is adjusted to the Jacquard head, the higher is the lift of the Jacquard harness, thus forming the shed. During recent years various modifications in building Jacquard machines have been introduced. The object has been either to simplify designing and card-stamping or to save card-paper and labor for special fabrics, as in the ingrain-carpet machines, the Brussels-carpet machines, etc. Again, the problem of "speed," and consequently of increased production for a given time, in damasks and similar fabrics, has been satisfactorily solved by the construction of the double-lift double-cylinder Jacquard machine (*pl.* 44, *fig.* 13). Another principle for a modification over the single-lift Jacquard machine is to be found in the double-lift single-cylinder Jacquard machine, which has for its object the saving of the warp by operating each individual thread only when required by the changes from up to down, or *vice versâ*, in the design or weave. The previously described auxiliaries for operating the warp-threads either by harness-shafts or the Jacquard machine can be applied to looms in which all the movements are produced by the hands and feet of the weaver, as well as to power-looms; but in the latter certain mechanisms have to be added, which derive the requisite motions from the revolution of a shaft moved by a belt.

The Double-lift Single-cylinder Jacquard Machine (*pl.* 47, *fig.* 3) is a power-loom with Jacquard machine attached. The principle consists in raising the warp-threads any number of times in succession without allowing the shed to close, thus performing the work in nearly half the time and with less wear and tear on the warp.

The Double-lift Double-cylinder Jacquard Machine (*pl.* 46, *fig.* 1) is another kind of Jacquard machine applied to a power-loom. The principle consists in the combination of two separate Jacquard machines. Two hooks (one of each machine) are connected to one leash of the Jacquard harness, and, as each machine is operated alternately, a high speed is attained, which is the purpose of the machine.

Roller-loom.—In the roller-loom (*pl.* 45, *fig.* 5) the raising and the lowering of the harness are governed by two cams, which can be worked with a two, three, four, or five scroll. The cams, which must be at certain distances apart, lower the harness only at regular intervals. The distance separating the cams can be selected for operating each alternate treadle or every third treadle. As the cams lower only the harness, the strapping on the rollers is so arranged that when one of the harnesses is lowered by the cams the roller to which the strapping is tacked has another strap tacked on the opposite side and connected to the harness or harnesses which are required to be raised; for when the roller turns to let one harness down, the harness or harnesses which are attached to the other side of the roller are raised.

The Positive Double-action Dobbie (*pl.* 46, *fig.* 6), the only practical one extant, is here shown applied to the Knowles loom. Its advantages are that it employs no springs, can be run at high speed, requires no additional alley-space, handles warps more easily than any other harness motion, and is suitable for any weight or width of fabrics.

The Heavy Worsted and Woollen Loom, shown in Figure 1 (*pl.* 47), represents one of the most advanced power-looms of the present time. This loom has twenty-five- or thirty-six-harness capacity, 4×4 box, and single or double beam. The main features of this type of machines are a positive box motion, a system of positive and conditional take-up motions, filling stop motion, and equal driving-gears for crank- and bottom shafts, composing a machine on which can be woven every variety of fabric, from the simplest to the most intricate.

Plush-loom.—Figure 7 (*pl.* 46) illustrates a velvet- and plush-loom. It is built with twelve-, twenty-, or thirty-harness capacity and with single box or double stationary boxes at each end, designed to run two shuttles at each pick, or with two or three pairs of drop boxes at each end, arranged to use two shuttles at each pick and call either pair as required by the pattern. The harness motion and the box motion are the same as on the worsted-loom, previously illustrated and explained. In this loom the goods are cut automatically. The take-up motion is positive and accurate in its operation, and the let-off for pile-warp is operated positively from the head motion and controls the length of the pile on the goods.

The New Power Ingrain-carpet Loom is shown in Figure 4 (*pl.* 47). In this loom the journals are controlled either by a cam motion or by a chain motion; the warp is handled with the greatest ease, and either journal is called at will, thus giving a wide range of pattern and design. Should it be necessary to change the shading, it can be done by changing the chain instead of cutting out the warp and redrawing it. The box mechanism in this loom is positive and is controlled by a chain on the same shaft as the journals, and may be used with the chain alone or with the chain in combination with the cards. The motion can be run forward or reversed at will and any box called as desired, thus giving a wide range to the shading facilities of the loom. The take-up motion of this loom is positive, consisting of fluted rolls, and operated by the usual train of gearing, while the goods are wound up on a roll below. The let-off is controlled by the tension of the warp over a rocking whip-roll operated by a cam on the bottom shaft, held by a clamp friction geared to the head of the beam. Two filling motions are used, one on each end of the lay, each working independently of the other, inside the selvedge, so that the breakage of the filling is instantly detected; and these motions are so combined with friction-pulley and brake that the loom is stopped instantly on the pick, and consequently, when filling is replaced, the loom is ready to start without loss of time in finding the pick or setting of Jacquard or box motion. The shuttle-smash protector, which knocks off the loom when the shuttle does not box properly, thus preventing what are known as "shuttle-smashes," a shuttle-check for easing the force of the shuttle as it enters the box, a foot-lever for throwing the lay back when the loom is stopped, making it very easy for the weaver, and the speed at which the loom can be run, together with the features mentioned previously, combine to make this loom a very efficient machine.

Terry-fabrics.—In the manufacture of terry-fabrics in which the pile-threads are raised without the aid of wires, such as Turkish towelling and certain kinds of scarfs used for ornamentation on chairs, bureaus, etc., two warp-beams are required, one to carry the "pile-warp" for forming the loop, and the other to carry the "body-warp" for forming the ground of the fabric. In the process of weaving a terry-fabric the upper or "terry" series of warp-threads is weighted lighter than the lower or "body" series, for the purpose of allowing the loops to be formed on the surface by the lay swinging or being driven fully up to the body of the manufactured cloth after two or more picks of the filling have been shot from the shuttle and only partially beaten up, the picks having in the mean time so tightened upon the upper or terry-warps that the latter are forced with them fully up, thereby forming the pile-loops or terry. As during the entire process of weaving the ground-warp remains tight, the two or more picks will slide upon it in the beating-up. Figures 4 and 5 (*pl.* 46) more clearly illustrate the method of operation. In Figure 5 the picks O represent the edge of the cloth. At the first stroke of the lay the first pick (*1*) is not driven home; at the second stroke the second pick

(*2*) is driven against the first pick (*1*), but no further; but the third pick (*3*) is driven home towards *o* and carries picks *1* and *2* along, pressing them up against the finished edge of the cloth (*o*). The pile or "terry"-warp will thus form the loops *s* as shown in Figure 4 (*pl.* 46). Figures 2 and 3 illustrate a loom and its method of operation in the present style of terry-weaving. In Figure 2 the loom is shown in the position it occupies when partially beating up the filling, and Figure 3 shows the lay forced fully up.

5. FINISHING-MACHINES.

To increase the beauty of their appearance all woven fabrics are subjected to certain operations collectively known as "finishing." Cotton goods, however, require very little finishing to be made ready for the market. Damasks, ginghams, shirtings, etc., after leaving the loom, are only starched, calendered, measured, and rolled. With many woollen fabrics finishing is the main process in their manufacture. Kerseys, beavers, broadcloths, doeskins, tricots, and similar fabrics (technically known as "face-finished" goods), are subjected to many different processes, such as washing, fulling, gigging, drying, dyeing, brushing, steaming, measuring, and folding, before they are ready for market.

Wet-finishing Process: Fulling-mills.—The fulling-mill serves for peculiar manipulation of cloth (woollens) by means of which the run of the threads is concealed and the thickness considerably increased, though at the expense of length and width, thus imparting to the fabric in a high degree the property of retaining warmth. The manipulation consists in a thorough kneading in soap-water, and is based on the property of sheep's-wool, when softened and warmed, to contract spirally and then to "felt" by the effect of the kneading manipulation. The German machine shown in Figure 5 (*pl.* 48) consists of a trough with smooth sides lined with wood, the bottom being semicircular. In this trough a block—the so-called "beater" or fulling-stock—oscillates to and fro like a pendulum, receiving its motion from the horizontal driving-shaft by means of short slide-rods. The fabrics to be fulled, being thoroughly moistened and irregularly folded together, are placed in the trough on both sides of the beater, and receive the above-indicated manipulation by receding before the beater and after mounting on the inner side of the trough falling again in front of the beater, thus executing a slow circulation. Only fabrics of sheep's wool can be fulled, but similar machines may be used for washing linen and cotton goods. Figure 2 (*pl.* 49) illustrates a cloth-washing machine, and Figure 1 a fulling-mill. Both are of the latest American make.

Gig.—Cloth is "gigged" for the purpose of raising the nap evenly over the fabric, or, in other words, to produce a velvet-like face and back. The nap is raised either by means of the teasel (*pl.* 48, *fig.* 1, the dried flower-head of a plant, *Dipsacus fullonum*, specially cultivated for this purpose), or by means of fine steel wires. The teasels are set side by side in rows one, two, or three high, according to their size, in wooden or iron frames, technically known as "slats," which, after being filled with the teasels, are fastened to the periphery of the main cylinder of the gig. The position of the slats can be reversed so that two portions of the teasels may be utilized. Figure 3 (*pl.* 49) illustrates an "up-and-down" gig, by which the direction of the running of the cloth can be changed, and which is so arranged that there can be one or two applications of the cloth to the cylinder. In operating the machine the cloth winds on small rolls, which lie against the cloth-beams, and can therefore be handled on the rolls. The operator can reverse the nap by allowing the cloth to run entirely on the lower roll, and then by taking it from the lower cloth-beam and putting it against the upper cloth-beam.

The Wire Napping-machine (*pl.* 50, *fig.* 2) consists of a skeleton cylinder on whose circumference revolve fourteen card-rolls in their respective bearings, while suitable frames and guide-rolls are provided to carry forward the cloth. As the cylinder revolves in the direction in which the cloth travels, each one of the card-rolls comes in contact with the cloth at five different points. If, however, these rollers were not subjected to some action other than the mere revolution of the cylinder, there would be no napping, for as the cloth presses upon the cards and the cylinder carries them forward the friction of the cloth causes the rolls to revolve on their own axes in a direction opposite to the motion of the cylinder; consequently, as the points of the cards are bent in the direction in which the cylinder revolves, they have no action upon the cloth. But by an arrangement of cones, pulleys, and belts this reverse action is controlled at the will of the operator, and may be varied almost indefinitely.

Cloth-drying Machine.—As during the process of gigging the cloth is kept wet, it must be dried after the nap is sufficiently raised. For this purpose there is employed a machine known as the "cloth-dryer" (*pl.* 49, *fig.* 4), which when in operation is closed up with the exception of a sufficient opening for the entrance and the exit of the cloth. The cloth is drawn into and guided through the machine by two endless chains, one on each side, as seen in the illustration. In these chains are inserted medium-sized steel pins, which catch into the selvage of the cloth and hold it taut, during its travel in the machine, between pipes heated by steam. The cloth, which is run in at the upper front of the machine and leaves at the bottom of the rear, will, by its own weight and on account of its dry condition, liberate itself from the pins when leaving the dryer.

Hydro-extractor.—For the removal of the greater portion of adhering water the cloth, if very wet when leaving the gig, is first put into a hydro-extractor, which consists of a cylindrical kettle of sheet copper fastened to a vertical spindle. The sides of the kettle are perforated with numerous small holes. The motion is imparted by two horizontal driving-shafts, revolving in opposite directions, which by means of friction-wheels cause the spindle to rotate at great speed. The frame in which the driving-shafts rest is screwed to a trough enclosing the kettle. By placing the wet fabrics in the kettle and revolving the latter at great speed the centrifugal force produces the well-known effect of pressing the fabrics against the sides of the kettle and forcing through the holes in the sides the adhering water, with the exception of a fractional portion, which has to be removed by evaporation. The water collecting in the trough enclosing the kettle runs off constantly through an aperture on one side. Figures 6 and 7 (*pl.* 38) illustrate two styles of hydro-extractors. Figure 6 shows an improved centrifugal hydro-extractor. This machine is extensively used by silk-dyers. The extractor has a vertical engine attached to the side, which operates the vertical spindle fastened to the cylindrical kettle by means of cone-pulley friction. Figure 7 is another form of machine, operated by means of a direct-acting steam-engine, which is clearly visible in the illustration. This machine is in general use with cotton- and woollen-manufacturers, and is capable of the heaviest work.

Dry-finishing Process: Brushing-machine.—The cloth, after leaving the drying-machine, is run through the brushing-machine, though special fabrics—such as chinchillas, whitneys, montagnacs, etc.—which require no brushing or whose face would be injured thereby are not brushed. Figure 5 (*pl.* 50) illustrates a brushing-machine and its mode of operating.

The Shearing-machine, commonly called the "shear" (*pl.* 48, *fig.* 2), receives the cloth after it has left the brushing-machine and gradually evens the nap raised by the gig. The cutting is done by quick-revolving sharp steel knives, called "blades," which make about one thousand revolutions per minute.

Pressing- and Measuring-machines.—After the fabric is finished on the shear it is again brushed and forwarded to the pressing-machine. Figure 1 (*pl.* 50) is a single-bed press; Figures 3 and 4 (*pl.* 48) show a double-bed press; Figure 3 shows the press with pressure applied, and Figure 4 shows it with pressure removed. After the cloth is pressed it is measured and then rolled, when it is ready for market. Figure 3 (*pl.* 50) illustrates a cloth-measuring machine, and Figure 4 represents a combined cloth-measuring and winding machine.

6. TWISTING-FRAMES AND BRAIDING-MACHINES.

Plate 51 exhibits typical machines for combining two or more separate filaments into strong thread-like products (thread, cords, ropes, cables, etc.). Such a combination can be effected either by twisting, by plaiting, or by braiding.

Ropemaker's Wheel.—The simplest contrivance—capable also of being used for spinning—is the ropemaker's wheel, a typical arrangement of which is shown in Figure 1. It contains a number of spindles, whose outer or free-lying ends are bent in the form of hooks and receive a rapidly revolving motion by suitable mechanism. In the arrangement shown on the Plate the motion is provided by means of a pulley actuated by a cord. By drawing this cord the workman, who walks backward in spinning and twisting, sets the pulley in motion, while with the earlier wheels a separate workman was required for turning. In spinning with this apparatus the workman draws a few fibres from a bundle of raw material—for example, tow—and after twisting them to a thread fastens the latter to one of the hooks on the wheel. He then moves slowly backward from 16 to 20 inches per second, the motion thus imparted to the wheel drawing from the bundle of material new fibres, which are suitably twisted by the rotation of the hook. If, now, two or more strands thus obtained are to be combined into a stronger thread (twine, cord, etc.), their ends are secured to another hook, revolving in an opposite direction, and twisted together, the other ends being generally suspended to a hook resting on a movable frame. Experience has shown that by choosing for the combination of the separate strands a revolving motion opposite to that applied in their formation a more intimate intertwining is effected.

Ropemaking-machine.—For working on a large scale the wheel is replaced by the ropemaking-machine, one type of which is shown in Figure 2 (*pl.* 51). By the machine represented in the Figure three cords, consisting of three separate threads each, are simultaneously twisted together, and are then further combined by twisting into one cord. All the movable parts of the machine producing this result are grouped around a horizontal spindle, to which a revolving motion is transmitted through the driving-pulley on the left of the machine. This spindle carries three frames, set at equal distances apart, in which are placed smaller frames, each provided with three yarn-bobbins, so that they can be turned. Inside each of the smaller frames the three threads coming from the bobbins are combined into one thread through an eye in the revolving axis, and at the same time are helically twisted together. The latter result is produced by the smaller frames, which may be considered as a reservoir for the thread material. These frames while revolving around the principal spindle have an independent motion around their own axis, imparted through a spur-wheel placed concentrically to the principal shaft, but fastened to the frame, on which three smaller intermediate wheels drive the above-mentioned frames. The three cords thus formed are finally combined in a common central discharge aperture on the end of the principal shaft, and the thicker cord here formed is slowly drawn off by passing between three revolving rollers, the two upper of which are pressed against the lower one. All large rope-machines must be provided with a winding-apparatus.

Thread-twisting Frames.—In many cases a simple doubling is sufficient for the production of a twisted fabric, such as sewing-thread, knitting-yarn, warp- or filling-threads for weaving, etc., for which the simple duplication of the apparatus may be advantageously applied. The upper portion of the twisting-machine is a frame of laths, on which the bobbins, filled with single threads, are placed. The threads coming from three, four, or five bobbins are guided to one eye and then pass between a pair of rollers, which receive a uniform motion from the driving-shaft and deliver the doubled threads at a corresponding rate. The threads are twisted by a revolving flyer, the arrangement of which has been already explained in describing the water-frame (p. 143), and are finally wound in regular convolutions on bobbins.

Bobbin-frames (*pl.* 51, *figs.* 4, 5) are closely allied to thread-frames. The combination of several threads, however, being, as a rule, omitted, only the winding process remains, the object of these machines being to wind on bobbins the customary commercial skeins or hanks of yarn intended for weaving purposes. Of these bobbins there are two kinds—movable bobbins (pirns), which render the unwinding possible in a direction vertical to the axis, requiring, therefore, the rotation of the bobbins; and fixed bobbins (cops), which are stationary during unwinding, the drawing off of the thread being effected in the direction of the axis. The former are used for the preparation of the warp and the latter for the preparation of the filling. With the pirns the separate spiral convolutions form cylindrical layers on a wooden spool, while with the cops the separate convolutions form conical layers, which are superimposed on the conical end of the bobbin.

This explains why a different arrangement is required for the warp spooling-machine (*fig.* 4) and the filling spooling-machine (*fig.* 5). In the former the threads pass from the reel over a rail moving slowly up and down to the quickly revolving bobbins set on vertical spindles; in the latter the threads pass through a vertical slit of a stationary hollow cone, in which is set the revolving bobbin, so as to touch the cone with its conical end and ascend as the winding progresses. The bobbin must, therefore, be so connected with its spindle that it is forced to participate in its revolving motion, while at the same time it is capable of moving upward.

Ball-winding Machine.—The finer products (sewing-thread, twine, knitting-yarn, etc.) being frequently demanded made up in regular balls, a ball-winding machine (*fig.* 3) is included. The cord to be made into a ball is passed through the hollow axis of a fork-like revolving fly and through an eye on one arm of the fly to a spindle, which simultaneously executes two motions—a slow rotation around its horizontal axis and a still slower oscillation around a vertical axis, the latter motion causing the helical convolutions produced to change their angle of incidence, whereby the necessary firmness of the whole is effected. The ball-winding machine shown in the Figure is worked by hand, three balls being made at the same time.

The Braiding- or Plaiting-machines effect an intertwining of the separate threads similar to braiding by hand. The threads are separated into two groups, those of the one group running like a right-hand spiral and those of the other like a left-hand one. Each thread of the one group passes alternately over and under a thread of the second group; so that here, upon a cylindrical surface, a similar intertwining of the threads takes place as between warp and filling in weaving. The resulting fabric forms a flexible tube, which, by means of a suitable number of threads loosely placed together, can be filled with a core. It is also possible to braid over solid bodies, or cores; as, for example, whip-handles, buttons, etc. The threads to be intertwined are wound on bobbins so set that they can be turned on special tubular bobbins, which by means of stelliform revolving drivers are pushed forward on two undulatory endless tracks, alternately crossing each other and returning. That all the threads may enter the braiding with the same constant tension, they are passed, as shown in Figure 6 (*pl.* 51), through the eye of a weight placed in the hollow part of the bobbin, the uniform closeness of the braiding being furthermore secured by the uniform drawing away of the braided cord by means of two revolving rollers, around which it passes, and is finally wound in regular convolutions on a bobbin.

7. KNITTING-FRAMES.

The Stocking-frame, an outcome of the method of knitting by hand, was invented in 1589 by the Rev. William Lee, a native of Woodborough, near Nottingham, England, and a graduate of Cambridge. It uses, as in hand-knitting, only one thread to produce a flexible fabric with an extended superficial area. The thread is curved in definite layers, called "meshes," which resemble two letters S standing symmetrically to each other, and which complete the fabric by intertwining (*pl.* 52, *fig.* 1). The thread, therefore, is not drawn in a straight line, but is disposed in curves in serial order throughout the fabric. On account of the elasticity of the thread its form readily re-establishes itself when drawn out of shape, and thus the fabric, being elastic, is better adapted for close-fitting garments than are other tissues.

The Needles.—For the production of the meshes, needles (*fig.* 2) with long hooks and thin pieces of tin, called "sinkers," provided with several notches, are required, the number of both corresponding to the number of meshes in the width of the fabric. While in hand-knitting each new mesh is separately formed by drawing the thread, in the form of a loop, through the one previously formed, in working the stocking-frame an entire row of meshes is produced at one time after the following preparatory manipulations (*fig.* 2): The knitted part of the fabric is drawn back upon the needles by the arches in the sinkers, and the thread, being laid lengthwise over the needles and beneath the ribs of the sinkers, is pressed, in the form of loops, between the needles by depressing each sinker. These loops are pushed in front under the hooks of the needles, while the previously formed meshes remain behind them. The barbs of the hooks are forced downward into the grooves in the stems of the needles by means of a bar, called the "pressure-bar;" so that finally the old meshes can be pushed upon the hooks and from the needles. They remain then suspended in the new loops, thus forming new meshes.

Couler-knitting.—This formation of meshes with but one thread is termed "couler"-knitting (from the French *couler*—that is, pushing the sinkers between the needles). By another method of knitting, invented in 1769, not one thread only, but a number of parallel threads—a so-called "chain" or warp—is used, the threads being united by forming meshes. This mode of working is termed "chain"- or "warp"-knitting. The machines for couler-knitting are the hand- or stocking-frame, the flat and the round power-frames. A so-called "French round frame," which contains the needles lying horizontally and radially upon an annular ring, is shown in Figure 5 (*pl.* 52). The leads are in separate boxes, the so-called "mailleuses" or mesh-frames. The illustration shows the best examples of these mailleuses (*mailleuses obliques*).

Lamb's Knitting-machine.—For about thirty years another method of forming meshes has been known, in which are used self-acting needles (*fig.* 3), the short hooks of which can be closed by placing upon them a movable arm (tongue); so that the pressure-bar is omitted The meshes are formed in the manner of crocheting by the needles passing separately through the old meshes and catching the thread with the hook, drawing it, in the form of loops, to new meshes through the meshes last made. This is the principle employed in Lamb's knitting-machine (*fig.* 8), an American apparatus invented in 1866, which is now in general use. The self-acting needles lie in two straight parallel rows, widening and narrowing being accomplished by increasing or diminishing the number of needles in action. Their lower ends, bent to a hook, are caught by the grooves formed by three plates (*fig.* 6) and are raised and lowered, whereby the meshes are separately formed one next to another. With small jointed levers (*fig.* 6) the position of the groove-plates can be changed so that the needles are more or less depressed and work loose or close. The name "knitting-machine" has been applied to this device because it is possible to produce with it fabrics, especially stockings, in nearly the same manner as by hand-knitting—that is, regular, round, and without seam. This term, however, has been also applied to other machines, working flat, like the hand-frame, provided they can be readily handled and produce stockings of a regular shape—that is, without cutting. Figure 7 is the guide and tension.

Hinkley's Knitting-machine (*fig.* 9) can produce only flat fabrics, like the hand-frame. It is really not a knitting-machine, but a single-thread, chain-stitch sewing-machine, which by means of a sewing-needle draws the thread, in the form of a loop, through the mesh last made, this loop being held by a catch and finally suspended as a new mesh upon a comb. The comb, which corresponds to the row of needles of the hand-frame, contains the new meshes separately alongside one another while going with its teeth past the sewing-needle. Machines for knitting are either hand-machines or power-machines. The first kind have their needles placed either in a straight row or in a circle (*fig.* 4), or only one needle is used (*fig.* 9). Power-machines are built either for producing a plain flat strip of fabric or for circular ribbed stuff. A machine for producing the latter fabric is shown in Figure 10. Figure 4 exhibits an American stocking-machine with belt and pulleys for operating it by power, but which, minus the power attachment, is usually worked by hand. (E. A. P.)

8. Sewing-Machines.

The idea of mechanical sewing was originally conceived in England, though the first practical sewing-machine was undoubtedly produced in America.

Saint's Sewing-machine.—In 1790, Thomas Saint, an English cabinet-maker, was granted a patent for "an entire new method of making and completing shoes, boots, spatter-dashes, etc.," and, though he may have constructed only an experimental machine, it yet embraced many of the germs of the perfected sewing-machine of the present day. It possessed (1) a horizontal supporting surface for the cloth, to resist the thrust of the needle; (2) an overhanging arm, to whose outer end was attached (3) a vertically reciprocating straight needle fed by a continuous thread from a spool placed at the top of the arm; and (4) a mechanism by which the material was moved automatically after each stitch. The inventor conceived the idea of sewing a seam without passing the entire needle through the material, but by pushing through it a loop, to be so held open by a hook as to receive the loop of the succeeding stitch. This interlooping or enchaining of stitches resulted in the production of what is known as the "chain-" or "single-thread" stitch (p. 172). The needle employed by Saint was so forked at its lower end as to span the thread and push it through a hole previously made by an awl in the material; the tension of the thread was adjusted by tighteners above and below. To Saint, therefore, must be accorded the honor of devising a connected piece of machinery, however crude it may have been, which was the prototype of the modern sewing-machine. An English patent in 1807 is also the first to show an automatically operating contrivance with an eye-pointed needle to carry a thread through the material to be connected.

Thimonnier's Sewing-machine.—In 1830, Barthélemy Thimonnier, a humble French tailor, patented a sewing-machine which was so far successful that in 1831 he was made a partner of the firm of Germain Petit & Co., and set up on Sèvres street, in Paris, a workshop where eighty machines, rudely constructed of wood, were in use for making army-clothing. At this time workingmen were hostile to every kind of new machinery, and these sewing-machines were destroyed by a mob, as the Jacquard loom and Hargreaves's spinning-jenny had been years before. Thimonnier escaped with his life and again set to work to improve his machine, and was so far successful, notwithstanding the privations under which he labored, that in 1845 his apparatus was run at the rate of two hundred stitches per minute, whereas the machine of 1830 was unable to make more than one stitch at each movement of the treadle. In 1848 he applied for an improvement patent for his machine, which he called "consobrodeur," but, the French revolution of that year having stopped his business, he went to England, where, after staying a few months, he sold his patent to a Manchester firm and returned to France. Exhausted by thirty years' struggling and suffering, he died penniless at Amplepuis in 1856.

Thimonnier's machine (*pl.* 53, *fig.* 1) comprised a horizontal bed for the support of the material; an overhanging arm, which was constructed as a sliding frame, and which was alternately depressed and returned by a treadle and spring; and a vertical needle with a hooked or barbed point. The hooked needle penetrated the cloth and caught a lower thread, by means of a thread-carrier and looper, from an ordinary spool, and in rising drew a loop of thread with it to the surface of the material and within a nipple sleeved upon the stem of the needle, the nipple resting upon the goods during the descent of the needle and rising when the latter cleared the goods. After the loop was drawn up, the cloth was moved by hand the length of a stitch, and the needle was again thrust downward through the material; in its next ascent it brought up a loop through the one previously formed, thus producing upon the surface of the stuff the chain of the stitch, unlike the Saint machine, whose chain was on the under side of the cloth. Thimonnier's machine was patented in the United States in 1850.

In 1843 there was patented in the United States by B. W. Bean a form of sewing apparatus which is now known as the "running-stitch" machine. The needle, pointed at one end and with an eye at the other end carrying a short length of thread, was held stationary between toothed rollers, and the material, in convolutions, was fed upon the point, along the body, and off the heel of the needle upon the thread, the operator pushing the fabric back upon the thread as in hand basting. There have been patented in the United States and in England a number of varieties of this machine, which are used principally for sewing together the ends of materials to be bleached, dyed, or printed (see p. 172).

Hunt's Sewing-machine.—In 1833, Walter Hunt of New York invented a sewing-machine with a curved eye-pointed needle operated by a vibrating arm and penetrating the cloth, and with a shuttle that passed through the loop made by the needle-thread, and by drawing it up on one side of the cloth making what is known as the "lock-stitch." The material was suspended vertically between clamps moved automatically after each stitch; but the machine could sew a seam only the length of the clamps without being stopped. Moreover, the seam had, substantially, to be parallel with the actuating mechanism of the clamps. Hunt laid aside his machine, which was destroyed, and was forgotten until 1854, when he applied for a patent, which was refused him on the plea of abandonment. The main features of Hunt's invention had, however, been patented in 1846 by Elias Howe, thus anticipating by eight years the application of Hunt, who by inattention to the value of his apparatus lost one of the greatest opportunities of the nineteenth century.

Howe's Sewing-machine.—The ingenious contrivances above described illustrate substantially the progress of the art of machine-sewing up to the date (1846) of the invention of the machine by Elias Howe, whose name is indissolubly associated with the history of the sewing-machine. From the foregoing it will be seen that the invention was a development, and not an inspiration. Sporadic attempts were made to solve the problem of mechanical sewing and to embody it in a successfully-operating machine. The greatest advance was the lock-stitch of Hunt, but, as above stated, it remained for Howe to be declared the inventor.

As originally made, Howe's machine (*pl.* 53, *fig.* 4) consisted essentially of a curved and grooved eye-pointed needle carried at the extremity of a vibrating arm, a shuttle with its point at one side of its axis and carrying a bobbin or cop, and a so-called "baster-plate," composed of sharp-pointed wires projecting laterally, comb-like, from a thin curved metallic plate, which was actuated intermittingly by a toothed wheel engaging with holes in the plate. It employed two threads, one of which was projected through the material, while the other was carried by the shuttle. The grooving of the needle was devised so as to receive and protect the thread from being broken by the rapid movement of the needle through the fabric. The point of the needle being driven about three-fourths of an inch through the material, the needle-thread, extending from the last stitch to the eye of the needle, formed the chord of the arc of the needle, and through the space thus formed the shuttle was projected by reciprocating drivers, so that when the needle was withdrawn the two threads were left interlocked at the point where the needle perforated the cloth. Before the needle penetrated the goods, a sufficient length of thread was drawn from the spool to afford the requisite slack to the needle and needle-thread for the passage of the shuttle between them. This slack thread was held up by a lifting-pin, which prevented the entanglement of the thread under the needle-point. The tension of both the needle- and the shuttle-thread was so adjusted as to cause the stitch to have the same appearance on both sides of the fabric, the interlocking point of the threads being drawn within the material. The edges to be united were vertically impaled on the wires of the baster-plate, which after each stitch was moved by the above-described mechanism. The length of the seam that could be sewed without stopping the machine was the same as that of the baster-plate; and when the latter had passed its full extent under the needle, it was necessary to stop the machine, remove the cloth, return the plate to the first position, and readjust the cloth. The latter was retained on the wires by means of an adjustable plate, and the outer side of the shuttle-race presented a bearing surface for the cloth, to resist the horizontal thrust of the needle.

Howe's early career was a struggle with misfortune, but his indomitable energy finally brought him financial success. Soon after he received his patent one of his machines was sold to William Thomas, a London corset-maker, who made Howe a proposition to come to London and adapt the machine to the manufacture of stays. The offer was accepted, and in 1847 he sailed for England, where, after remaining but a short time in the employ of Thomas, he was reduced to such extremes of poverty that he pawned his American patent-right to obtain means for returning to New York, where he arrived in 1849. During his absence in England sewing-machines had come into use in the United States. Against the infringers of his patent Howe instituted suits, which were sustained, and henceforth he gathered a golden harvest. He admitted at the time of his application for a second extension of his patent (1867) that he had received $1,185,000 from his invention.

The feasibility of mechanical sewing being demonstrated by the Howe machine, there followed in rapid succession other inventions of considerable ingenuity and excellence.

Batchelder's Machine.—In 1849, John Batchelder produced a machine which was the first to combine a horizontal support for the cloth, an eye-pointed needle, and a continuous feed. The supporting surface for the material consisted of an endless belt with projecting pins, carried on rollers, which moved intermittingly and put in motion the fabric after each stitch. A seam of any desired length could be sewed, but the pins of the feed-belt prevented the moving of the cloth in any direction except with the feed.

Blodgett-Lerow Machine.—Following the Batchelder machine a patent was granted the same year to S. C. Blodgett and J. H. Lerow for a rotary shuttle, or one which drove the shuttle in a circular race with each stitch. The needle descended through the material and then rose slightly, to form a loop of the needle-thread; the shuttle entered the loop and the needle again descended a little, while the shuttle passed through the loop, whereupon the needle ascended above the cloth. This movement is known as the "dip" motion.

Wheeler & Wilson Machine.—One of the most ingenious inventions of this period, and the next in historical importance, was that devised by Allan B. Wilson. His first machine employed a straight eye-pointed needle and a shuttle reciprocating in a curved race, but in subsequent patents (1851–52) he dispensed with the shuttle and substituted for it the disc-bobbin and the rotary hook, which catches the loop of the needle-thread, expands it, and passes it around the bobbin, within which is wound the lower thread, leaving the latter in the loop of the needle-thread. The rotating hook was a new departure from all former methods of sewing, and it effected by rotary motions what had previously been performed by reciprocating motions, while at the same time the speed and the efficiency of the sewing-mechanism were increased. The most important feature of the invention, however, was the "four-motion" feed. This feed-mechanism is so constructed that in rising and falling the material is intermittingly caught, fed forward, and released, and, moreover, allows the cloth to be turned, twisted, or moved by the operator in any desired direction between any two successive stitches. This feeding device is used in nearly every machine now constructed. Figure 14 (*pl.* 54) exhibits an early type of the Wheeler & Wilson machine, and Figure 15 one which embodies the latest devices.

Singer's Machine.—In 1850, Isaac M. Singer of Boston saw in operation a Blodgett machine whose construction he concluded could be improved. His idea was to make a machine which would embody a horizontal cloth-plate, a yielding presser-foot, to bear upon the cloth, a vertically reciprocating straight needle, and, placed below the cloth-plate on a horizontal axis, a feed-wheel with projecting pins, to engage the cloth and move it forward with each stitch. He constructed a model machine in eleven days, but it would not sew and was pronounced a failure. It was remarked, however, by one of the promoters of the enterprise that the loops of the thread were upon the upper surface of the cloth, when it instantly occurred to Singer that the adjustment of the tension of the needle-thread had been forgotten. After the tension had been adjusted five perfect stitches were made, when the thread snapped. But that was sufficient: it betokened the ultimate success of his invention; and this original (*pl.* 53, *fig.* 5), which was subsequently much improved, was practically the first machine used as a substitute for human fingers in sewing.

Singer's inventions contributed to the sewing-machine the following original devices: (1) A rotating shaft in an overhanging arm, a crank-pin or roller, and a heart-shaped cam, to give positive action to the needle-bar; (2) a pressure-foot at the end of a vertical rod, to hold the material down upon the feeding device, and so adapted by means of a spring as to yield to the thickness of the fabric; (3) a rotating feeding-wheel, which projected through and above the horizontal cloth-plate; (4) a friction pad, to prevent the kinking or twisting of the thread under the point of the descending needle; (5) a spring guide upon the shuttle, to control the slack of the shuttle-thread and keep it from being caught by the needle; and (6) he gave to the shuttle an additional forward movement after it had momentarily stopped, to draw the stitch tight, this being effected while the feed moved the cloth in the reverse direction and the needle completed its upward motion, so that the two threads were simultaneously drawn. Singer was also the first to construct a device to lay an embroidering thread upon the surface of the cloth, under the needle-thread, and the first to invent a machine for ruffling. Attachments for braiding, embroidering, etc., are now adapted to every popular machine (p. 173). Figure 13 (*pl.* 54) represents an improved machine with oscillating shuttle.

The Grover & Baker Machine was invented in 1851 by William O. Grover and William E. Baker, and was patented in 1852. It employed two reciprocating needles. The upper or vertical one was a straight eye-pointed needle, which passed through the material and made a loop, through which the lower curved and eye-pointed needle passed horizontally, forming a second loop, the needles so operating as to interlock the two loops, thus making the double-looped stitch, which, though elastic and strong, was objectionable on account of the ridge left on the interlacing side of the cloth. Later the machine was somewhat modified: the vertical needle was curved and was carried by a vibrating arm, and the looper or lower needle was made to operate by the special mechanism now common in the machine.

Willcox & Gibbs Machine.—In 1856, James E. A. Gibbs, a Virginia farmer, devised an improved chain-stitch machine which, under the subsequent patents of C. H. Willcox and others, is popularly known as the Willcox & Gibbs sewing-machine (*pl.* 53, *fig.* 6). It employs the eye-pointed needle and an ingenious rotating hook, which revolves beneath the cloth-plate. The needle is carried by a reciprocating bar actuated by a vibrating lever connected by a link with an eccentric on the main shaft. As it rotates, the hook, which is at the forward end of the main shaft, catches the loop of the needle-thread, expands it, and holds it expanded while the feed moves the cloth. When the needle descends through the first loop, the point of the hook is again in position to catch the second loop, at which time the first loop is cast off and the second is drawn through it, the first loop being drawn up against the under surface of the cloth, thus forming a chain-stitch. Subsidiary devices are attached for regulating the thread-delivery, the feed, the tension, etc.

Sewing- and Buttonhole-machine.—Figure 16 (*pl.* 54) represents a sewing-machine with which is combined the important feature of a buttonhole-machine without the use of attachments or complicated mechanism. The combination is so effected that neither branch of work interferes with the other. It is adapted to use one or two needles and will make at one operation two seams, either straight or zigzag (*fig.* 8), the latter seam being produced by the same device that is employed in making the buttonhole stitch (*fig.* 8).

Needles.—Sewing-machines employ either straight or curved eye-pointed needles. The straight needle, which is fixed in a vertical bar and reciprocates in a straight path (*fig.* 1), is the least likely to bend or spring when in operation, in which respect it has the advantage over the curved needle, and must ultimately take the place of the latter. The curved needle oscillates on an axis, and it must be so set that its curve shall exactly coincide with the arc in which it moves, otherwise it will draw the material, and in crossing seams be liable to spring and to break.

Shuttle and Rotary Hook.—Externally the ordinary sewing-machine shuttle is shaped, approximately, like the half of a cigar cut lengthwise, with a cavity in its flat side for the bobbin containing the lower thread (*pl.* 53, *fig.* 16). Of this form of shuttle there are various modifications. The shuttle rests in a guide-way or track, called a "shuttle-race," into which the needle descends, so that the point of the shuttle may enter the loop of the needle-thread. At first the race-way lay parallel with the line of the seam, but in the Blodgett-Lerow patent the race-way was circular, and in later forms it is at right angles to the feed, by which the transverse reciprocation of the shuttle greatly improves the evenness of the seam. Various contrivances have been devised for driving the shuttle in the race, but the preferred form of mechanism is the shuttle-cradle or carrier, which is shaped to receive the shuttle within it and to move with and pass the shuttle through the loop of the needle-thread. An improved device for passing the lower thread through the needle-thread loop is a rotating hook which is so bevelled and notched as to seize the loop, expand it, and pass it around a stationary discoidal bobbin containing the under thread (*pl.* 53, *figs.* 13, 14). Intermediate between the shuttle and the rotary hook is the Singer oscillating shuttle (*fig.* 15). The latter is hook-shaped, similar to the preceding, and carries within it a circular bobbin. The shuttle is driven by an oscillating driver in an annular raceway, but, instead of revolving completely, it is moved in an arc of only 150°, or so far as serves to catch and clear the upper thread.

Feed.—For moving the material intermittingly past the needle there have been employed various devices, most of which, in describing the development of the sewing-machine, have been noticed in the preceding pages. In popular makes of machines the feeding mechanism is for the most part of the "four-motion" class, in which a notched bar rises against the cloth, moves it forward horizontally the length of a stitch, falls, and returns to its original position. The direction of feed may be either in a line parallel with the eye of the needle or at right angles to it. In the latter method the thread, after passing through the eye of the needle, is turned about the needle, which produces more friction upon the thread than the first plan.

Stitches.—The perfection of mechanical sewing necessarily depends on the stitches produced in the seam of the fabrics to be connected. The different inventions patented in the United States are capable of forming upward of sixty-five distinct stitches, employing from one to three threads. These, however, may be reduced to three varieties—namely, the simple chain- or crochet-stitch, the double chain-stitch, and the lock-stitch. The last-named is the most popular of these stitches and requires the smallest amount of thread.

Single-thread Stitches.—The earliest attempts to produce a seam mechanically were in imitation of hand-sewing. In 1755, Charles F. Weisenthal devised a double-pointed needle with a central eye (*pl.* 53, *fig.* 2) for the production of the ordinary basting-stitch made by hand. In this contrivance the needle was pushed through the material, then guided through the stuff in another place in the opposite direction, being alternately caught by two nippers, one on each side of the piece to be united. This mode of operating is now utilized in Heilmann's embroidery-machine, which will be considered farther on. By another method the needle penetrated several convolutions of the undulated material (*fig.* 3). For producing the latter form of basting seam Figures 7 and 8 exhibit two machines which are much used in finishing- and print-works for stitching together the ends of separate pieces of goods. Two cog-wheels gearing into each other catch and gather the fabric into many regular folds, which are pushed upon a long threaded needle. The needle is fastened to the frame and can be brought close to the gear-wheels by means of a groove in their peripheries. By detaching the needle from the frame and drawing it completely through the folds the thread is drawn after it, and the united ends of the stuff are then straightened.

Attachments.—Sewing-machines are provided with auxiliary devices called "attachments," which are designed for special work, such as hemming, tucking, cording, quilting, braiding, ruffling, etc., and by which the capacity of the machine is very much enlarged and its value greatly enhanced. Figure 9 (*pl.* 54) exhibits an attachment for gathering or forming ruffles in goods. Several varieties of work may be done with the ruffler, such as making scalloped edging, puffing, and shirring. Figure 10 is a quilter, the spaces between the seams being regulated by the guide, which is adjustable to any width within the limit of the apparatus. Figure 11 exhibits an adjustable plaiter or tucker, and Figure 12 a binder which shows the binding strip being lapped on the edge and stitched to the cloth. This attachment may be used for putting braid on the bottoms of dresses and for a variety of trimming devices.

Manufacturing Machines.—In sewing-machines modifications are frequently necessary in the external disposition of the parts when the articles to be sewed are to have a tubular or sack-like shape, such as sleeves of clothing, shoes, etc., the sewing-plate being in such cases replaced by a projecting hollow metal cylinder (*pl.* 55, *figs.* 1, 3) or a truncated pyramid (*figs.* 2, 4) for the support of the work. The machine exhibited in Figure 1 is used largely by manufacturers of gloves, pocketbooks, etc., and is adapted for all grades of shoe-work, but especially for vamping. The machine is furnished with a platform to make a work-plate on a level with the feed when a table is required for other work.

A great reduction in the prices of clothing has been caused by the use of manufacturing machines. This is especially marked in the production of shoes, whose output has been enormously increased since the invention of sewing and other machinery. While shoe-sewing machines do not strictly fall within the scope of the present section, we may be permitted to include a description of one example and also of a book-sewing machine, both of which are among the most important manufacturing machines of the present time, and which are typical of American ingenuity.

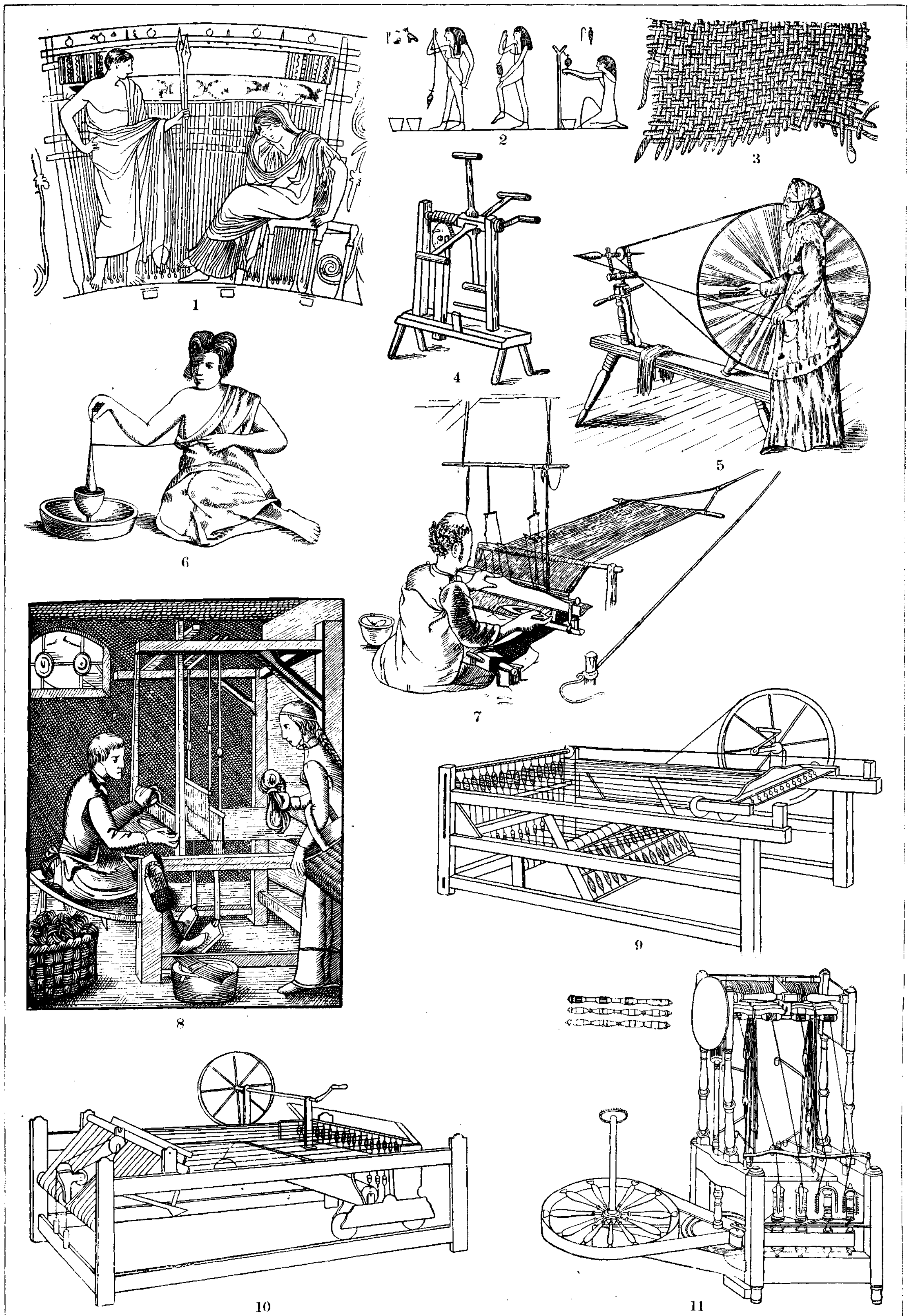
Shoe-manufacturing Machines.—The mechanical sewing of boots and shoes was for some time done on machines similar to the ordinary leather-sewing machines, but these did not satisfactorily reach the inside of the shoe to sew the "upper" to the "insole," although the soles could be sewed together by stitches put on the outside. The machine illustrated in Figure 4, in which a device at the end of the horn is made to act in conjunction with a hooked needle piercing the sole from the outside, seems successfully to fulfil the requirements. A large spool of thread coated with shoemaker's wax is attached to the rotating horn, through which the thread passes to a "whirl" at the tip of the horn. The whirl is a small ring through which there is an opening for the passage of the needle and having bevel teeth on the exterior, so that it can be rotated by a pinion which receives its motion by rods and bevel-gearing communicating with a cam movement in the rear of the upper part of the machine. During the descent of the needle through the centre of the whirl, the latter makes a partial revolution, carrying the thread with it, the effect of which is to throw the thread into the barb of the needle. In preparing a shoe for the machine the upper is fitted to the form or "last" and to the insole, and the outer sole is then tacked on. The shoe is then placed on the horn and the stitching is begun, preferably near the shank. As the stitching proceeds the horn is rotated, and the shoe is moved thereon so as to bring it properly under the action of the needle. The needle, after penetrating the sole, has the waxed thread laid in its hook by means of the whirl, and in ascending draws a loop of the thread through the sole and the turned edge of the upper. A cast-off closes the hook and prevents the escape of the loop, while the shoe is moved for a new stitch. When the needle again descends it passes through the loop on its shank and draws a new loop up through the loop previously formed, thus enchaining one loop with another. The horn is kept warm by a lamp or by gas, which tempers the wax on the thread as it passes the horn.

Figure 5 exhibits a machine for webbing the linings and for staying the shoes. It is of the Willcox & Gibbs system, with double needle-bars, which are actuated by a single vibrating arm and fed from two spools, making two parallel rows of stitches. The tape is supplied from a roll placed on a bent rod or carrier above the machine. Figure 6 is a machine for overseaming the edges of blankets.

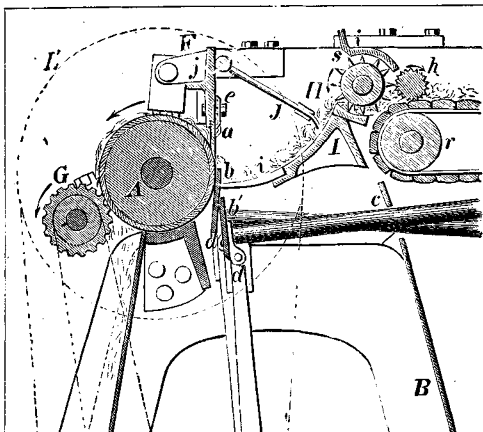
Book-sewing Machines are now largely employed to stitch together the sheets or "signatures" which make up the body of a book. These machines are remarkable not only for the great ingenuity of their construction, but also for the rapidity with which they operate and for the strength of their finished work. The Smyth machine is capable of sewing sixty signatures per minute, and inserts when required eight separate threads, any one of which may be cut or broken without impairing the holding of the others. In this machine each of the signatures is hung upon one of the horizontal arms of a four-arm reel, which presents the signatures in succession to the action of the clamps and the operation of the needles. The signature is secured by the clamps, the arm drops away, makes a quarter revolution, rises, and presents the next signature.

Embroidery-machine.—Closely allied to the sewing-machine is Heilmann's embroidery-machine (*pl.* 55, *fig.* 7). In this machine the needle, with a central eye, is guided in the manner illustrated in Figure 2 (*pl.* 53), but its great capacity is attained by the simultaneous movement of a large number of needles (from two hundred to five hundred, arranged in two horizontal rows), each of which repeats the flower or device on a piece of silk or other material from one governing design. The material to be embroidered is stretched smoothly in a vertical frame, which is movable in every direction in its own plane. Before each passage of the needles this frame receives a motion corresponding to the interval between two adjacent stitches, from a pantograph by means of a style called a "point" set further forward upon the design by the operator. Running on horizontal rails in front of and behind this frame are broad carriages which carry a small nipper for each needle. All the nippers of each carriage can be simultaneously opened and closed by a simple mechanism operated by the attendant, so that all the needles can be liberated or grasped. From the above description the working of the machine can readily be understood. The needles, threaded through the central eye, are passed into the stuff by the advancing carriage on one side, while the nippers of the carriage on the opposite side seize the presented needles and pull them sufficiently through to tighten the threads. The frame is then shifted according to the requirements of the pattern, the needles are again passed through in another place, and, being seized by the nippers of the first carriage, are drawn tight; the frame is then shifted the interval of one stitch by means of the pantograph and the operation is repeated.

As will be seen, the capacity of this machine is based on the frequently mentioned principle of the duplication of the tool, the moving by natural forces, as in the case with the sewing-machine, being, however, impossible.



1. Penelope's web. 2. Egyptian women using the distaff. 3. Prehistoric flax-cloth, from a Swiss lake-dwelling. 4. Reel of the olden time. 5. Olden-time spinning-wheel. 6. Mode of spinning by the Pueblo Indians. 7. East Indian peasant's loom. 8. Mediæval hand-loom. 9. Hargreaves' spinning-jenny (1767). 10. Crompton's mule (1775). 11. Arkwright's spinning-frame (1768).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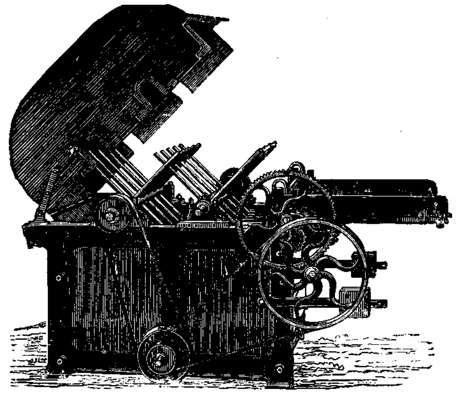
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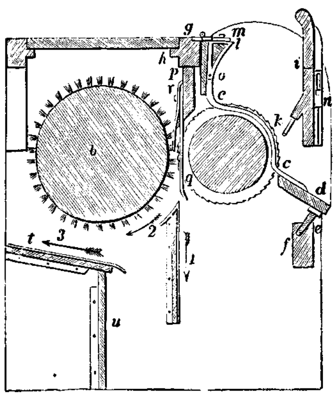
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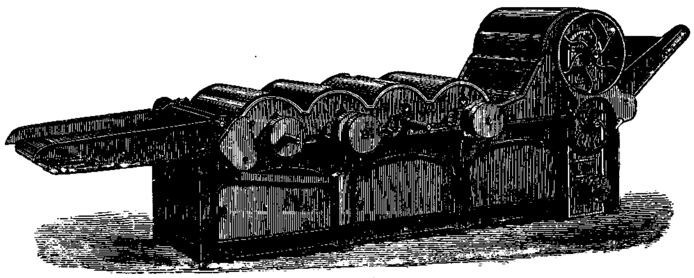
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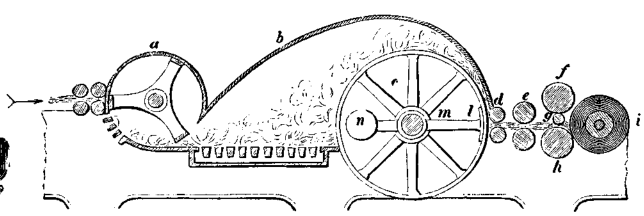
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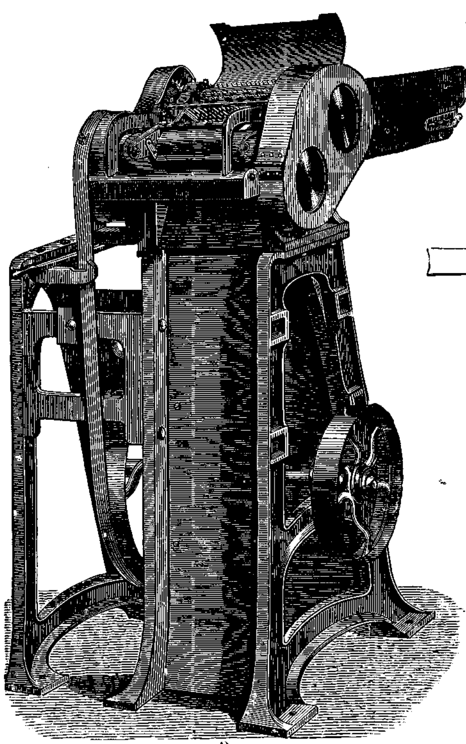
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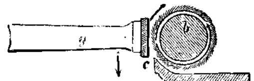
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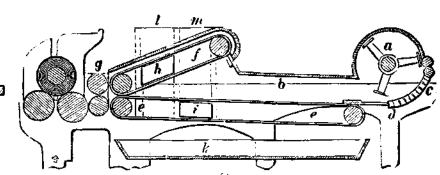
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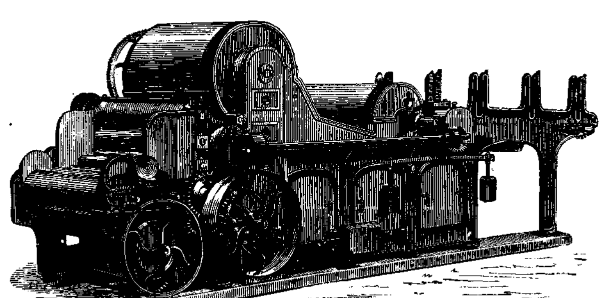
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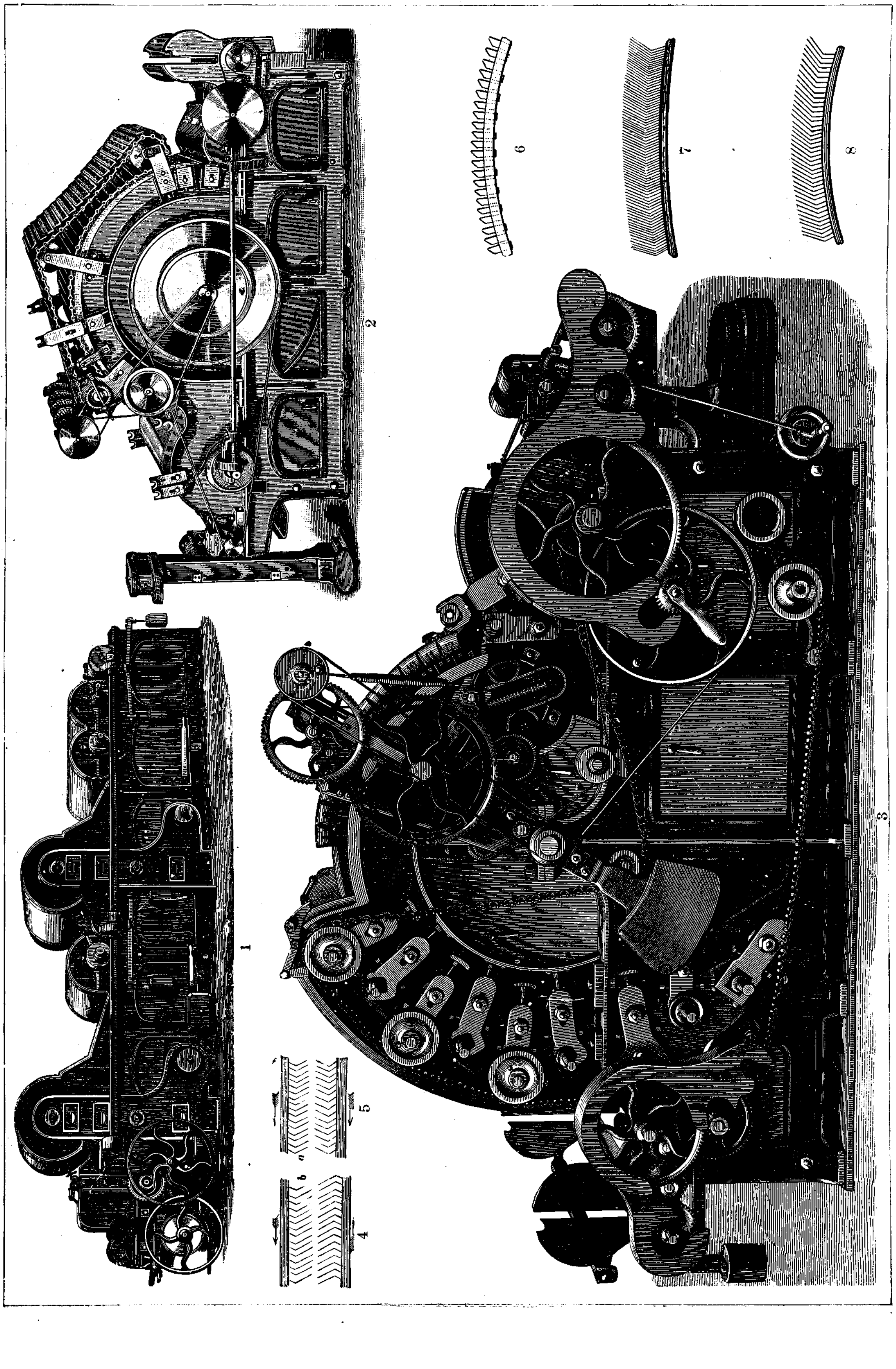
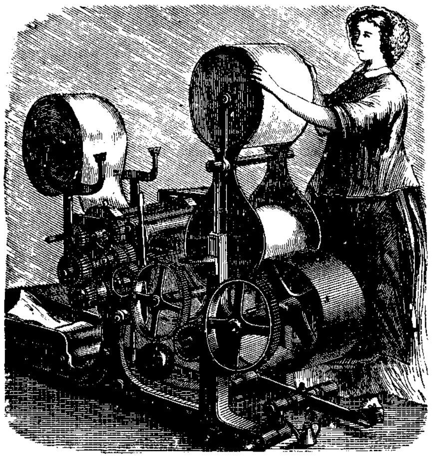
1. Comb-gin (vertical section of fig. 3). 2. Whitney saw-gin (1793). 3. Comb-gin (perspective). 4. Willow. 5. Opener. 6, 8. Longitudinal sections of batting-and-lapping machines, illustrating the principle of scutching and of producing the lap. 7. Tray-feeding for batting-machine. 9. Combined finishing-scutcher and lapping-machine.



1. Opener and lapping-machine. 2. Revolving flat carding-engine (Pettee Machine Works, Newton Upper Falls, Mass.). 3. German carding-engine. 4, 5. Principle of action of card-clothing. 6. Card-clothing for "licker-in" roller. 7. Card-clothing for main cylinder. 8. Card-clothing for dirt-roller.



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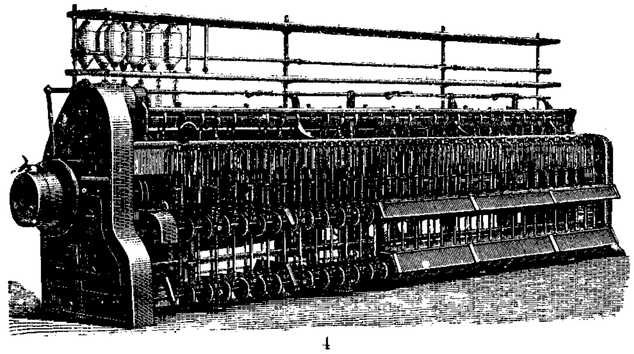

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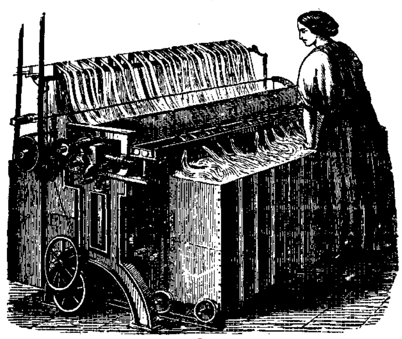

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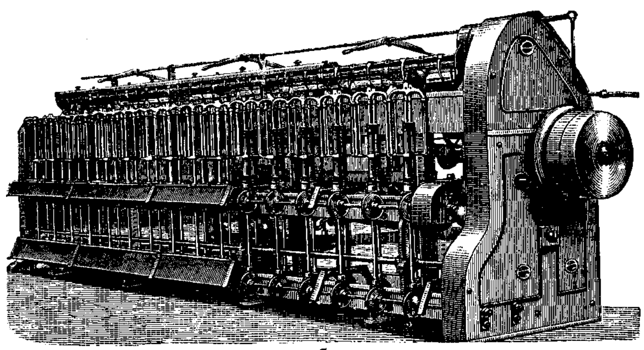

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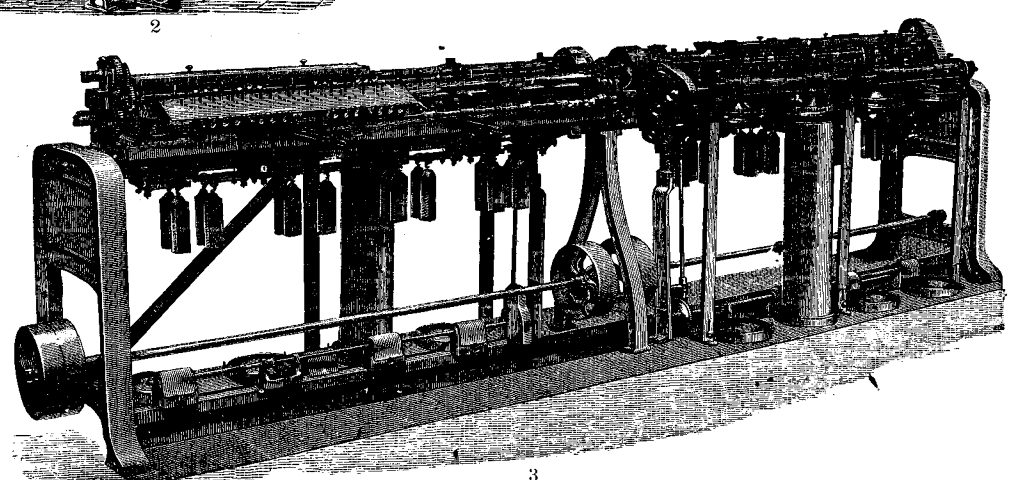

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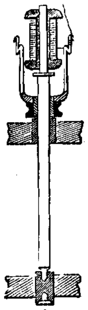

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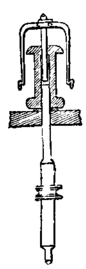

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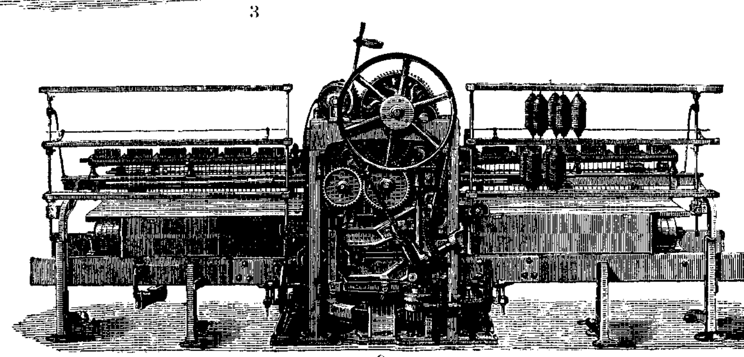

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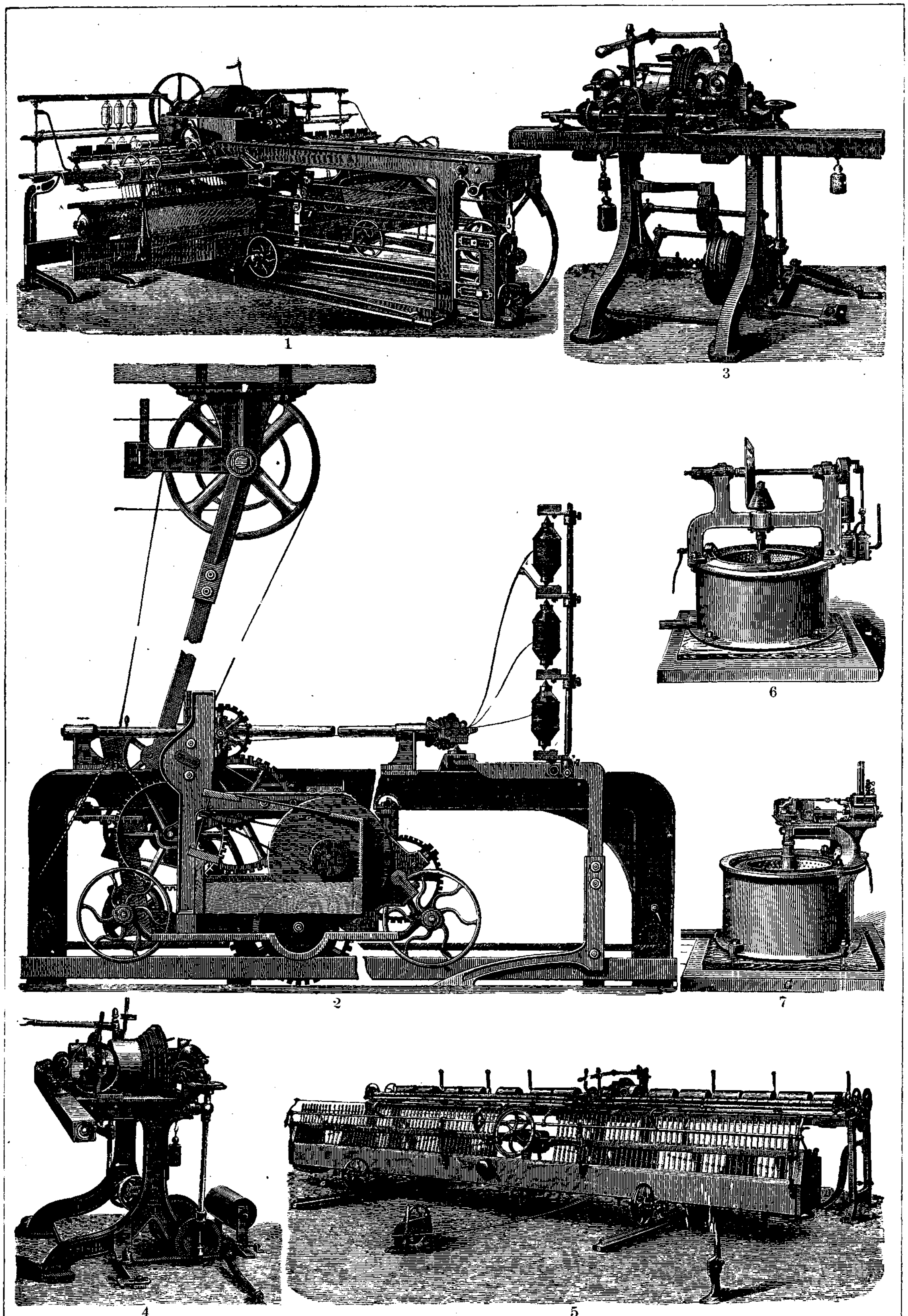
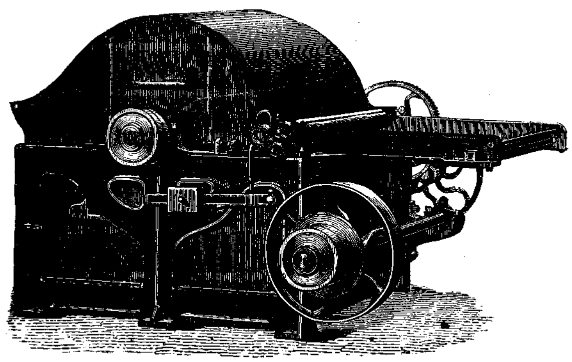
1. Canal drawing-machine. 2. Temporary-twist roving-machine. 3. Drawing-frame. 4, 5. Fly-frames for permanent-twist roving. 6, 7. Fly-throstles. 8. Section of "cop" produced by mule-spinning. 9. Self-acting mule-jenny.



1, 2. Mules. 3. Front view, 4. Side view, of the head-stock of a self-acting mule. 5. Self-acting mule for spinning woollen yarn. 6. Hydro-extractor operated by belt and friction cones. 7. Hydro-extractor operated by direct-acting steam-engine.



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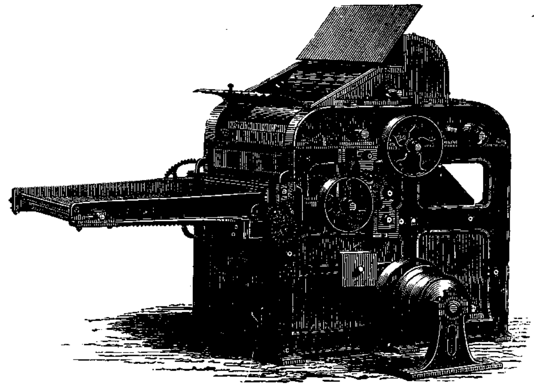

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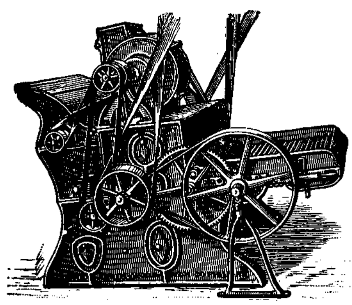

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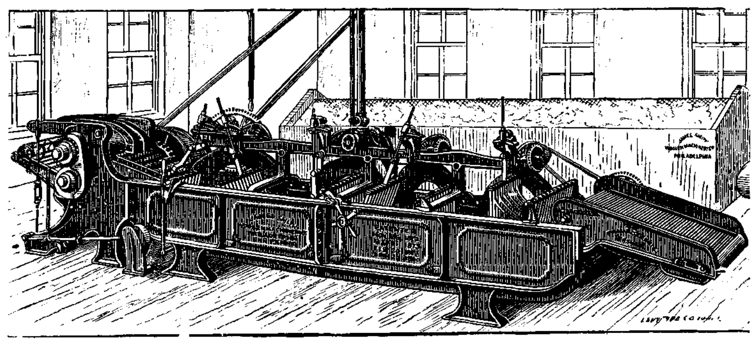

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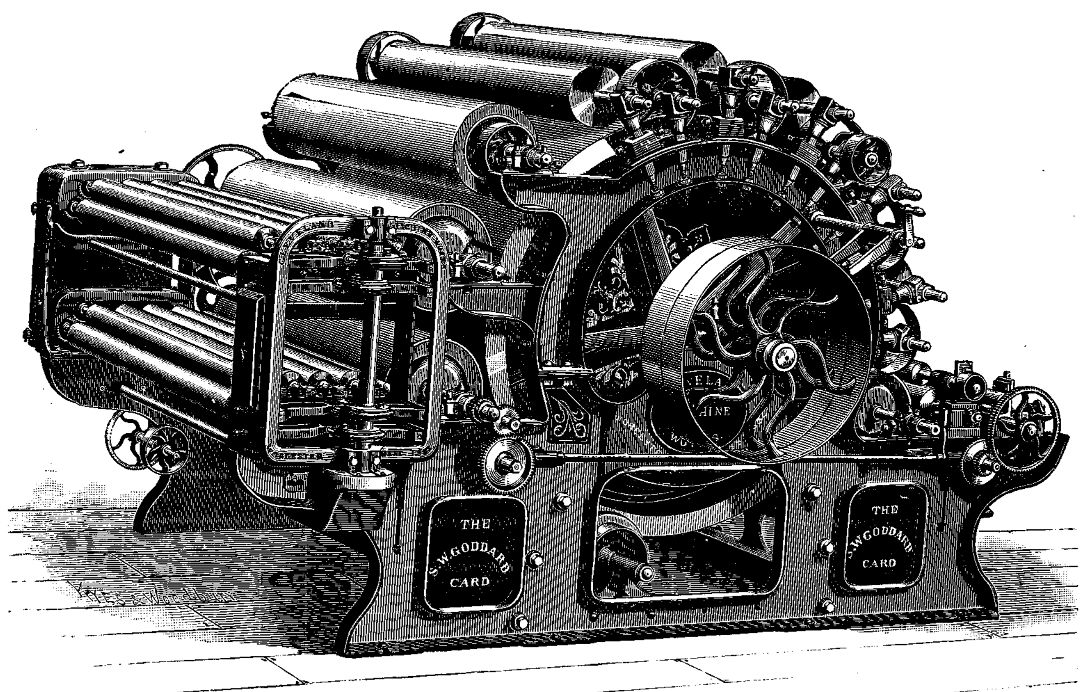

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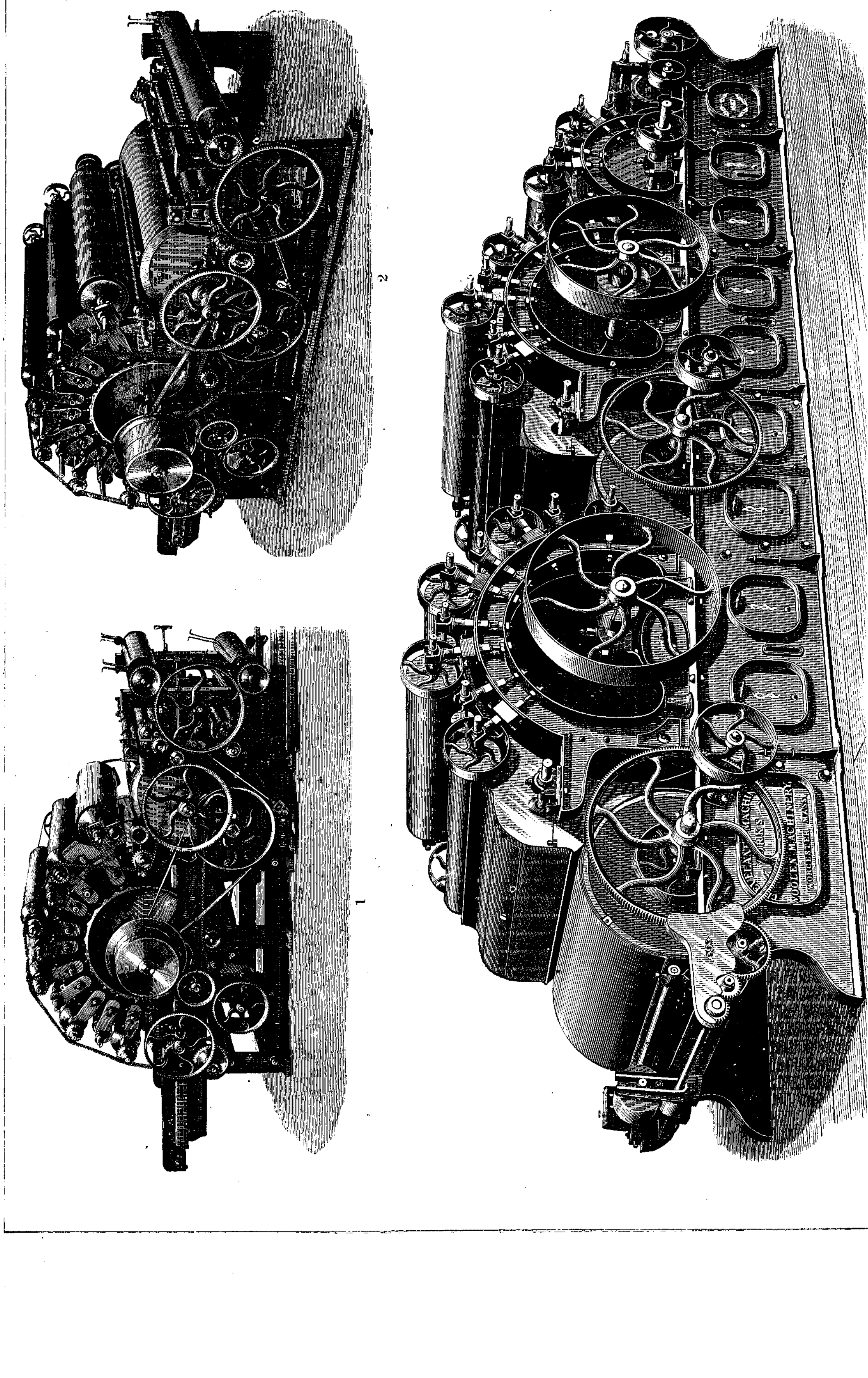
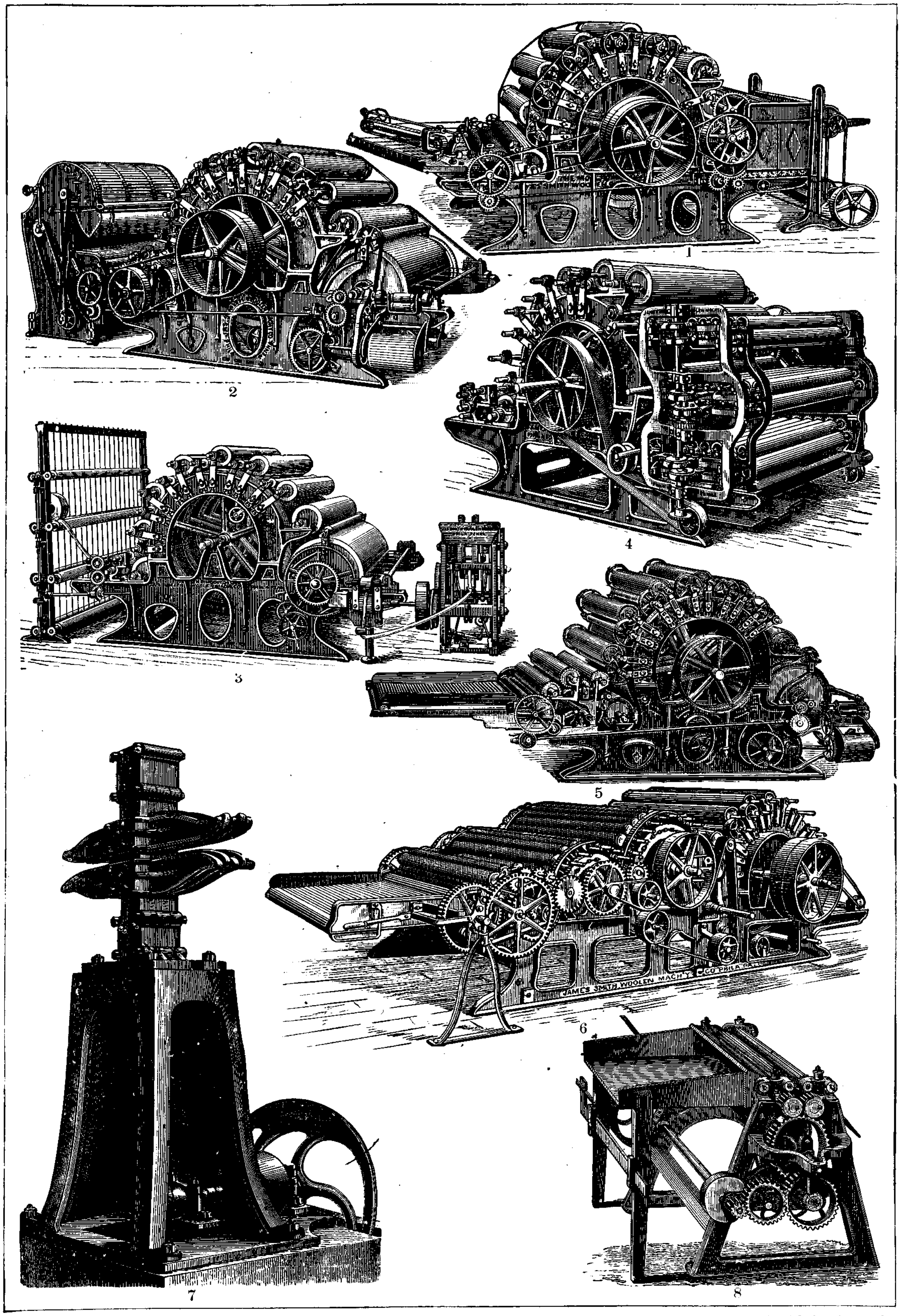
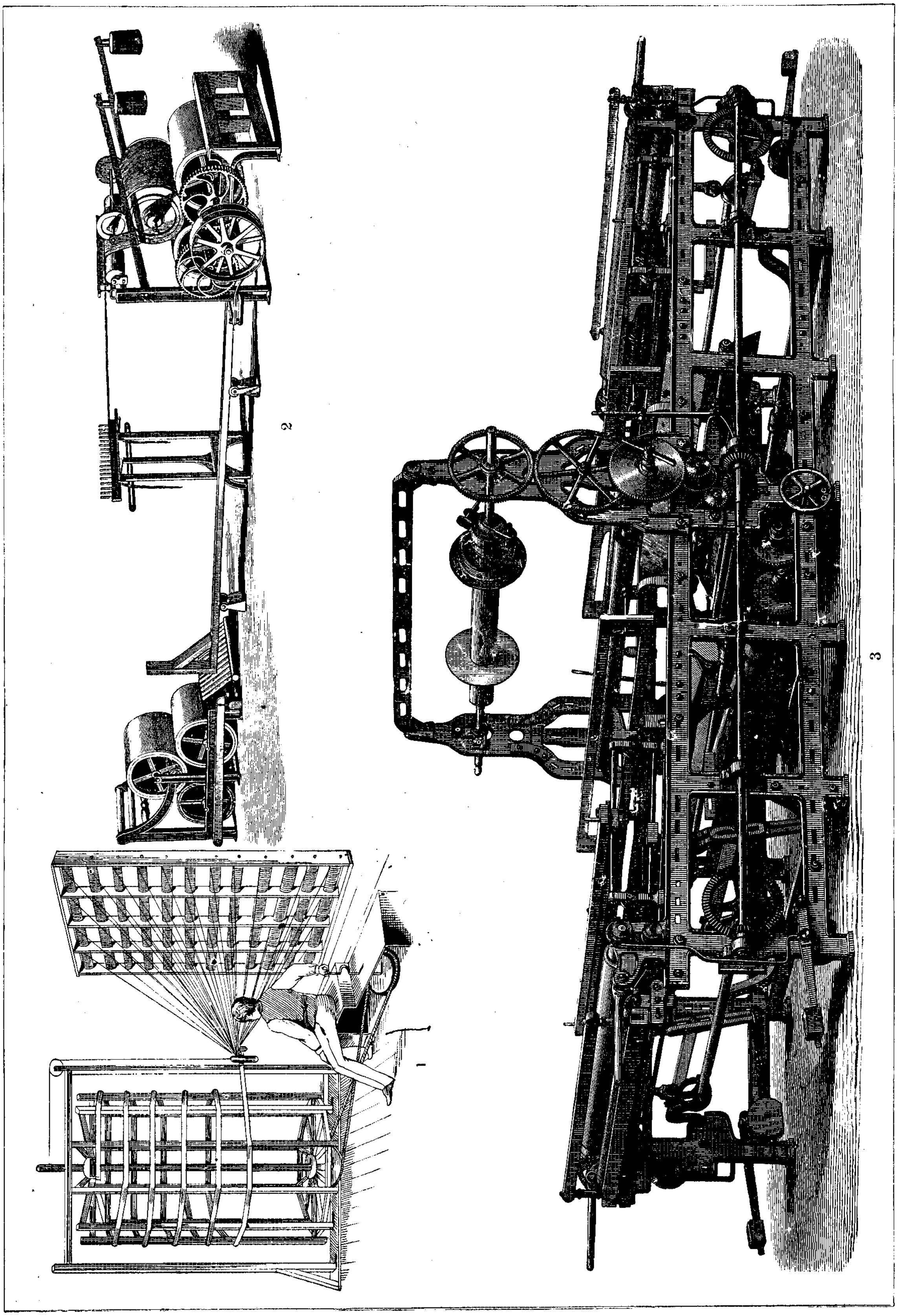
1. Wool-picker or opening-machine. 2, 3. Wool-burring machines. 4. Wool-washing machine (James Smith Woollen Machine Co., Philadelphia). 5. Finisher-card of an American set of cards (Cleveland Machine-Works, Worcester, Mass.).



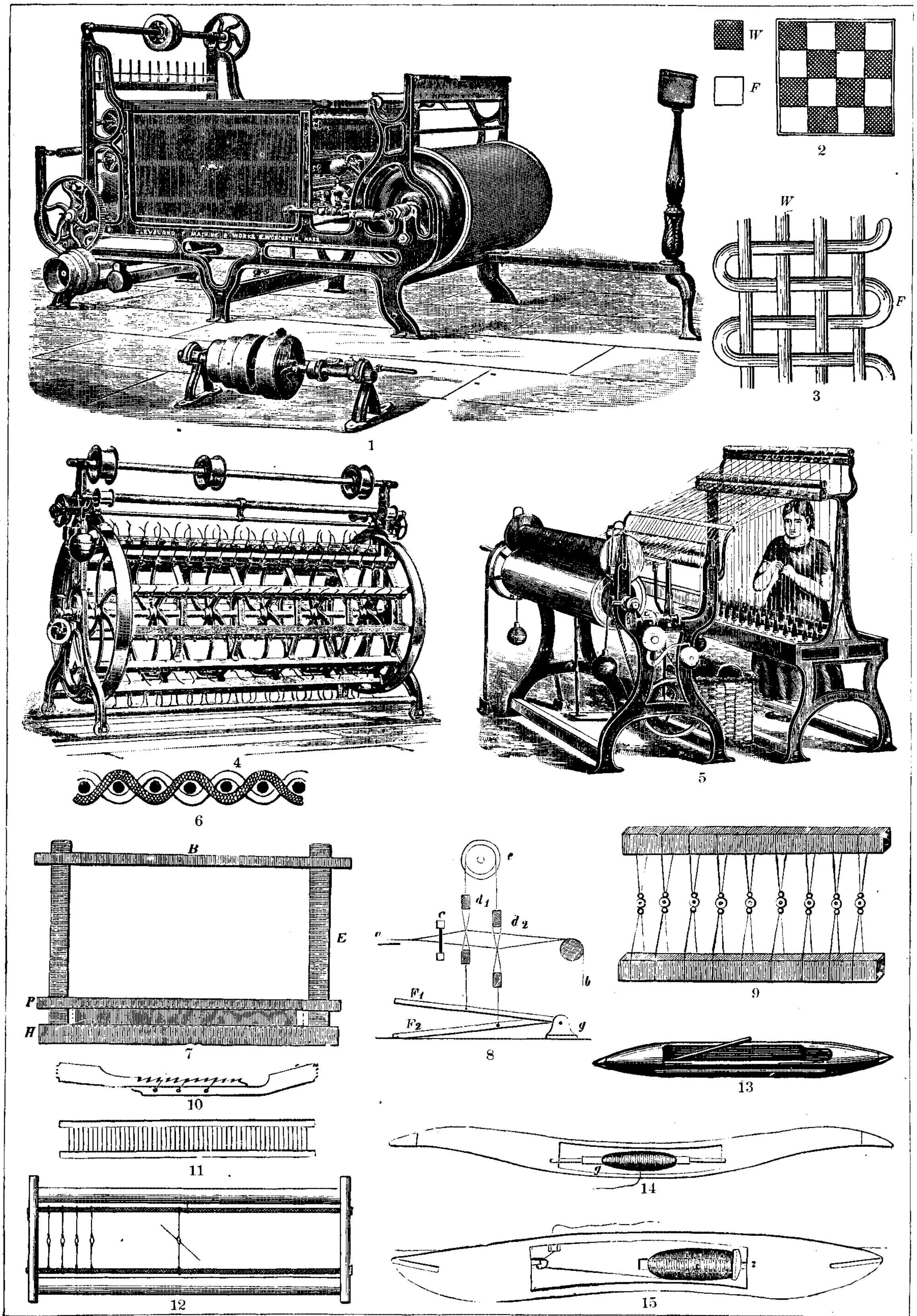
1. Double-deck finisher-card. 2. Single-deck finisher-card. 3. Double-cylinder worsted card with breast (Cleveland Machine Works, Worcester, Mass.).



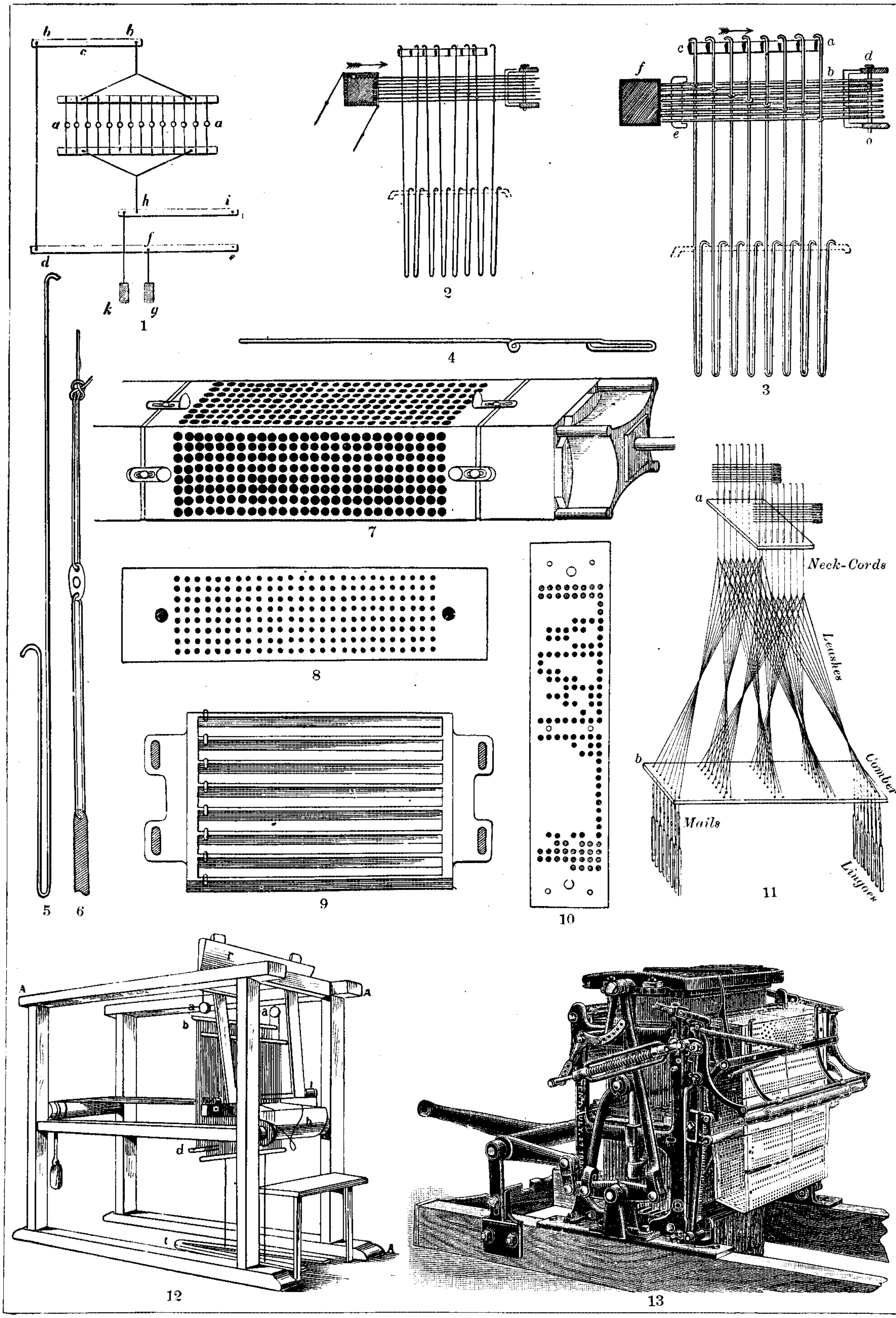
1. Finisher-card with Apperly feed, 2. First breaker-card with Bramwell feed, 3. Second breaker-card with bank-creel and balling-head, 4. Three-doffer finisher-card, 5. First breaker-card with hand feed, 6. Combined Garnett machine and card (James Smith Woollen Machine Co., Philadelphia). 7. Lever flax-breaker. 8. Guild's roller flax-breaker.



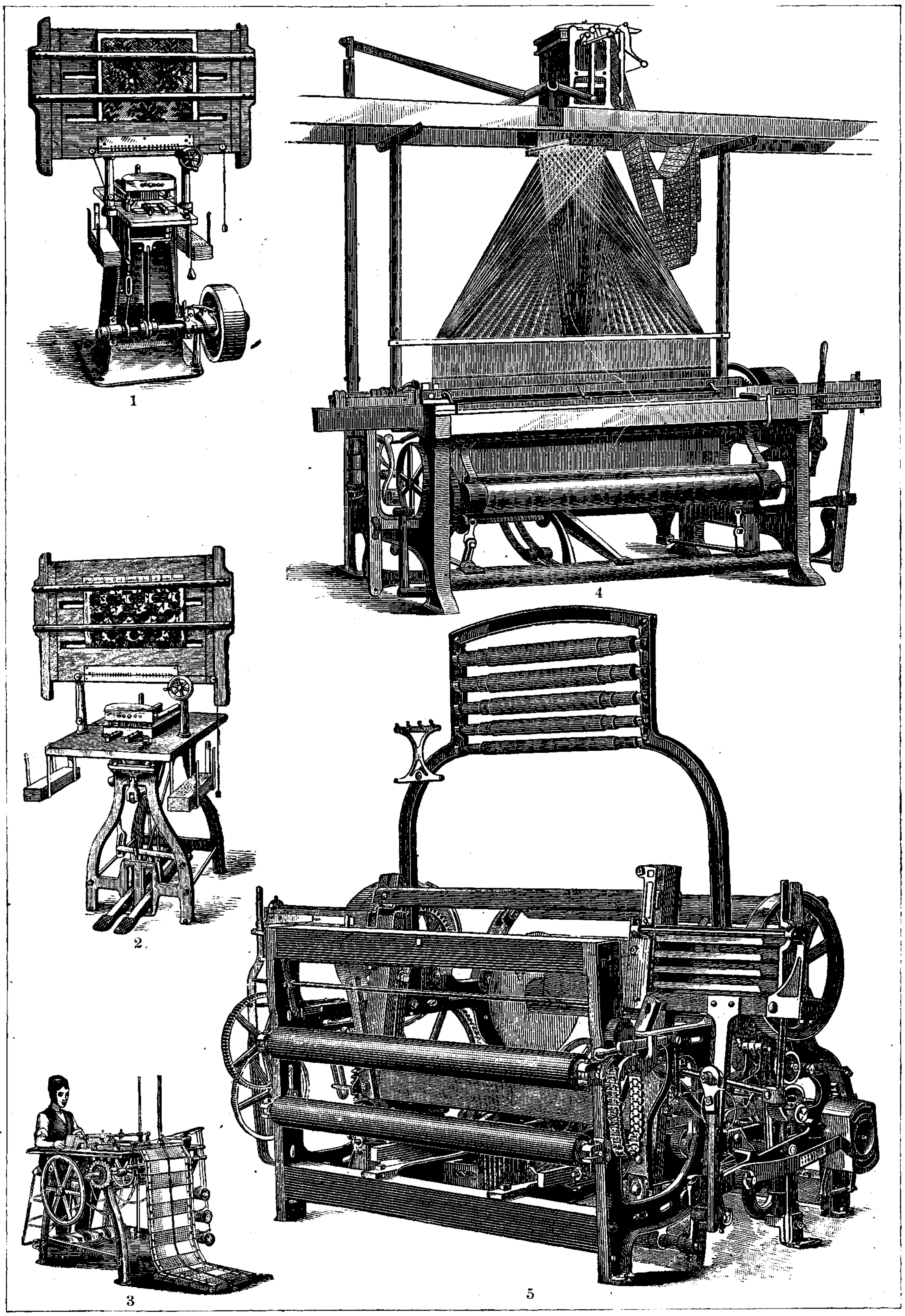
1. Chain-warping machine. **2.** Beaming-machine. 3. Warping-machine for cotton.



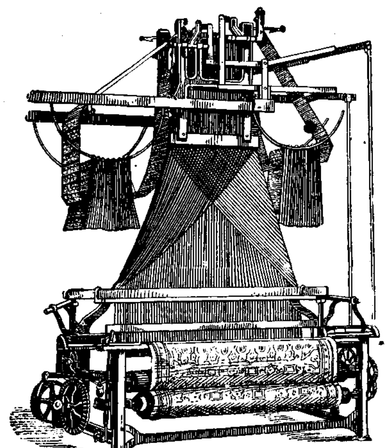
1. Yarn sizing-dresser (Cleveland Machine Works, Worcester, Mass.). 2. Plan of plain weave. 3. Fabric interlaced with plain weave (*fig.* 2). 4. Section-reel (Cleveland Machine Works). 5. Yarn-spooler and stand (Cleveland Machine Works). 6. Cross-section of plain weave. 7. Batten of a hand-loom. 8. Arrangement of harness for plain weaving. 9. Harness-frame and twine heddles. 10. Temple. 11. Reed. 12. Harness-shaft with wire heddles. 13. Power-loom shuttle for weaving cloth. 14, 15. Shuttles for hand-looms.



1–11. Details of the Jacquard machine: 1. "Couper," 2, 3. Action of needles and hooks, 4. Needle, 5. Hook, 6. Lingo, 7. Cylinder, 8. Needle-board, 9. Griffe, 10. Card, and 11. Tie-up of harness. 12. Harness-loom. 13. Double-lift double-cylinder Jacquard machine.



1. Piano steam-power card-stamping machine, 2. Piano foot-power card-stamping machine, 3. Jacquard card-lacing machine, 4. Single-lift Jacquard machine adjusted to a loom (Schaum & Uhlinger, Philadelphia). 5. Roller-loom (Bridesburg Manufacturing Co., Philadelphia).



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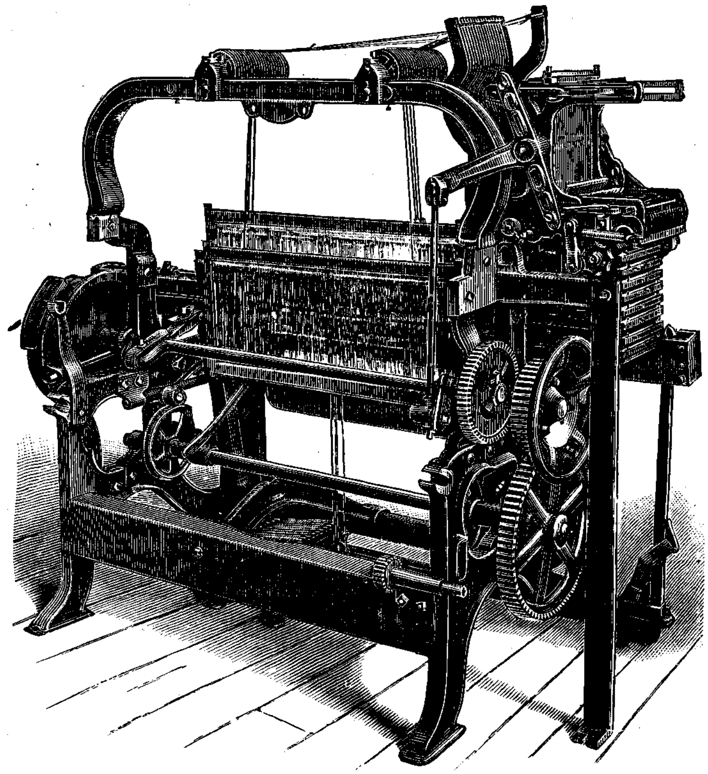

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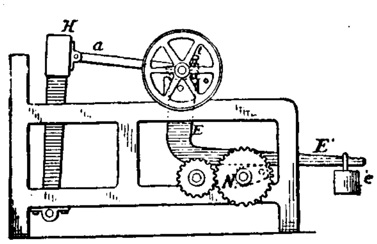

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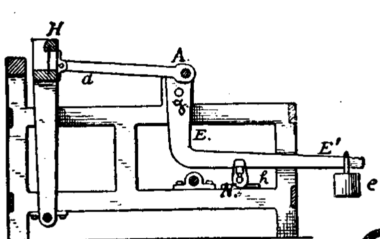

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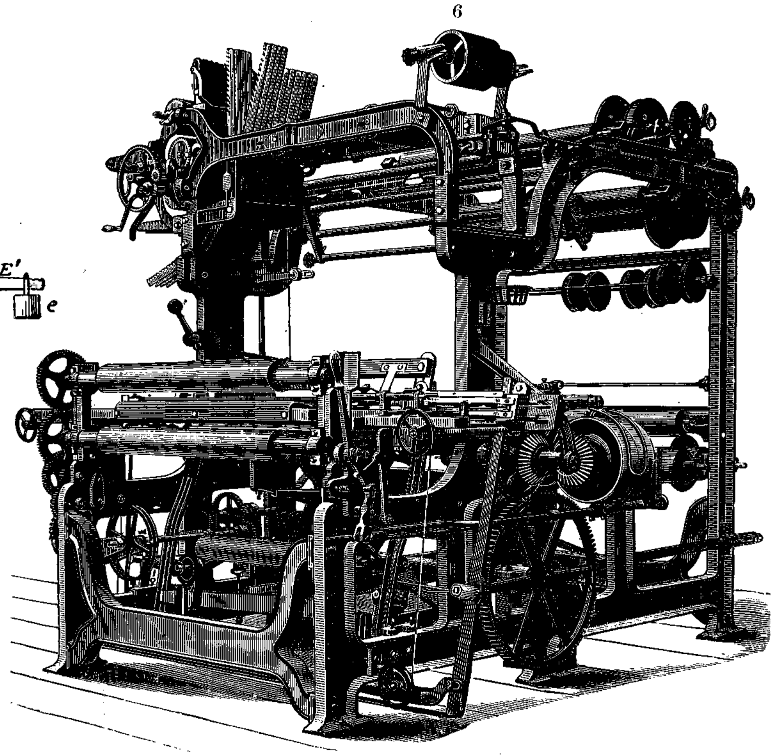

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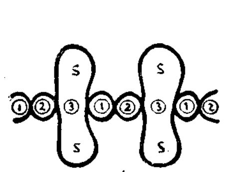

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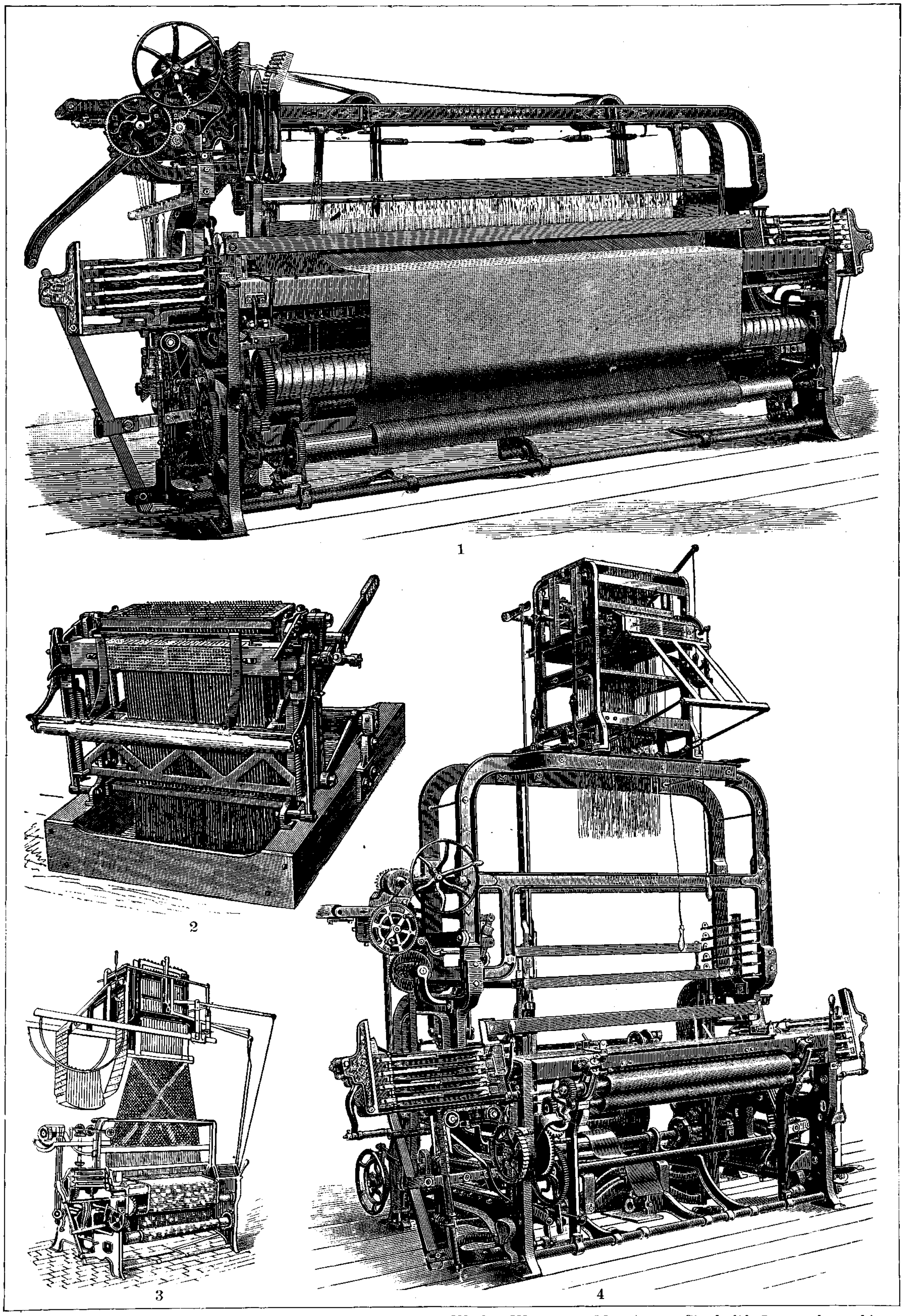
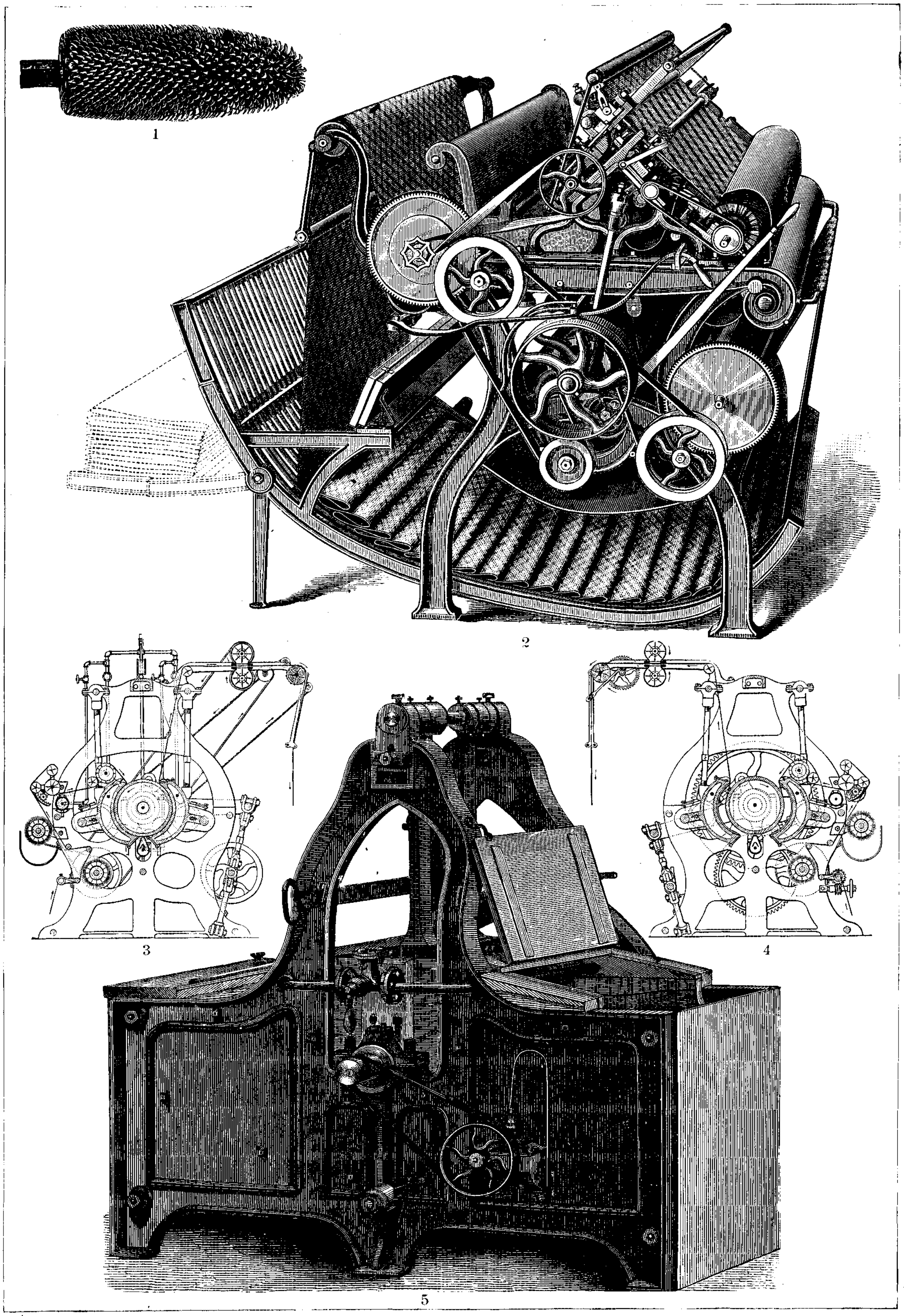
5

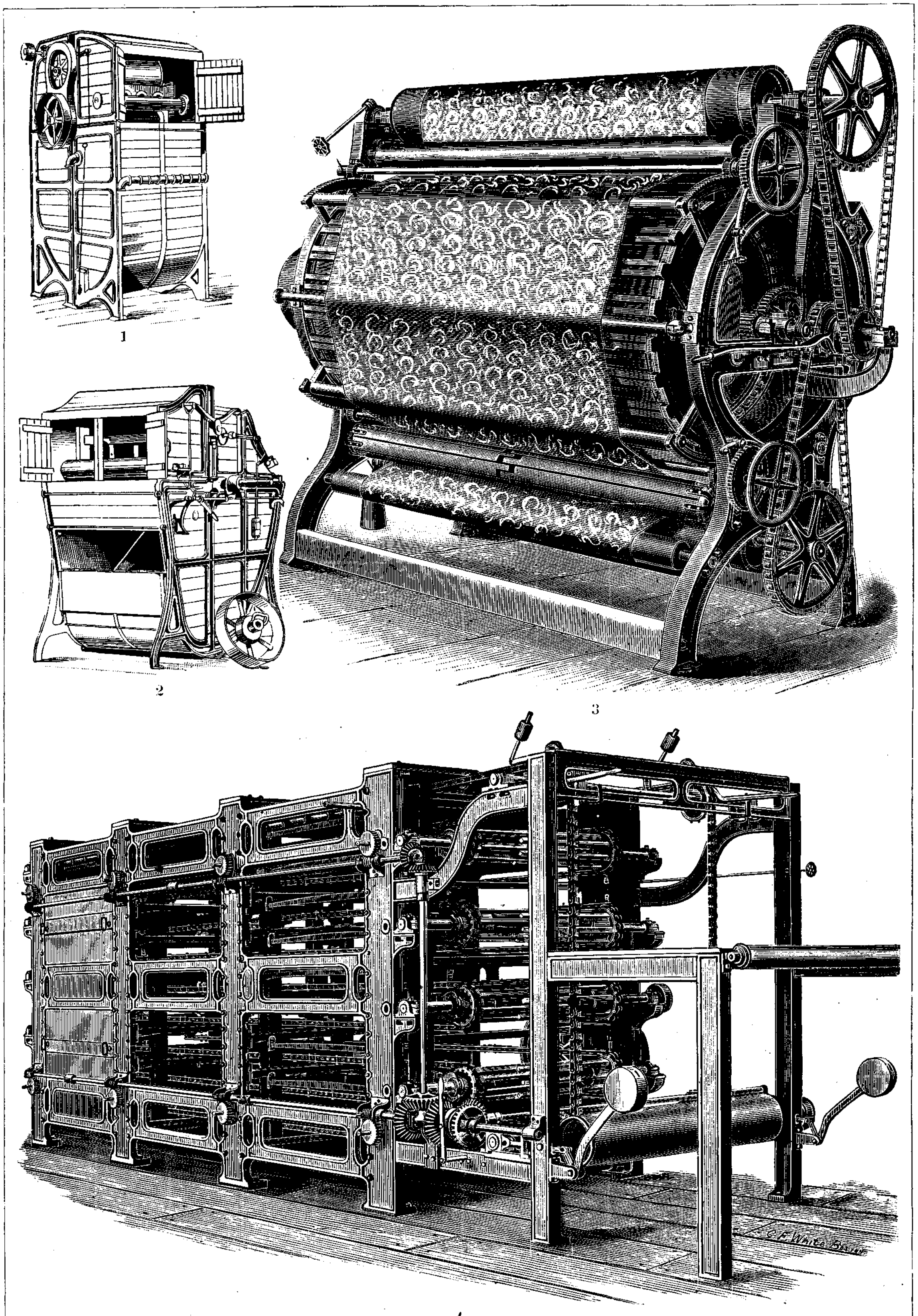
1. Double-lift, double-cylinder Jacquard machine attached to loom. 2, 3. Terry-looms. 4, 5. Pinciple of terry-weaving on looms in Figures 2 and 3. 6. Positive double-acting dobbie (George W. Stafford & Co., Providence, R. I.). 7. Double-shuttle plush-loom (Knowles Loom Works, Worcester, Mass.).



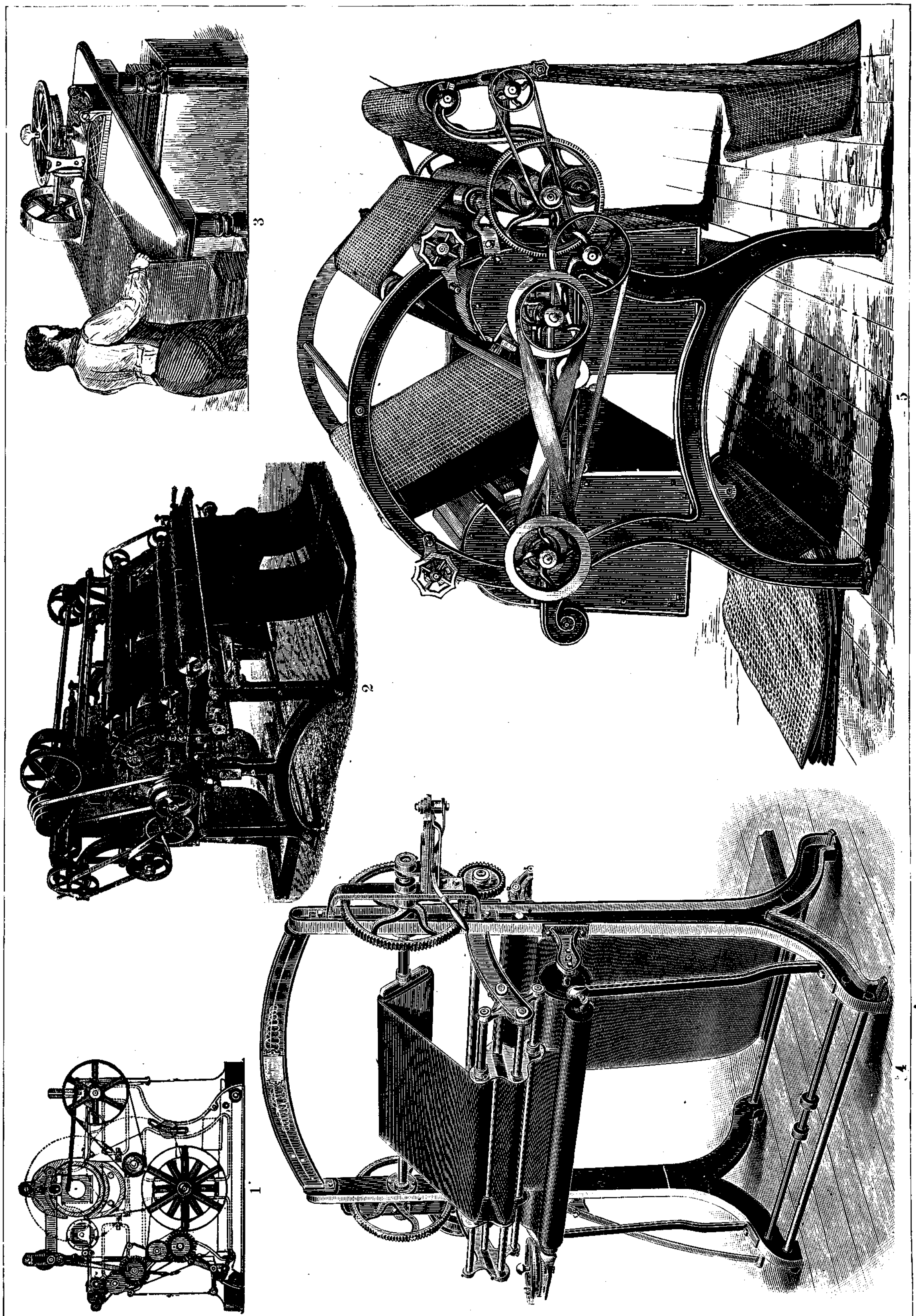
1. Heavy worsted- and woollen-loom (Knowles Loom Works, Worcester, Mass.). 2. Single-lift Jacquard machine (Schaum & Uhlinger, Philadelphia). 3. Double-lift, single-cylinder Jacquard machine attached to loom. 4. Ingrain-carpet power-loom (Knowles Loom Works).



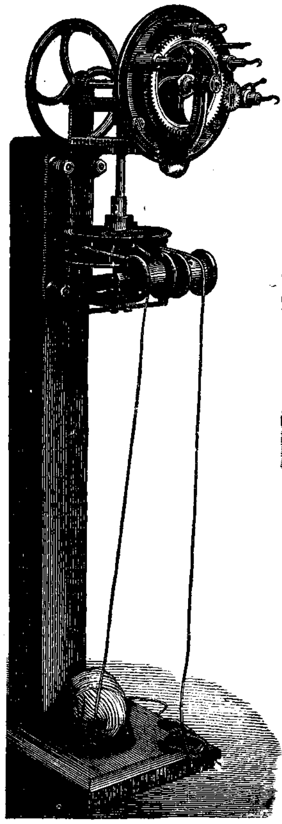
1. Teasel. 2. Improved shearing-machine (Parks & Woolson Machine Co., Springfield, Vt.). 3, 4. Improved rotary cloth-press (David Gessner, Worcester, Mass.). 5. German fulling-mill.



1. American fulling-mill, 2. Cloth-washing machine (A. Hopkins & Co., Pascoag, R. I.). 3. Brown's improved up-and-down gig (Parks & Woolson Machine Co., Springfield, Vt.). 4. Cloth-drying machine (Granger Foundry and Machine Co., Providence, R. I.).



1. Miller double steam-cylinder rotary cloth-press (Woonsocket (R. I.) Machine & Press Co.). 2. Raising or napping-machine (Charles Heap, Boston). 3. Cloth-measuring machine. 4. Brown's cotton-measuring and winding-machine (Parks & Woolson Machine Co., Springfield, Vt.). 5. Brushing-machine (Parks & Woolson Machine Co.).



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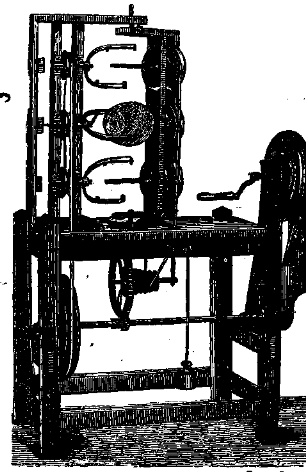

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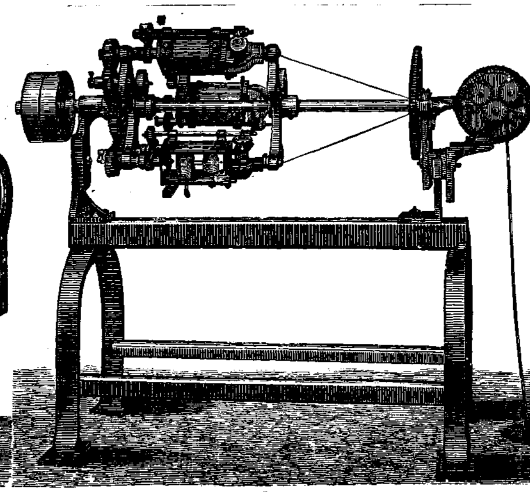

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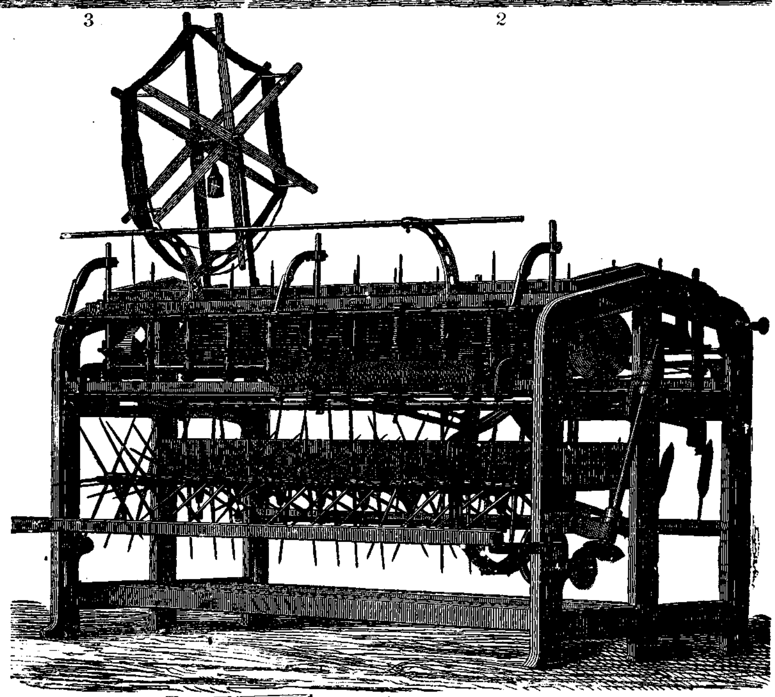

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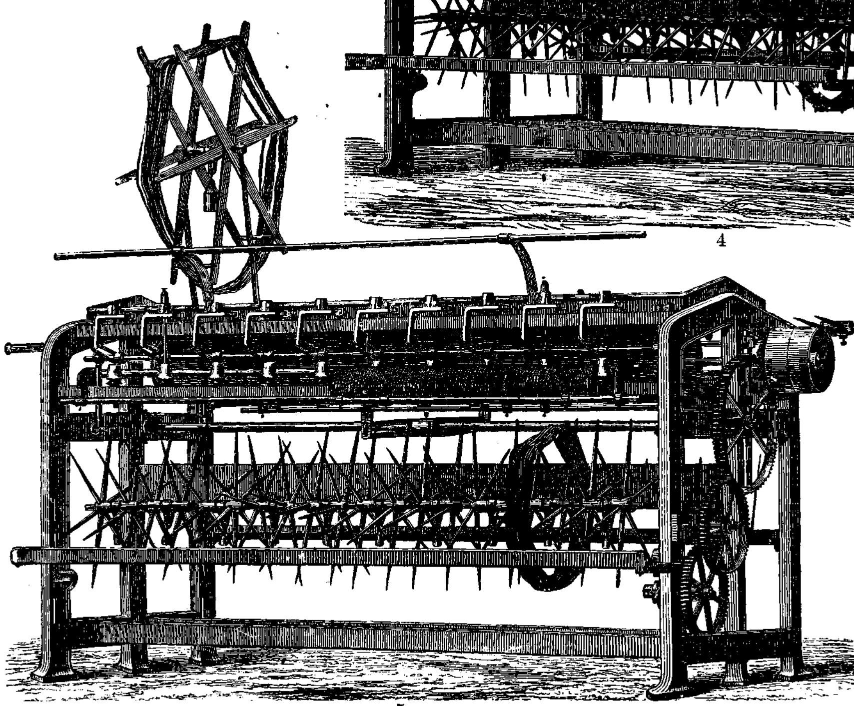

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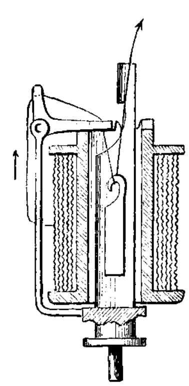

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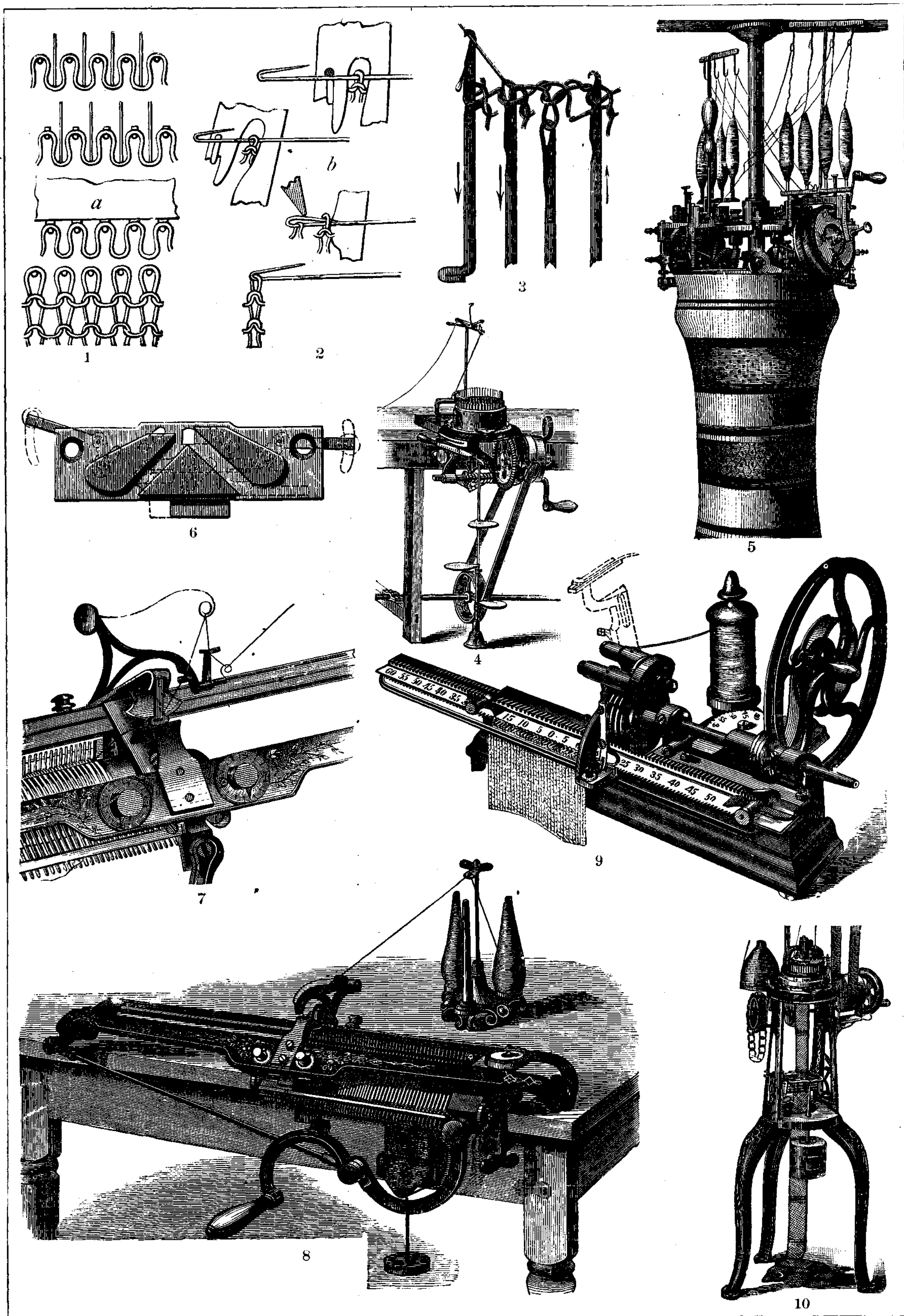
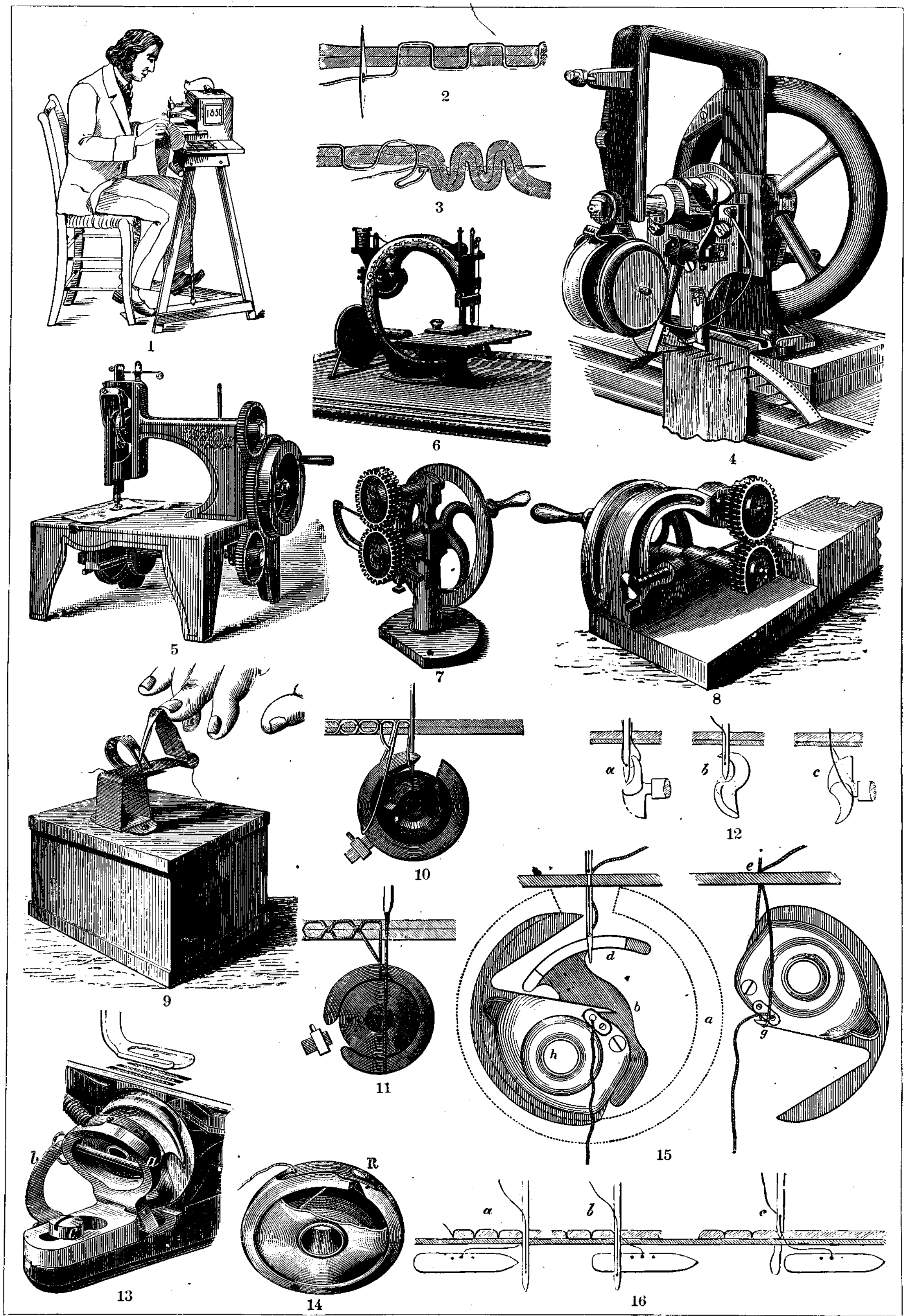
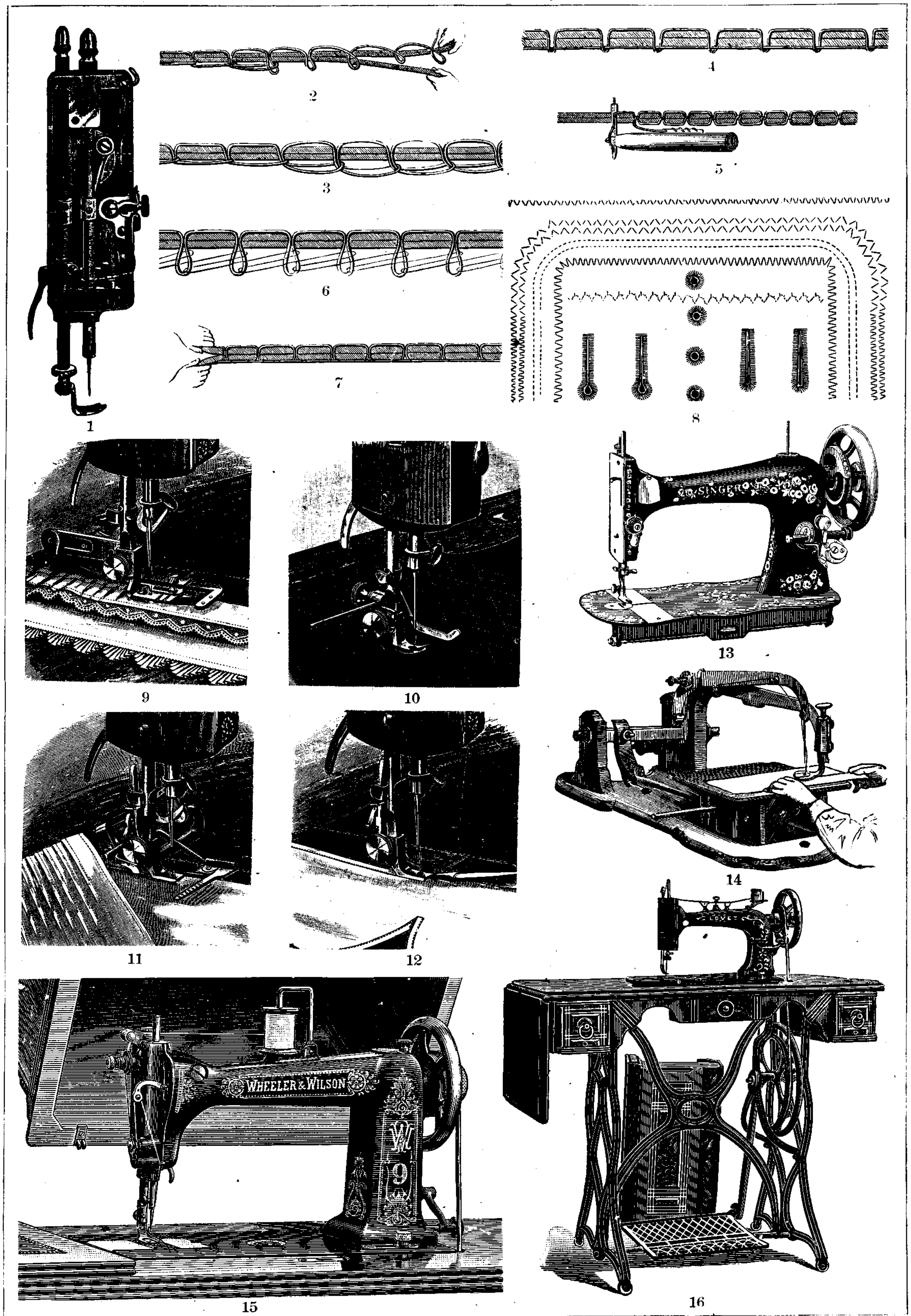
1. Rope-maker's wheel. 2. Rope-making machine. 3. Ball-winding machine. 4. Bobbin-frame warp spooling-machine. 5. Bobbin-frame filling spooling-machine. 6. One of the heads of a braiding- or plaiting-machine.



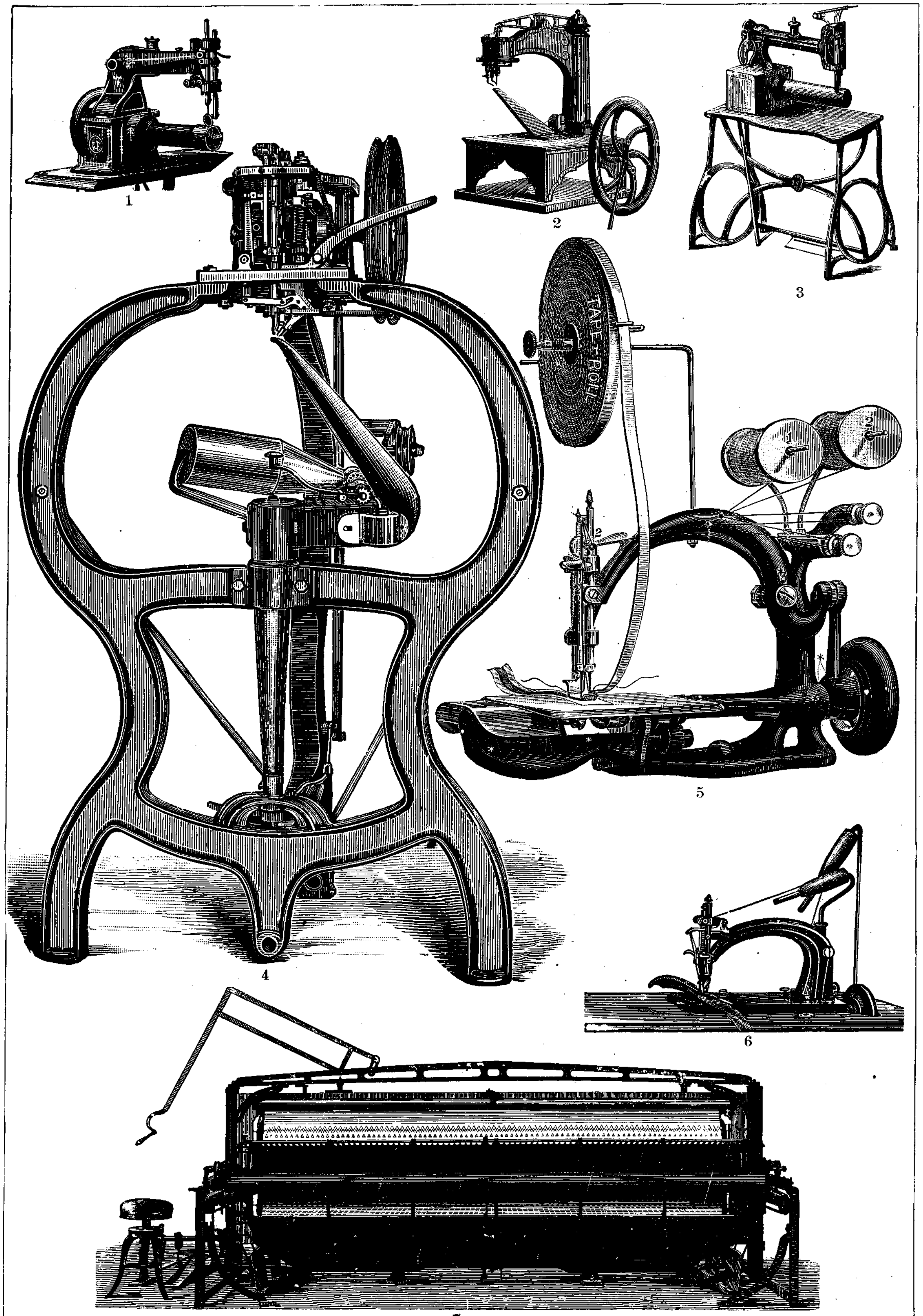
1. Thread meshes. 2. Needles of a knitting-machine. 3. Self-acting needles of Lamb's machine. 4. Branson's stocking-machine (James L. Branson, Philadelphia). 5. French round-frame machine. 6. Needle-plate of Lamb's machine. 7. Guide and tension of Lamb's machine (enlarged). 8. Lamb's knitting-machine. 9. Hinkley's knitting-machine. 10. Branson's machine for circular ribbed-stuff.



SEWING-MACHINES:—1. Thimonnier's sewing-machine (1830). 2. Double-pointed needle. 3. Basting needle-stitch (produced by machines in figs. 7, 8). 4. Elias Howe's original sewing-machine (1846). 5. Isaac M. Singer's original sewing-machine (1851). 6. Willcox & Gibbs' sewing-machine. 7, 8. Hand basting-stitch machines. 9. Heyer's single chain-stitch machine. 10, 11. Early form of Wheeler & Wilson's hook and bobbin. 12. Willcox & Gibbs' rotary-hook. 13. Rotary-hook and bobbin in position, 14. Bobbin-case, of the improved Wheeler & Wilson sewing-machine. 15. Singer oscillating shuttle. 16. Operation of the reciprocating shuttle.



1. Head of a straight-needle machine. 2, 3. Crochet- or single chain-stitch of the Willcox and Gibbs machine. 4, 5. Lock-stitches. 6, 7. Double chain-stitch of the Grover & Baker machine. 8. Stitches and button-hole work, Love machine (*fig.* 16). 9–12. ATTACHMENTS: 9. Ruffler, 10. Quilter, 11. Plaiter, 12. Binder. 13. Improved Singer machine with oscillating shuttle. 14. Early type of Wheeler & Wilson machine. 15. Wheeler & Wilson No. 9 high-arm machine. 16. Button-hole and sewing-machine (Love Manufacturing Co., Rochester, Pa.).



SEWING-MACHINES:—1. Cylinder sewing-machine (Wheeler & Wilson Manufacturing Co., Bridgeport, Conn.). 2. Truncated-cone support manufacturing machine. 3. Cylinder manufacturing machine. 4. McKay shoe-sewing machine. 5. Double-needle machine (Kruse Manufacturing Co., New York). 6. Blanket-overseaming machine (American B.-H. & O. Sewing-machine Co., Philadelphia). 7. Heilmann's embroidery machine.