PART II  TEXTILES

CHAPTER II

TEXTILE MANUFACTURE

The term textiles is the general designation for the materials of which dresses and the majority of garments are made. To insure a suitable selection of materials for any specific use in the making of dresses and garments a knowledge of textiles is required. This knowledge entails a study of the various standard fabrics as to fibre and general design, also a comparison of the different qualities in which the materials are made and of the different prices at which they may be purchased. Such work must be based on a preliminary study of the processes of manufacture of the four fibres, cotton, wool, silk, and linen, which are most important because most used. These processes vary somewhat according to the fibre used and the finished product desired. There are some processes, however, required for nearly all fibres and practically identical in general principle for each. These processes are:

(a) Carding, or some allied process, which prepares the fibre for spinning by converting the tangled mass into a continuous strand.

(b) Spinning, which prepares that strand for weaving by making it, through various drawing and twisting operations, into a yarn.

(c) Weaving, which makes that yarn into a fabric by interlacing it in various designs.

I. CARDING, SPINNING, AND WEAVING

I. Carding

Carding is the process by which tangled and matted fibres are cleaned, opened up, and arranged in a continu-
ous strand for subsequent spinning. It is probable that the need of this process was not felt until the art of spinning was fairly well known; but when its value was once understood its development paralleled that of spinning.

1. **Hand Carding.**—Carding, like spinning, was evidently first done by the fingers without the aid of tools. Later,

![Image: From a photograph, copyright by American Woolen Co., Boston. Worst card.](image)

two flat pieces of wood with handles were used. These pieces, called cards, were covered on one side with skin or leather which was set with fine wire points or teeth. The wire was so bent that the points turned toward the handles of the cards. The fibres were placed between the cards, which were so manipulated, one on the other, that the fibres were disentangled, cleaned, and then made to form a soft roll called a sliver which was the length of the cards. In the subsequent spinning these rolls were drawn out and joined to form a continuous strand which was sufficiently fine and strong to be used in weaving.
Carding by this method was obviously a slow process. It is now done with great rapidity by the use of machines which have a large revolving cylinder covered with fine wire points called clothing. This cylinder comes in contact with many small cylinders or with revolving flats, and the fibres are cleaned, opened, and finally delivered continuously in the form of a web, which is in some cases reduced to a soft roll, or strand, called a sliver, and in others to a smaller roll, called a roving.

The first machines invented were fed by hand and delivered the sliver in short lengths as did the hand cards. Through many inventions, however, cards have been evolved which are fed by machine continuously and deliver the fibre in a continuous strand.

2. Machine Carding.—There are two general types of carding-machines; those used for wool, which have a large cylinder and several small ones, and those used for cotton, which have a large cylinder and revolving flats.

(i) Carding-Machines for Wool.—The carding-machines which are used for the two branches of the wool industry, worsted and woolen, differ somewhat in detail.

(a) Worsted.—For worsted (which does not require as much carding as woolen because of the subsequent combing processes) generally only one machine is used. This may be a single or a double cylinder card.

A machine in general use in the worsted industry is made up as follows:

(i) An automatic feed, which receives the fibre in bulk and regulates the amount to be delivered to the card. The machine consists of a travelling apron, which receives the fibre and carries it forward; a stripper, a cylinder or comb which works against the apron at the back and removes the surplus fibres; another stripper at the front, which removes the fibres brought forward on the apron and sends them into the card.

(ii) A series of cylinders or rollers, each of which is called a licker-in. These are placed in front of the feed and have metallic clothing which takes up the fibre and gently opens and cleans it preparatory to the carding.
(iii) **Burr guards**, metal rollers which revolve against the surface of the licker-ins and snap off any burrs in the wool. These burrs are received and held on a tray. (If any burrs and wool hold together the wool is also removed and later used for woolens.)

(iv) **First large cylinder**, which follows the licker-ins and is covered with card clothing. This clothing consists of a leather or cloth backing, or foundation, set with fine wire teeth, turned in the direction in which the cylinder moves.

(v) **A series of small cylinders**, called workers and strippers, which are also covered with card clothing. The workers revolve against the surface of the large cylinder. The strippers remove the stock from the workers so that it is again taken up by the cylinder and carried forward. There are the same number of workers as strippers, usually three of each for worsted.

(vi) **A fancy**, a kind of wire brush which runs into the clothing of the cylinder and raises the fibre to the surface of the teeth.

(vii) **A doffer**, a cylinder which is set close to the large cylinder and receives from it the fibre raised by the fancy.

(viii) **An angle stripper**, which removes the fibre from the doffer and passes it to the second large cylinder.

(ix) **Second large cylinder**, like the first.

(x) **A doffer**, like that which follows the first cylinder.

(xi) **A doffer comb**, a metal bar with corrugated edges which works against the surface of the doffer and removes the fibre, now made into a thin web, as it comes up on the doffer.

(xii) **A trumpet**, or tube, which is placed at one side of the machine. It takes the web as it is delivered by the comb and, condensing it into a roll, passes it through drawing-off rolls.

(xiii) **Drawing-off rolls**, from which it comes in the form of a continuous strand, or sliver, and is wound on a ball or coiled in a can ready for the subsequent processes which prepare it for spinning.

(b) **Woolen.**—In the woolen industry a set of cards, two or more in sequence, is used. At present each card
is a separate machine, called a breaker. Usually there are three—first breaker, second breaker, and finisher. In general principle the breaker is the same as the worsted card, but there is a difference in detail. Usually burr guards are not necessary, as in the majority of cases the fibres have been passed through a separate machine called a burr-picker before coming to the woolen cards. There are generally more workers and strippers on the large cylinder of the breaker—from six to nine of each. The fibre used for the woolen industry requires much more carding than for the worsted, as it is not combed but goes from the breakers directly to spinning.

(i) Feeding the Fibre.—There are two general methods of feeding the fibre from one breaker to another, the purpose of each feed being to produce uniformity of product.

(a) Traverse feed. The web is drawn in the usual method from the large cylinder to the side and made into a continuous sliver by a revolving tube and drawing-off rolls. From these rolls it is carried to a travelling apron placed at the back of the second breaker. Here lengths of this continuous sliver are so arranged on the bias, side by side, as to form a solid lap. This lap is carried forward by the apron and fed into the second breaker.

(b) Creel feed. The web is made into a sliver by the side drawing, as in the other machine, and then wound into a ball on a spool. Several of these balls are placed in a creel, or frame, and fed side by side straight into a card. More manual labor is required for this method than for the other.

(ii) Removing the Fibre.—The method of removing the fibre from the final card, or finisher, differs somewhat from that used with the worsted card. In the finisher there are two ring doffers placed one above the other and working against the surface of the large cylinder. On these the clothing does not cover the entire surface, as in the worsted doffer, but is in narrow strips or rings around the cylinders. As these rings alternate on the two rolls, by working in conjunction, the full width of the web is removed. Each doffer delivers narrow strips or ribbons of
the web to a condenser. The condenser is a travelling apron having an oscillating or sidewise motion which reduces each strip, as it passes over it, to a small roll, called roving, or roping. These strands of roving go over guides and are wound side by side ready for spinning on a big spool, generally termed a jack-spool.

(2) Carding-Machine for Cotton.—The carding-machine for cotton is simple. The fibre has already been made into a thick lap. This is placed at the back and is fed directly to the card.

In place of the workers and strippers working on the surface of the large cylinder, there are revolving flats, a kind of endless lattice which is supplied with card clothing. The motion of the flats is like that of a travelling apron, continuous. They card the fibre, which is delivered in a thin web from the cylinder to the doffer. This is made to form a sliver by passing it through the trumpet and the drawing-off rolls and is then coiled in a can for the subsequent processes which prepare it for spinning.

The process in detail for all is as follows: If the raw fibre is fed to the card in bulk the amount delivered is regulated by the automatic feed at the back. If a lap is used, as in cotton, no automatic feed is necessary. The fibre passes in a wide sheet to one or more small rollers, and they, in turn, pass it on to the large cylinder, over which it goes, carded by the action of the teeth of the large cylinder and those of the flats, or the small cylinders. The fibres are opened, cleaned, separated, and finally removed by another small cylinder called a doffer, which has its teeth so arranged that it takes the fibre from the large cylinder.

The fibre comes from the doffer of the carding-machine in a wide, thin sheet or web. For convenience in handling, this web is made by various methods into a continuous, untwisted strand which, according to its size, is termed a sliver or a roving.
II. Spinning

Spinning is the drawing out and twisting of fibres to form a continuous strand or yarn. It is not known when or how the discovery was first made that certain fibres could be spun; that is, could be drawn out and given enough twist not only to hold the fibres together but to make them sufficiently strong for use.

1. Hand Spinning.—When spinning was first mentioned in early records, it had reached a stage of development at which it evidently remained for centuries. At that time the three fundamental processes—drawing, twisting, and winding—were done, with more or less difficulty, by the fingers. The first improvement came with the use of tools, when the spindle and whorl and the distaff supplemented the work of the fingers.

(1) Spindles.—The earliest spindles seem to have been merely straight sticks used for the winding of the continuous strand which the fingers had made by drawing out and twisting the fibres. This strand was kept from unwinding by tying it about the stick or fastening it in a notch at one end. Later the spindle was made to assist the work of the fingers in both the drawing and the twisting. After the fibres were attached to it, it was given a twirl and allowed to fall to the ground. In twirling, it twisted the fibres together into a strand, which was drawn out as the spindle fell. After a sufficient length had been twisted and drawn it was wound on the spindle and fastened. The spindle was then set twirling again and the operation repeated.

It was soon seen that the spindle fell more quickly and easily when it had yarn wound on it, so a weight, called a whorl, was added. It was probably, at first, of mud, clay, or stone. Later both spindle and whorl were made of wood, bone, and metal and much ornamented.

(2) Distaff, or rock. This was also a stick and carried the raw fibre. It was generally tucked under the arm or worn in the belt. This facilitated the work somewhat, as it left both hands free to draw out the fibres and operate the spindle.
2. The Introduction of Spinning-Wheels.—With the appearance of the hand-wheels at the last of the Middle Ages there was greater production. There was also a differentiation of method which still persists in modern spinning-machinery.

(i) Jersey Wheel.—The wool, great, or Jersey wheel was first used. It had a large and a small wheel placed on a standard and connected by a belt. The spindle was attached to the small wheel and both were turned by the revolutions of the big wheel. The worker stood. The motion was intermittent; that is, the twisting and drawing were done together by the turning of the spindle and the receding movement of the spinner. For winding, the motion of the spindle was temporarily reversed in order to bring the yarn into place. When this was done its regular motion was again started, and the spinner advanced toward it, guiding the twisted strand with her fingers.

The process in detail was as follows: One end of the carded roll of fibre was attached to the point of the spindle. This roll was drawn out or attenuated by the worker as she walked back away from the spindle to start the big
wheel. As the big wheel turned the spindle turned with it. The worker held the attenuated strand of fibre out, almost in line with the spindle, so that it could not wind on it but fell from its point at each revolution and in consequence was twisted rather than wound, each revolution of the spindle giving one twist to the strand. After the fibre was sufficiently drawn out and twisted, the big wheel was stopped and its motion reversed to bring the yarn into position on the spindle for winding. The spun yarn was then held at right angles to the spindle and nearer its centre; the wheel was turned in the original direction and the yarn was wound on the spindle.

(2) *Saxony Wheel.* — The Saxony or flax wheel, which next appeared, was of more complicated mechanism. It also had a large and a small wheel placed on a standard and connected by a belt. These wheels were turned by a treadle which was attached to the big wheel by a rod. The spindle was fastened to the small wheel and turned with it. In addition to the spindle, however, there was a bobbin and flyer.

In spinning, the yarn was wound on a bobbin rather than on a spindle as in the other wheel. The bobbin was a hollow cylinder which was put on over the spindle but not attached to it. It revolved with the spindle in the same direction, but more slowly, as it fitted loosely and was retarded in its motion by the winding of the yarn.

The purpose of the flyer was to twist the yarn. It was
shaped somewhat like a horseshoe but with its ends more spreading. It was attached to one end of the spindle and turned about it and the bobbin at the same rate of speed as the spindle. A series of hooks were placed on each prong of the flyer. These served to guide the yarn as it was wound on the bobbin. In order to bring the yarn into position for winding, it was passed through a hole or eye in that end of the spindle to which the flyer was attached, then carried around one hook in the flyer and fastened to the bobbin.

A distaff to hold the carded fibre was usually placed high at the front of the wheel. As this wheel was operated by foot-power, the worker sat. The motion was continuous; the worker guided and drew out the fibres, which were then twisted by the flyer and wound by the bobbin without interruption.

The process in detail was as follows: The fibre was taken from the distaff by the spinner and drawn out sufficiently to pass through the eye of the spindle. It was then carried over a hook of the flyer and attached to the bobbin. The big wheel was started by placing the foot on the treadle; this in turn started the spindle with its bobbin and flyer. The worker, who had both hands free, took the fibre from the distaff with her left hand and, slightly twisting and drawing it with her right, guided it to the eye of the spindle. The drawing, twisting, and winding went on continuously and followed each other. The drawing was done by the worker, the twisting by the rapid revolution of the flyer, and the winding by the slower revolution of the bobbin. It was not necessary to stop the wheel except for changing the yarn from one hook of the flyer to another in order to wind the bobbin evenly.

The product of these two wheels differed somewhat, the continuous motion of the flax wheel giving a harder-twisted, stronger yarn than the intermittent motion of the wool wheel.

3. The Development of Spinning-Machines. — In the latter part of the eighteenth century various spinning-
machines appeared. Their appearance was due to a demand for an improved quality of yarn and for a much greater product than could possibly be supplied by the use of the hand-wheels. Two spindles could be used on a spinning-wheel, but this doubling of the productive power of some wheels did not in any way meet the demand, which was soon still further increased by the invention of a fly-shuttle for the loom. Formerly the two industries, spinning and weaving, were evenly balanced. With this invention, however, more yarn could be woven than could be supplied by the spinners.

The underlying principles of the spinning-machines which were invented seem to have been borrowed from one or the other of the hand-wheels.

(i) Spinning-Jenny.—The first important invention was made by James Hargreaves about 1764. His machine was called a spinning-jenny. Its principle was like that of the wool or Jersey wheel. The motion was intermittent; that is, the drawing and twisting were done together, followed by winding.

The jenny had an oblong frame. Across one end of it were (a) eight or ten upright spindles. Over the spindles were (b) the wires, which could be regulated to place the roving in position for twisting, and later the spun yarn in position for winding, as required. The spindles were operated by (c) a big wheel which was at one side of the opposite end or back of the frame. The wheel was connected by (d) a belt with (e) a cylinder placed in the centre of the lower part of the frame. This cylinder had (f) a separate belt or cord for each spindle, and as it revolved with the turning of the wheel the spindles were made to revolve also.

Set near the cylinder in the lower part of the frame was (g) a creel which held (h) bobbins of the roving to be spun. There were as many bobbins as upright spindles. On the top of the oblong frame, extending from side to side, was (i) a carriage which, set on wheels working in grooves made in the framework, could be pushed back and forth the length of the frame. Across this carriage was (j) a
holder which could be regulated to allow the roving to pass through it or to be firmly held as desired.

The process in detail was as follows: The carriage was placed in front of and close to the upright spindles; the ends of the roving were brought up from the creel and passed through the holder of the carriage; each end was then attached to one of the spindles. When the roving was fastened to their points the spindles could twist in the turning, as in the big wheel, but because of the guide wire they could not wind.

To begin spinning, the worker turned the wheel, causing the spindles to revolve. Having thus started the twisting, with the other hand he drew the carriage some distance away from the spindles, letting out a length of roving. When enough roving was delivered the holder on the carriage was closed and held the roving. The carriage was then drawn back the full length of the frame, while the spindles continued turning. As a result, that length of roving was both attenuated or drawn out and twisted. When the carriage reached the far end of the framework, it was stopped and backed a little to loosen the tension of the yarn so the spindles could continue to turn and give a still tighter twist to the drawn-out yarn.

When twist enough had been given, the spindles were stopped and the guide wire was adjusted to press the yarn down on the spindles in position for winding. The turning of the spindles was then continued and, as the carriage was sent slowly back toward the spindles, the twisted and drawn-out yarn was wound on them.

While the operation of this machine was slow and tedious, yet it was an improvement, as it had eight or eleven spindles working at one time in place of the one or two of the hand-wheels. It helped in amount of production, but the yarn it made was softly twisted and not very satisfactory for use as warp.

(2) Water-Frame.—Arkwright's water-frame was the next invention, about 1768. It was first run by horse or water power, as it was an exceedingly heavy machine. Later steam was used. Its principle was in general that of
the Saxony wheel. The motion was continuous, the drawing, twisting, and winding being done separately but continuously.

In addition to the bobbin and the flyer, which were used for twisting and winding, a series of rollers, called drawing-rollers, were introduced to draw out the roving. The machine had an upright frame, on the top of which, at the back, was placed the roving to be spun. In front of the roving were (a) the sets of drawing-rollers revolving at different speeds. Placed somewhat below these, and at the very front of the frame, were (b) several upright spindles provided with (c) bobbins and flyers.

The process in detail was as follows: The roving passed from its spool, or bobbin, through the two sets of rollers. The set at the back which first received the roving moved slowly; the other set moved much more rapidly. Consequently, as the intake of the second set was greater than the output of the first, the roving was drawn out or attenuated. The roving passed from the rollers through the hole or eye in the top of each spindle, and over the hooks on the flyer which twisted it, to the more slowly moving bobbin on which it was wound.

The introduction of this machine marked the beginning of successful roller-drawing which is employed in nearly all modern spinning. Formerly, in the wheels and even in the jenny, the amount of drawing which the yarn received was dependent on the worker, and might, in consequence, be very uneven. With the use of rollers the drawing was governed entirely by machinery. As a result the yarn was more even in quality and, due to the continuous motion of the water-frame, harder twisted. It was a more satisfactory warp-yarn than that of the jenny.

(3) Crompton’s Mule.—A machine which combined the most valuable points of the water-frame and the jenny appeared about 1779. It was the invention of Samuel Crompton. Its motion was intermittent. It was called a mule because of the combination of parts of the two machines, Crompton having used Arkwright’s drawing-rollers and combined with them Hargreaves’s movable
carriage for more drawing and his upright spindles for the twisting and winding. At the top and back of the stationary part of the machine the roving was placed as in the water-frame, and immediately in front of it were (a) sets of rollers operating at different speeds. The (b) upright spindles were placed on (c) the carriage, which travelled away from and toward the rollers on a track some feet in length. The (d) spindles were made to twist and wind the strands alternately, much as in the spinning-jenny, by their turning and by the use of the (e) guide wires and the movement of the carriage. This machine combined drawing by rollers with drawing by the receding of the carriage.

The process in detail was as follows: The carriage with the spindles was drawn close to the drawing-rollers. The roving from the creel of bobbins at the back was passed through the rollers and attached to the point or end of the spindles, where it was held by a guide wire. As the rollers delivered, the carriage withdrew on its track and the spindles turned, so that the strand was drawn by the rollers and twisted by the spindles at the same time. After the required length of roving had been delivered the rollers were stopped but the carriage continued to recede to draw out the roving still more. When the carriage reached the end of the track it stopped, the tension was loosened by a slight backing of the carriage, the spindles continued to turn to give extra twist, and then they also stopped. Another guide wire placed the yarn in position for winding on the spindles. The motion of the wheel was reversed and the carriage returned to its original place, while the spindles were turning to wind the yarn.

This machine forms the basis of the modern self-acting mules. Even when first invented the mule was more satisfactory and more used than the jenny or water-frame. Various improvements were made from time to time in the various parts of it, but it was not until about 1830 that it was made self-acting.

4. Types of Modern Spinning-Machines.—There are two general types of spinning-machines in use now: the mules
and the upright spinning-frames. Both types have developed from the two hand-wheels through the series of machines just described. The mules are based on the wool-wheel and spinning-jenny, and the spinning-frames on the Saxony wheel and water-frame, both having added rollers for feeding or drawing. The underlying principles have been the same throughout as those of the early wheels, but the modern machines differ in that all the processes of drawing, twisting, and winding are done by complicated machinery, which can operate many hundreds of spindles at one time, while the spinner using the hand-wheels must do some of the work herself and in consequence cannot, at best, manage more than two spindles. In running the modern machine these mechanical contrivances enable the worker to produce probably more than a thousand times as much yarn as can be produced in the same length of time on the wheel.

(1) Mules.—There are two kinds of mules, one which is used in the spinning of woolen yarns, the other which is used in the spinning of worsted and cotton yarns. Both are based on the Crompton mule and are alike in general method of procedure. Both have rollers which guide and feed, or draw; upright spindles placed on a movable carriage which travels back and forth on a track averaging from sixty-four inches to seventy-two inches in length; and faller wires which guide and maintain the tension in winding. In both machines the motion is intermittent, the drawing and twisting being done on the outward journey of the carriage and the winding on the return.

In the winding, one section of the bobbin or cop is filled at a time. End-to-end winding is not done as it is on some of the spinning-frames.

(a) Woolen Mule.—The roving for this comes from the woolen card and is on a jack-spool, which is placed at the back of the stationary structure of the machine. Directly in front of the roving are the guide rail and feed-rolls. These rollers do not draw, but they are arranged to regulate the tension and guide the roving as it is fed to the spindles. The drawing of the roving is done by the con-
continued recession of the carriage after the feed-rolls have ceased to deliver. The twisting and winding are alternately done by the turning of the spindles, which are provided with bobbins and guide wires, called fallers, and are so placed in the carriage that they slant a little forward toward the machine. This slant causes the roving to drop off the point of the spindle as it revolves on its outward journey, so that the roving is twisted and not wound.

In detail the process is as follows: The carriage with the spindles is drawn close to the stationary machine. The ends of roving are carried from the jack-spool over the guide rail, through the feed-rolls, and attached to the spindles.

As the carriage withdraws, the feed-rolls deliver and the spindles turn. No drawing is done at first. When about half the journey of the carriage is completed, however, the feed-rolls stop delivering, and as the carriage continues to withdraw, the roving already delivered is drawn out and reduced in size. The spindles are twisting all the time, and even after the carriage has reached the end of the track they continue turning to give additional twist.

While this final twist is put in, the carriage moves back a very little toward the machine to free the tension on the yarn, as it is somewhat shortened in length by the twisting.

When enough twist has been given, the spindles are stopped, the yarn is backed off the top of the spindle and placed in position for winding. The faller wires drop into position, one serving as a guide in the winding, the other maintaining the necessary tension, while the carriage returns and the spun yarn is wound.

(b) Worsted Mule.—The roving for this comes from the roving-frame and is generally on shells which are placed in a creel at the back of the stationary machine. Directly in front are the guide rail and drawing-rollers. There are two sets of rollers which draw, and between them are two more sets whose purpose is to guide and maintain an even tension on the roving.

All the drawing is done by the rollers; the recession of the carriage merely gives opportunity for greater length of
gyration in the twisting, which keeps the fibres in better shape and gives a yarn more regular in size and even in twist. The twisting and winding are done alternately by the turning of the spindles, which are provided with tubes, on which the spun yarn is wound, and with faller wires. The spindles are set to slant forward as are those of the woolen mule.

In detail the process is as follows: The carriage with the spindles is drawn close to the stationary machine. The ends of roving are carried from the shells through the guides and rollers and are then attached to the spindles.

The front rollers turn at greater speed than those at the back, and the roving is thus drawn out and attenuated. As the carriage withdraws, the drawing-rolls deliver this attenuated roving and the spindles turn to give it the necessary twist. The carriage moves at a rate of speed which keeps the roving taut while the twisting is going on but which does practically no drawing. Additional twist is put in after the carriage has reached the end of the track. Exactly as in the woolen mule, the winding is done by the aid of the faller wires as the carriage returns.

A mule requires a skilled attendant, as it is an exceedingly complicated machine. Men are usually employed for this work. A man with attendants can take care of two machines. The number of spindles on a machine differs, as does the distance which the carriage travels, both depending on the kind of yarn spun.

A woolen mule generally has about four hundred spindles, a worsted about six hundred, while a cotton may have from six to twelve hundred, according to the size of the yarn.

(2) Upright Spinning-Frames.—There are three kinds of upright spinning-frames in general use for the different fibres: the ring, the cap, and the flyer.

These are all based on the Arkwright water-frame and are alike in their method of drawing, but vary in the contrivances used for twisting and winding.

In the original water-frame the twisting was done by a flyer. It did not prove satisfactory, however, for the high
speed necessary in the majority of the modern machines, and other inventions took its place. The flyer is still used, but much of the work in spinning formerly done by it is now done by a ring and traveller or by a cap.

All the spinning-frames have drawing-rollers and upright spindles with bobbins. The motion is continuous, the drawing, twisting, and winding being done separately but continuously. In the winding, the cop may be formed either by filling the bobbins in sections (filling wind) or by end-to-end winding (warp wind).

(a) Ring Spinning.—In this process big spools of roving as they come from the roving-frame are placed at the back of the upright frame. Just in front, but on an incline, are arranged the series of drawing-rollers. These differ in their rates of speed, the front set going faster than those at the back in order to draw out the fibre. Below these and at the front of the machine are the spindle and bobbin, which are turned by power. They are enclosed by the ring, which carries the traveller. The spindles are upright and are attached to a stationary rail. They pass through circular openings in another rail or platform, called a lifter, which is so arranged that it moves up and down the length of the bobbin. In the circular openings are placed stationary rings with flanges. Sprung on each flange and revolving on it is a small wire ring called a traveller.

In detail the spinning process is as follows: The roving goes through the drawing-rollers and is attenuated. It is then passed through the traveller and fastened to the bobbin. The spindle with its bobbin revolves rapidly. The tension of the thread between the rollers as they deliver and the bobbin as it revolves rapidly causes the traveller to turn, but, in turning, it lags behind the bobbin, so that in revolving it not only twists the attenuated yarn, which it receives directly from the rollers, but winds it on the more swiftly turning bobbin. The winding is regulated by the movable platform, or lifter, which carries the ring and traveller. It rises and falls, winding the yarn evenly.

The ring is generally used in the spinning of cotton, but is seldom used for worsted except for twisting after spinning.
(b) **Cap Spinning.**—The machine for this process differs mainly in having a cap in place of the ring and traveller. The spindle is upright and to the top of it is attached a metal cap. Both are stationary. On the spindle is a bobbin which is driven by power. This bobbin moves up and down as well as around on the spindle and winds the yarn evenly. In order to wind on the bobbin, the yarn coming from the drawing-rollers must revolve about the cap, the lower edge of which guides it in the winding.

In detail the spinning process is as follows: The roving goes through the drawing-rollers and is attenuated. It is then brought through an eye in a guide rail, down over the cap, and attached to the bobbin. The power turns the bobbin, and by its swift turning the thread is made to balloon rapidly about the cap and in this way is twisted as it is wound.

Yarn which is spun on the cap very frequently has many loose fibre-ends, which stand out. This is caused by the speed with which it is whirled through the air about the cap.

Cap spinning is used very largely for worsted.

(c) **Flyer Spinning.**—The machine for this process differs in turn from the other two in that its twisting and winding are done by a flyer.

The spindle is upright and has the flyer attached to it and moving with it. On the spindle is a bobbin which is turned, as was the traveller in ring spinning, by the tension of the yarn. It also moves up and down to wind the yarn evenly.

In detail the spinning process is as follows: The roving goes through the drawing-rollers and is attenuated. It is then brought down through the eye of the fly-board, or guide, through a guide called a twizzle in the end of the flyer, and attached to the bobbin. As the spindle is turned by power the flyer turns with it and twists the yarn. The tension of the yarn moves the bobbin, on which, as it revolves more slowly than the flyer, the yarn is wound.

The flyer is used on the spinning-frames for the long fibres, like linen, mohair, alpaca, hemp, jute, and long
wools, when a smooth yarn is desired, and on the so-called fly-frames which by drawing and twisting prepare the cotton roving for spinning.

The upright spinning-frames are much simpler in operation than the mules. The machines are usually so placed that many spindles can be watched at the same time by one attendant.

III. Weaving

Weaving consists in interlacing at right angles two or more series of threads, of which the lengthwise are called warp, and the transverse woof, weft, or filling. In weaving, the warp-threads are always arranged first and the filling threads are then interlaced in various ways, as required by the design. Weaving was at first done by hand, with but little assistance in the way of mechanical devices, and yet the products of the most perfected of the power- looms of to-day have never surpassed the beauty of the texture and design of those hand-made materials.

1. Hand Weaving.—The first weaving was, without doubt, exceedingly simple. The warp and filling threads were probably alike, and were of material which could be handled easily, such as grass, reeds, and leaves. The size of the finished product was dependent on the length of these materials. The design was the simplest,—the plain weave,—over one, under one, alternating with each row.

As has been said, in all weaving the warp materials, or threads, are first arranged in parallel order. To interlace the filling, certain of these warp-threads must be lifted by some means, probably at first by the fingers, and the filling passed in and out. Each row as it is put in must be carefully pushed close to the last; otherwise the interlacing will not appear regular and the fabric will not be firm when completed.

The lifting of the warp-threads to open a path for the filling was called shedding, or opening a shed; the passing of the filling through the shed was called picking; while the pushing of the rows of filling into place was called
battening, or beating up. These three fundamental steps or processes are present in all weaving operations, whether of hand or machine, and take place always in the same order. The gradual evolution of the stationary loom and the later use of power-machinery have affected only the exactness and speed of the work, and not the method of procedure.

The first efforts to make weaving easier seem to have been by the use of (a) two sticks or beams, to which the ends of the warp were attached. These stretched the warp and kept it in place, so that the interlacing of the filling was less difficult. Later, when materials of greater length were made, these same sticks served still other purposes. On one, called the warp-beam, was wound the extra length of warp to be woven; on the other, called the cloth-beam, was wound the finished fabric.

To facilitate the work further, a stick was put through the warp and so attached to it that all the desired threads could be raised at once, rather than one at a time, as by the fingers, thus making a better shed for the more rapid insertion of the filling. This stick, called (b) a heddle, has developed into the complex harness of the modern loom, and has still the same function, that of forming a shed. Another stick, on which the filling was wound and which took the place of the fingers in passing it through the shed, later became (c) the shuttle, and carried the bobbin wound with filling. Still another stick, which was called (d) a batten, lay, or lathe, and was used to push the filling-threads together to make a firm fabric, is to-day represented in the loom by the reed, which does the beating up or battening.

2. The Appearance of the Hand-Loom.—Improvements and changes in all devices led in time to the construction of what was called in Europe the hand-loom, and later, in America, the Colonial loom. This loom had a stationary, square framework which held a revolving beam at the back on which the warp was wound, (a) the warp-beam; and another beam at the front which received the finished cloth as it was woven, (b) the cloth-beam. Between these
two beams and near the front was \( c \) the harness for opening the different sheds. There were two or more of these harnesses, the number depending on the elaborateness of the design to be woven. Each harness was made up of a series of healds, or heddles, or cords, suspended between two flat strips of metal or wood. To form a heddle, a cord was

so knotted as to make an eye or loop at the centre through which one warp-thread might be passed when the loom was set up for operation. The harness was suspended from the top of the frame of the loom by cords and pulleys and was worked by \( d \) treadles. In a simple design one treadle usually operated one harness. In front of the harness was the lay, or batten, now become \( e \) a reed, a metal comblike arrangement enclosed in a wooden framework. This was so arranged that it could be moved as required, backward, out of the way of the shuttle when the shed was open, or
forward to beat the filling into place. The warp-threads were drawn from the warp-beam through the different harnesses, according to the design, and through the reed, and then attached to the cloth-beam at the front. Near the warp-beam two sticks, called (f) lease-rods, were interlaced through the warp, to help in keeping the warp-threads taut and to prevent tangling. These sticks were used in the primitive looms, but, unlike the other sticks, their form remained practically the same for the most modern loom. The tools necessary in weaving were (g) the shuttle with its (h) bobbin, or quill, and a cloth-stretcher, now called (i) a temple. Generally the filling-thread was wound on a quill, or bobbin, and placed in the shuttle, which carried it back and forth through the warp for the interlacing. The shuttle was of wood and usually boat-shaped. It is much the same in the power-loom to-day. The temple kept the material at the proper width as it was woven. In putting in the filling-threads it was very easy to make the fabric narrower than intended, by pulling the threads too tightly. To prevent this the stretcher or temple was placed in the material close to the end which was being woven, thus keeping it stretched to the right width. It might be made of wood or metal; its length could easily be changed to suit the width of the material, and at each end were teeth to catch in the cloth. The temple has now been entirely changed in form and become a part of the loom. It is generally a small cylinder set with pins or teeth and placed at each side of the loom near the front. It is turned by the friction of the cloth. Its teeth catch the edge of the material as it is woven and drawn forward to the cloth-beam, or roll, and keep it stretched to the proper width.

To operate the hand-loom for the plain weave—one over, one under—the process in detail is this: Two harnesses are required, through one of which the even threads—2, 4, 6, 8—are drawn; through the other the odd—1, 3, 5, 7. All the threads in regular order—1, 2, 3, 4, 5—are then passed through the reed and carried forward to the cloth-roll and fastened. The warp must be so wound that there is an
even tension on each thread. One treadle operates one harness, which in turn operates the one set of threads passing through it. This opens a shed. To weave, a foot is placed on one of the treadles and it is pressed down. This opens a shed by drawing down or depressing one set of threads. The shuttle carrying the filling is thrown through this opening or shed. The reed is then brought forward and pressed firmly against the filling-thread just put in to beat it into place; the next shed is opened by pressing down the other treadle; the shuttle is thrown back again, and thus the work continues. The later hand-loomss had an automatic arrangement for unwinding the warp and winding the cloth as the weaving progressed. The power-loom is essentially the same as the more modern hand-loomss.

3. Inventions.—The first two important inventions were made in weaving while the hand-loomss were still in use. These were the fly-shuttle and the drop-box.

(1) Fly-Shuttle.—With the invention of the fly-shuttle in 1733 by John Kay one person could manage an ordinary loom, where before two were needed to send the heavy shuttle back and forth. The arrangement of the fly-shuttle was this: At each side of the loom was a box for the shuttle, and in each box was a driver. These drivers were connected by a cord which had a handle at the centre of the loom. By drawing the handle sharply the driver, in the box containing the shuttle, struck the shuttle and sent it across through the shed.

(2) Drop-Box.—The drop-box, invented by Robert Kay in 1760, was an arrangement by which bobbins carrying various colors of yarn could be brought into place and sent through the shed automatically as desired, without stopping the loom, as had been necessary formerly.

4. The Use of Power-Looms.—Many attempts were made to operate a loom by power. In 1785 a heavy automatic loom was invented by Doctor Edmund Cartwright. It became the basis for the modern power-loom.

(1) Plain Harness-Loom Weaving.—In the power-loomss used to-day all the old operations are present but are
now done practically by machinery; and in addition there are various devices for holding and changing shuttles, replacing empty bobbins, and stopping the loom if warp or filling threads break. All power-loomsin without special devices are limited as to pattern, because the pattern is dependent on the number of harnesses, and only a comparatively small number—about thirty—can be used conveniently in one loom. Each harness can control a large number of warp-threads, but it can open only one shed. After exhausting the number of harnesses which a loom can carry, the weaving can be continued only by repeating the pattern just made by these harnesses.

(2) Pattern-Weaving.

(a) Jacquard Loom.—The difficulty of repetition of pattern was met by the invention of the Jacquard loom. In this loom the warp-threads may be operated separately rather than in groups, which allows a practically unlimited variety of patterns to be made. Each warp-thread passes through the eye of a harness-cord, which is attached to a hook overhead. Each hook is in turn attached to a horizontal needle and operated by it. All these needles are driven forward by springs, against the face of a cylinder. This cylinder has four sides, and over it go the perforated cards which bear the design to be woven. Only those needles which, when driven forward, go through a perforation in the card affect the pattern. In entering the perforation they carry forward their hooks, which catch on a crosspiece, or griffe, in the loom and are held there; the other needles fall back into place, taking their hooks with them, and the warp-threads which are connected with them are lowered. In this way a shed is formed. As there are many sets of these needles, many sheds may be opened and a very elaborate pattern made. The expense in setting up the loom and in making the design and perforating the cards is somewhat of a drawback to its use.

(b) Harness-Loom Attachments.—There have been many devices invented which may be attached to the harness-loom to secure special results.

There are two in very general use which accomplish
somewhat the same results as the Jacquard, with less expense. These are the Dobby and the Head-motion. The Dobby is an English invention. In this attachment the pattern-cards of the Jacquard are replaced by an endless chain of narrow strips of wood, called bars. These have rows of holes in which pegs may be placed according to the design. Each bar opens one shed. The bars move around a cylinder and operate levers which lift hooks. The hooks in turn raise the harness fastened to them and open the shed. The Head-motion is an American invention. In this attachment the pattern-cards of the Jacquard are replaced by an endless chain of rods on which are movable collars, called risers and sinkers, which operate the harness and give much the same results as do the pegs of the Dobby.

Other less elaborate attachments are used to secure special effects. By an attachment called a lappet, which is practically an additional harness set in front of the reed, designs are added to the face of the cloth which give the effect of embroidery. The swivel attachment gives much the same result as the lappet but is more often used in the more expensive fabrics. Terry fabrics, like Turkish towelling, are made by a specially arranged reed which beats up the thread firmly only on every third or fourth pick. This, with an additional warp which is loose, gives the loops which are its characteristic. For warp-pile fabrics there must be added to the regular loom equipment a series of wires, with or without knife-edges, which bring up into loops, at right angles to the foundation warp and filling threads, an extra warp-thread and thus form a pile.

5. Preparation of Warp and the Threading of the Warp for Hand and Power Looms.—Preliminary to all weaving are two important processes, the preparation of the warp and its threading into the loom. In general, the method of procedure for both is somewhat the same in the hand and power loom. In the hand-loom the warp is prepared and drawn in entirely by hand. In the power-loom the preparation of warp is by machinery. It is not so in every case with the threading, which, when many harnesses are
used, is a rather difficult operation and requires not only patience and time but skill.

(i) **Hand-Loom.**—For the hand-loom the processes of warp preparation and threading are generally as follows:

(a) **Preparation of Warp.**—The number of warp-threads required and their length depend on the width and length of the material to be made. The yarn comes wound on bobbins from the spinning-wheel. In spinning, the amount of yarn wound on each bobbin is not uniform, and in order to secure even lengths for the warp the yarn must be measured. This is done by winding the desired lengths into skeins on a reel which somewhat resembles a wheel. From the reel the skeins are put on a swift and wound back on bobbins, the required length to each bobbin. To transfer the yarn to the warp-beam of the loom, several bobbins are placed in a bobbin-frame, and the threads from these are wound on warping-bars which are of various kinds. This operation is repeated until enough lengths to give the required width have been prepared. From the bars the different groups of threads are transferred by various methods to the warp-beam of the loom. In this transferring they pass through the teeth of a comb-shaped guide, often called a raddle, which is placed near the warp-beam and helps in keeping the threads separated and in winding them on the beam evenly and smoothly. Two people are needed for this operation, one to watch and guide the threads, the other to turn the beam.

In winding the threads on the warping-bars a cross, or lease, must be made in them at one end. Through this the lease-rod is to be placed as the warp is set up in the loom.

(b) **Threading.**—When the warp is wound on the beam and the cross is secured by the placing of the lease-rod, the ends are drawn, as the pattern requires, through the harness and then through the reed. A reed-hook, resembling somewhat a flattened crochet-hook, is used to pull these threads through the eyes of the heddles and the dent, or teeth, of the reed.

The simplest weaving design, the plain weave, requires
two harnesses—one for the odd threads, one for the even. In threading, care must be taken to keep the threads in the regular order in which they come from the warp-beam. One harness is threaded at a time. In doing it, thread No. 1 goes into the eye of the first heddle, No. 2 goes between the first and second heddles, No. 3 goes into the eye of the second heddle, and No. 4 between the second and third heddle, and so on. This is followed by drawing the even threads, which were passed between the heddles of the first harness, through the eyes of the heddles in the second harness.

The reed then receives both odd and even threads in regular order—1, 2, 3, 4, 5, etc. After the threads are drawn through the reed their ends are tied together in groups. A stick is passed through these knots and is firmly attached to the cloth-roll. The loom is then ready for work.

(2) Power-Loom.—For the power-loom the processes in general for the preparation and drawing in of warp are as follows:

(a) Preparation of Warp.—By machinery this operation is comparatively simple. It differs somewhat in detail, however, for the different fibres.

As in the hand-loom, the width and length of the material decide the number and length of the warp-threads. All yarn, as it comes from the spinning, is on bobbins, or cops. From the bobbins it is wound on big spools; that is, it is made into larger packages for greater convenience in handling. These packages are placed in frames, or racks, and the yarn wound by different methods on to the warp-beam. In the preparation of some warps for the power-loom it is necessary to add sizing to the yarn in order to strengthen it to withstand better the wear of the weaving-machinery. This is usually done by passing the yarn through a tank of sizing, after which it must be carefully dried. All warp must be evenly wound; otherwise, as the weaving progresses, the warp will not feed with an equal tension on each thread.

If the warp is very fine, as is frequently the case in silk,
thin paper is placed between the layers of thread as it is wound on the warp-beam.

(b) Threading.—The threading of power-loom is now done both by hand and by machine. The method in general parallels that of the hand-loom. As the threading of any loom takes time and skill, when a warp is no longer of use or its length exhausted, all the threads are carefully tied in groups back of the harness. The new warp is then wound on the beam by the usual methods, and each new warp-thread is twisted or tied to an old one and drawn through the harness. This can be done much more quickly than can the regular threading.

II. Processes of Manufacture for Cotton, Wool, Silk, Linen, and Other Lesser Fibres

There are four general classes of fibres:

1. Animal—wool, silk, and mohair.
2. Vegetable—cotton, flax, ramie, jute, and hemp.
4. Artificial—artificial silk and spun glass.

The four important fibres—cotton, wool, silk, and linen (flax)—are those most used in the manufacture of clothing and consequently are those chiefly discussed here. Cotton, wool, silk, and linen fibres are, when manufactured, suitable for use both in undergarments and in outside garments. In this chapter, however, both the fibres and fabrics are considered only as to their suitability; that is, their wearing quality from the standpoint of dressmaking.

1. Cotton

Cotton is a vegetable fibre. It is the hairs which are attached to the seeds of the cotton-plant. While growing, they are enclosed in the pod formed after the flower dies. The fibre is made up of a single cylindrical cell which collapses as the pod bursts and the air reaches it, and becomes ribbonlike, with thickened edges and an irregular spiral twist. This twist is important, since it assists in the interlacing of the fibres in spinning.
There are many varieties of the cotton-plant. The value of the fibre depends somewhat on the variety, but the desirable qualities—color, length, strength, smoothness, fineness, pliability, and uniformity—are greatly affected by the climate, soil, and cultivation.

1. Field Picking.—Cotton must be picked as soon as it is ripe. The picking is done both by hand and by machine, and an effort is made to pick only the ripe fibres, as the presence of the unripe injuriously affects the character of the whole. It is a tedious operation and often badly done because of the great number of people required for the work and the consequent necessity of employing unskilled labor.

2. Weighing.—Cotton is weighed after the picking. About two-thirds of its weight is due to the seed which is still attached to the fibre.

3. Ginning.—Ginning is the next process; it separates the seed and the fibre. There are two general kinds of gins—the roller-gin, which seems to have developed from primitive methods and is now used chiefly for long-staple cottons, and the saw-gin, which was invented by Eli Whitney and is more generally used but often tears and injures the fibre. In the roller-gins the seed is removed by passing the fibre over a roller against the surface of which a kind of knife operates and separates seed and fibre. In the saw-gin revolving circular saws separate fibre and seed by pulling the fibre from the receiving hopper through a grating which is too fine for the seeds. If the cotton is fed into this hopper too rapidly, knots, or nep's, will result and interfere later with the spinning process.

4. Baling.—From the gin the cotton is carried to a condenser and then baled. In this process it is subjected to pressure, covered with jute or some similar material, and bound with metal bands. Before transportation the bale is usually subjected to more and greater pressure in the cotton compress. This makes it the required size for shipping, but does not improve its appearance, as the covering often bursts in many places.

These processes—picking, ginning, and baling—might
be called preliminary processes. Those which follow have to do with making the fibre into yarn, and they vary somewhat; that is, the number of processes used and the quality of yarn made, depend on the effect and quality desired in the finished product.

Before giving the mill processes, it is necessary to explain that nearly every mill manager has a different method of procedure. The attempt is made here to show a representative method which includes the number and variety of general processes required and places them in an order followed by many mills. No attempt is made to explain intricate machinery.

5. Opening.—After the bales are opened at the mill the cotton is usually mixed to establish a uniform quality. This mixing may be done by hand, but is usually done in a machine called a bale-breaker, which cleans the fibre as well. The cotton from various bales is carried on a travelling apron, or lattice—a feed which regulates the amount—and fed to a beater, after which it is usually sent through a cleaning-trunk and delivered to another beater. In the trunk the fibre is shaken up and carried forward by a draft of air, and the dirt, which is thus removed, settles and the two are separated. The beaters are cylinders set with heavy teeth; these seize the cotton and throw it against a grid through which the dirt goes. The fibre is then taken up by other teeth and thoroughly opened up. By means of condensing-rollers it is delivered in the form of a thick web.

6. Picking.—Machines called pickers follow. There are usually three, the breaker-picker, intermediate picker, and finisher-picker. These are in general principle like the bale breaker or opener in that they have beaters and condensing-rolls. In many mills the bale-breaker is omitted and its work done by the breaker-picker.

Each picker has attached to it an automatic feed, which receives the fibre from the previous machine and regulates by pressure the quantity to be delivered to the beater. These pickers remove the dirt, separate the tufts of cotton, and finally deliver it in a lap which is wound into a roll on
a shell and is then ready for carding. The three machines are used, because by repeating the beating and condensing processes the final lap is made much more uniform and the fibre much cleaner.

7. Carding.—The roll of lap is next placed at the back of a carding-machine. The purpose of this machine is to separate, clean, and arrange the tangled fibres.

As already explained, the carding-machine has a large cylinder the surface of which is covered with small wire teeth which are turned in the direction in which the cylinder revolves. Above this cylinder and coming in contact with it are revolving flats, a kind of endless lattice with teeth, which are turned in the opposite direction to those of the cylinder. The cotton is fed in between these two sets of teeth, and is straightened and cleaned by them and the poor fibres removed. The cotton comes from the machine in a continuous thin web, is condensed by the trumpet and drawing-off rolls into a narrow band, or roll, called a sliver, and coiled in a can. Double carding is sometimes done. (For detail in Carding, see page 53.)

8. Combing.—If a fine grade of yarn is required the cotton must next be combed. It is an expensive operation. Practically all mercerized yarns and such as are used for sewing-threads, batistes, and laces are combed. There are a few preliminary processes after carding before the sliver is ready for the combing. (a) Sliver Lap-Machine.—Several slivers from the cards are passed side by side through the rollers of a sliver lap-machine and made into one lap the required width, about ten or twelve inches. (b) Ribbon Lap-Machine.—A few of these laps are then combined by feeding them to a ribbon lap-machine, which delivers them as one lap more uniform in size than the product of the sliver lap-machine and ready for the comb. (c) Comb.—Some form of nip comb is used. There are several different makes, but the general method of procedure is the same for each. The comb removes from the lap all the short fibres and straightens and parallels those which are fairly uniform in length. There is much waste from this machine, called comber waste. It is used in cheap-grade
cotton fabrics. The combing is done by the action of combs set in cylinders, over which the lap passes, and by an overhead comb. Sections of the lap are held in position by the jaws of a nipper and combed one-half of the length at a time. When thoroughly combed these lengths are again made into a continuous strand, condensed, and finally delivered as a sliver and coiled in a can.

9. **Doubling and Drawing.**—The slivers, either from the card or from the comb, are next subjected to a process called doubling and drawing, the purpose of which is to continue paralleling and straightening the fibres, to make even the sliver, and to reduce it in size for spinning. This is accomplished by feeding from four to eight slivers to a machine called a drawing-frame which has a series of drawing-rollers. These rollers, like those of the upright spinning-frames, revolve at different speeds, the last set going much faster than the first. Because of this difference in speed the sliver is drawn and not only evened but reduced in size. Drawing may be done once, twice, or three times. From the last drawing-frame the fibre is again delivered as a sliver and coiled in a can.

10. **Drawing and Twisting.**—From the drawing-frames the sliver goes to the fly-frames, of which there are four. In many cases only three of these frames are used, depending on the quality of yarn desired. The four are called (a) the slubber, (b) the intermediate, (c) the roving, and (d) the fine, or jack frames.

The fly-frames have drawing-rollers, like those of the drawing-frames, but in addition they have a bobbin-and-flyer attachment, as, in these frames, the strand is so reduced in size as to require a twist to give sufficient strength for winding and handling.

One thick end or sliver is fed to the first frame, the slubber. It is drawn out by the rollers and twisted and wound on the bobbin by the flyer. The product of this machine is called slubbing. Several strands of slubbing are united when fed to the different fly-frames which follow. On each a strand still more reduced in size is twisted and wound on a big spool or bobbin. From the last, or
jack, frame it is called a roving, and is sufficiently small and has twist enough to be ready for spinning.

11. Spinning.—Spinning may be done on either of the two spinning-machines, the worsted mule or the ring spinning-frame; the latter, for many reasons, is more often used. On these machines the roving is reduced in size by the drawing-rollers and is then given a twist and wound on a bobbin or tube. Two strands of roving may be combined in the spinning. The product from any spinning-machine is a single yarn.

12. Twisting.—Many of the single yarns are doubled and combined by more twisting to give strength or to produce special effects in the weaving. Greater strength is more often necessary when the yarns are to be used for warp. The twisting-frames are like the upright spinning-frames except that they have no drawing-rollers.

13. Weaving.—For this some preparation of the yarns is necessary.

(a) The filling-yarns are wound on bobbins which are suitable for the shuttles. Filling-bobbins are always wound a space at a time and not end to end, as the yarn is thus delivered more easily.

(b) The warp-yarn requires more preparation, as it must be sized before it is wound on the warp-beam. The yarn is transferred from the bobbins to spools which are set up in a rack and the yarn wound from them to several warp-beams. From these warp-beams the yarn passes through a machine called a slasher, in which it goes through a tank of sizing and over a big drum for drying. It is then drawn through a guide and is wound, as the design requires, on one warp-beam ready for the loom. This sizing is to give the yarn sufficient strength for the weaving process; it is later removed during the finishing processes.

Cotton yarns are made into a great variety of materials, which include all kinds of weaves from the plain to the very elaborate. These may be made on the plain harness-loom or by special attachments, such as the Dobby and Head-motion, or on the Jacquard. A large number of cotton fabrics have the plain or cotton weave and are given vari-
ety by finishing processes or by a combination of yarns of
different color, size, or fibre.

14. **Finishing.**—The final appearance of cotton material
depends very much on the finishing processes employed
and on the dressings used after the weaving is done. Many
materials are alike in weave and the size of the yarn
used, yet quite unlike when ready for purchase. For ex-
ample, long cloth and cambric have the same weave, the
plain or cotton; but while the cambric has a somewhat
polished surface the long cloth has a dull one which shows
a little fluff or fuzz. This difference is made in the finishing.

Many of these finishes are often removed to some ex-
tent in the laundry and the appearance of the material
decidedly altered. For instance: in some cases loosely
woven cotton fabrics are made to feel and look firm and
thick by the use of sizing, which is somewhat like starch.
Water will dissolve and remove this and leave the fabric
as it originally was—sleazy and thin.

(1) **Regular Processes.**—No matter what is desired in
the appearance of the finished product, all materials from
the loom must be subjected to certain processes. These
usually include:

(a) **Inspecting and Marking for Repairs.**—The woven ma-
terial is drawn over a frame which is placed in a strong
light, and its defects are carefully marked. (b) **Repairing.**
—All the defects marked must be repaired; all broken
threads must be joined and any missing ones replaced,
otherwise the design in the finished fabric will not be com-
plete. This is especially important in cotton materials, as
the weave is seldom entirely concealed by any finish.
(c) **Singeing.**—This is done to one or both sides of the
material to remove the many short fibre-ends which show
on the surface. The material is passed through gas flames
with such rapidity that only the loose fibre-ends are af-
fected. To prevent any burning, however, the material
is immediately washed and dried. (d) **Starching, wet or
dry.**—All materials have some starch or sizing added dur-
ing the finishing. In many cases a loose weave and poor
quality of fibre are concealed by sizing, thus necessitating
a larger quantity. (e) Spraying.—This is done by forcing water on the fabric, much as sprinkling is done in laundry work preparatory to ironing. (f) Calendering.—All materials are pressed with heavy rolls. The detail of this process differs somewhat according to the finish required. For example: for gingham and long cloths, which do not have polished surfaces, cold rollers are used in the calendering, as merely rolling contact is required to give the desired result; for cambrics, which do have polished surfaces, hot rollers revolving at different rates of speed are used as heat and friction are required to give polish. (g) Bleaching, Dyeing, or Printing.—If material is to be white, it is necessary to bleach it. If it is to be colored, and the raw stock or yarn was not dyed, it is dyed in the piece. Many materials have a design printed on the surface of the fabric by some of the usual methods rather than woven in. Such fabrics usually require a preliminary bleaching.

(2) Special Processes.—Cotton, by special treatment, may be made to look like silk, linen, or wool.

(a) The general method of giving cotton the appearance of silk is by mercerization—a process in which the cotton is subjected under tension to a concentrated caustic alkali bath. As a result, the fibre becomes round, full, and rod-like and reflects the light sufficiently to give a lustrous surface. This can be more satisfactorily done to the yarn than to the woven fabric, but it is done to either.

(b) Many methods are used to make cotton cloth look like linen. None of the methods are permanently successful, because of the marked differences in the fibres, especially in the length and lustre. Much dressing is usually required, followed by beetling, or some allied process, and pressing. These give the fibre all the lustre and firmness it is possible to secure.

(c) Various methods are even more frequently employed to give a woolen or worsted effect; the most common is that of raising a nap on the surface of the fabric by using cylinders with napper clothing. The result gives such materials as outing flannel, flannelette, duckling-fleece, and blankets.
Cotton is the cheapest and the most used of the four important fibres. Because of its cheapness there is no need of adulteration; but, as has been said, it can be made to look like various other fibres, and in consequence is often used as a substitute. A few years ago cotton was said to supply nine-tenths of the material employed in the manufacture of clothing. That includes, of course, materials which are all cotton and many which are shown on the shop counters as all wool, all silk, or all linen.

The character of the various cotton fabrics manufactured is discussed under *Fabrics*.

II. Wool

Wool and hair are the most important of the animal fibres. They come from sheep and other similar animals, such as the angora goat, the camel, and the alpaca. Both wool and hair are used in manufacture and are subjected to much the same general processes. Chemically, they are the same, but in appearance they differ somewhat. Hair is generally rather stiff, straight, and lustrous. Wool is soft, flexible, elastic, and wavy.

Each wool fibre is formed from a series of cells in the skin of the animal. These cells are grouped about each other and are filled with a fluid which evaporates as the cells force their way, in series, through the cuticle into the air. The evaporation of this fluid allows the cell walls to collapse, one on the other, and as they are gelatinous they form a continuous stalk which is the fibre. On the surface of this fibre are scales or serrations, sawlike edges, which are made by one cell's overlapping another, as they collapse on reaching the air. These serrations and certain other characteristics, such as its cellular structure, give to the wool the shrinking, felting, or matting quality which is so valuable in manufacture.

There are many varieties of wool, depending chiefly on the breed of the sheep. There are also many different grades on any one sheep. As a result, wool fibres differ greatly as to length, strength, fineness, softness, elasticity,
lustre, number of serrations, and waviness. All these qualities cannot be combined in any one fibre, but in proper combination they have much to do with the value of the wool.

The wool industry as a whole includes two important clothing industries: woolen and worsted, both of which are not usually carried on in the same mill. The different processes necessary in the manufacture of each require different types of machines.

Almost from the first the wools intended for the two branches need quite dissimilar treatment. In the sorting and blending the method in general is the same, but it is done with a different result in view for each. The dusting and drying, on the contrary, are the same in method and result for both. Beyond the drying the processes differ very much.

The difference between a woolen and a worsted yarn is in the mechanical arrangement of the fibres in the finished thread.

The fibres in the worsted yarn are straightened and paralleled. All the processes in its manufacture, especially the spinning with its roller drawing, work toward that result. In many cases the beauty of the finished fabric depends on the twisting of the yarn and the clearness of the design and weave, and all the finishing processes applied are to aid in emphasizing that effect. Worsted fabrics include serges, whipcords, albatross, Bedford cord, etc.

The fibres of the woolen yarn, on the contrary, are as intermixed and interlaced as possible. The yarn in the spinning is always spindle-drawn, and in general the weave is chosen to give firmness as well as design to the finished fabric. Woolen fabrics include such materials as broadcloth, tweed, melton, and beaver.

1. Preliminary Processes for Worsted and Woolen.

(i) Shearing.—Sheep are sheared by hand and by machine. The wool, in the shearing, comes off in a whole sheet, called a fleece. Each fleece is tied up separately, and about forty are packed in a bag together for shipping. Paper twine is very generally used now for the tying, in
place of sisal and jute, from which the fibres are easily rubbed off and intermixed with those of the wool.

(2) Grading.—Wool grading is often done by the middleman before the wool is finally sold to a mill for manufacture. The qualities are determined without untieing the fleece and depend in general upon the cleanness of the wool, as affecting its shrinkage in the scouring, and the length and diameter, or fineness, of the fibre.

Following these two processes, shearing and grading, come those of the mill in which the wool is first prepared for manufacture by sorting and scouring and is then manufactured by various processes into yarns.

The kind of yarn and its quality affect the number and kind of processes necessary. As with cotton, an attempt is made here to show a representative method which includes in their regular order the number and variety of general processes required.

(3) Sorting.—This is the first process at the mill. Woolsorters are trained to detect the various qualities and can quickly divide a fleece into parts, the number of parts depending entirely on the use to which the wool is finally to be put. A fleece, in general, is divided according to length, fineness, and suitability of fibre. While the various required qualities are being separated, the undesirable parts of the fleece are also determined and assembled for other uses. Some wools, usually those from the Far East, are opened on tables provided with screens and having a downward draft of air which prevents the dirt from rising.

2. Special Processes for Worsted.

(1) Blending or Mixing.—Blending is done to secure a desired price and quality in the finished product. After the various mixtures are chosen they are spread out on the floor, in the right proportion, layer upon layer. In using, care is taken to secure the complete mixture by taking from the side of the mass rather than from the top.

(2) Dusting.—The purpose of the duster is to take out as much as possible of the loose dirt and sand. Dusting is not always considered necessary. If the wool has much sand and dust in it, however, soap is saved in the scouring,
which is to follow, by sending the loose fibres through the duster first. Generally, a machine called a cone duster is used. It has a cone-shaped cylinder made of wood or metal arms set with heavy pins, or teeth. The fibre is fed in at the small end of the cylinder, is carried by its revolutions to the big end, and thrown out at the back. There is a screen and fan at the top which takes away some of the dust, and a grid at the bottom against which the fibre is beaten and through which the dirt drops.

(3) Scouring.—The scouring or washing is to remove the chemical and mechanical dirt; that is, the grease, or yolk, a skin secretion, and any sand and loose dirt. These are found in all wools. The scouring must be carefully done or the fibre may be injured. Soap, with carbonate of potash, or carbonate of soda—depending on the wool—is generally used and followed by careful rinsing.

The wool-washer has (a) a self-feed which delivers a regular amount at regular intervals. The fibre is placed in the hopper of the feed and taken up by a revolving spiked apron. At the back of the apron is a stripper which knocks the surplus wool back into the hopper; at the front there are revolving drums which strike off all the wool, allowing it to pass over the apron and delivering it to be washed. (b) A series of tanks, three or four in number, as required. Each tank has a false bottom, or screen; this keeps the wool away from the dirt which settles to the bottom. In each tank there are rakes or harrows which take up the wool as it enters the tank and carry it slowly forward through the water, cleaning it and preventing felting or matting.

Between the tanks are squeeze rolls which act as wringers. They have an immense pressure and remove much of the liquid as the wool is passed forward through them. These rolls are placed over screens, and the liquid runs down into other large tanks and, after settling, is used again.

The first two or three tanks through which the wool passes contain some detergent; the last, pure water for rinsing.
(4) Drying.—Drying must follow scouring and may be done in various ways, but, whatever the method, care must be taken to maintain the correct amount of heat and moisture. A drier may be attached to the washer or it may be a separate machine.

One type of drier frequently used has a self-feed and a chamber which is kept at a certain temperature by steam-pipes, an inlet for fresh air, and an outlet for hot, moisture-laden air. In this chamber is a travelling wire apron with a fan underneath. The feed delivers the wool in regular amount to the apron, which carries it as a rather thin web forward through the heated chamber and dries it.

(5) Oiling.—Wool loses its natural oil in the scouring, and some must be added to make the fibre sufficiently soft and pliable and prevent static electricity, so that it will go through the remaining processes without injury. The oil is applied either by hand or by a simple spraying apparatus attached to some machine. Different oils, but usually olive-oil, are used in different mills.

(6) Carding.—Preparing.—After the drying and oiling the fibre is put through a carding-machine or a set of preparers. The choice of the machine used depends on the kind of fibre to be manufactured; that is, the cards are used for the medium and fine wools, the preparers for the longer wools, twelve inches or fourteen inches, and for mohair and alpaca, for which the cards are not suited.

About nine-tenths of all the worsteds are carded. The purpose of both the cards and the preparers is the same. They separate and clean the tangled fibres and deliver them in a continuous strand called a sliver.

(a) Cards.—A single or double cylinder card may be used. The double-cylinder card differs from the single only in having two large cylinders rather than one. These are connected by a doffer and an angle-stripper, which pass the fibre from the first to the second cylinder. The fibre is first delivered by an automatic feed to cylinders called licker-ins, which begin the opening and cleaning. On the licker-ins are burr-guards which knock off any burrs left in the wool. The large cylinders with their sets of workers and
strippers do the carding. The second cylinder is provided with a doffer and doffer-comb which removes the carded fibre. The fibre comes in a thin web from the second cylinder to the doffer and is taken off by the comb. It is then made into a continuous strand called a sliver by passing through a tube or trumpet and through drawing-off rolls, after which it is coiled in a can or wound on a ball. (For detail in Carding, see page 50.)

(b) Preparers.—The general result of the set of preparers is the same as that of the card, plus the work of machines called gill-boxes, which must always follow the card. The action and principle of the preparers, however, differ from those of the cards and are like those of the gill-boxes. At the back of the preparers is an apron-feed which delivers the fibres to rollers. These in turn pass the fibres forward to movable bars set with parallel rows of upright pins—a kind of comb, called fallers. These fallers automatically come up in front of the rollers, receive the fibre, and, moving forward faster than the rolls, comb the wool and then deliver it to two rollers at the front. These front rollers are moving at a faster rate of speed than the fallers, and they draw the fibre as it is delivered to them by the fallers and thus assist further in the straightening and drawing.

Usually five or seven of these preparers are used in sequence; from the last two or three the fibre is passed through a hole and condensed into a sliver and coiled in a can. When the sliver leaves the last preparer it goes directly to the comb.

(7) Gilling.—This process, which is a kind of combing and much resembles the preparing, must follow the card but is not used after the preparers. The work is done in a machine called a gill-box, which has drawing-rollers and fallers like the preparers. It continues the arranging of the fibres for the comb.

In this machine doubling and drawing are done as well as the preliminary combing. Several slivers, the number depending on the quality of the product required, are fed to the back rollers of the gill-box. From the rollers the slivers are carried forward by the fallers and delivered to
the more rapidly moving front rollers. The fallers are set with pins much finer than those of the preparers. After leaving the front rollers the fibre is made into a sliver and coiled in a can or wound in a ball.

For the fine and medium wools, after the double-cylinder card there may be generally two operations of gilling, one machine following the other, before the sliver is ready for the comb.

For coarser wools a single-cylinder card and one operation of gilling sometimes precede the comb.

(8) Combing.—The fibres in the sliver which results from any one series of the preceding processes are fairly well straightened and paralleled, but they are of uneven length. Both long and short are combined in one strand. To remove the short fibres and further straighten the remaining long ones, they are put through a rather complicated machine called a comb.

The Noble comb is most frequently used for worsteds, though the work can also be done by a nip comb.

For use in the Noble comb the slivers are arranged by winding in a punch or ball-winder. This machine has a plate with four holes for the sliver to pass through, two rolls in front of the plate which guide and keep an even tension, and a revolving spindle on which the winding is done. Four ends, or slivers, from the last gilling or preparing operation are passed through the holes and guide-rolls and wound side by side into a ball. The spindle is withdrawn from the balls and eighteen of these are placed in the comb.

The Noble comb is circular in shape. It has one large circle set with concentric rows of steel pins; the coarser pins are on the outside rows, the finer on the inside. On each side of the machine are two smaller circles; these are set inside and practically touch the big circle at one point. These small circles are also set with concentric rows of steel pins, but on these the fine are outside to be next the fine of the large circle and the coarse ones inside. The big circle and the two small circles revolve, and as they revolve there is always a point of contact between each small circle
and the big one. At this point of contact the strand of fibre is fed in and pressed down, or dabbed, into the teeth of the big and small circles. As the two circles revolve, the points at which they were in contact separate and the strand of fibre is drawn through the teeth of both circles and combed as they continue separating.

From a photograph, copyright by American Woolen Co., Boston

Noble comb

The short fibres, called noils, are removed by a knife. These are frequently, though wrongly, included in the list of wool substitutes. Noils are used in the manufacture of woolen fabrics, as they give many short ends which are useful in the teasling and gigging processes to raise the nap. The long fibre is taken from the circles by rolls, carried by travelling leather aprons, and finally delivered, a united strand, through a trumpet or tube which gives it a false twist, to a can in which it is coiled. It is called a sliver.

(g) Spinning Systems.—From this point either of two different methods of procedure in the manufacture of the
yarn may be followed, according to the kind of yarn desired; that is, worsted yarn may be drawn and spun \((a)\) by the Bradford system, which gives a smooth, lustrous, level yarn, or \((b)\) by the French system, which gives a soft, rather fuzzy yarn.

These two systems differ in an operation called back-washing, which removes any oil from the wool, and in the drawing operations.

In manufacturing the wool fibre it is necessary to add oil frequently to facilitate the carding and combing processes. If the wool is to be Bradford-spun no effort need be made to remove the oil except: \((i)\) If top dyeing is to be done the oil must then be removed by back-washing and later applied. In the end the same result is accomplished. \((ii)\) Back-washing may be done from choice to give the top a very good appearance, if, for instance, the wool is to be sold in the top. The oiling must then be done later before the manufacture of the top can be continued.

Back-washing is not an absolutely necessary process, except for the tops to be used in the French system of drawing and spinning.

\((a)\) Bradford System.—For the Bradford system the following operations are required:

\((i)\) Gilling.—Two operations of gilling follow the comb, the first in a can gill-box, the second in a balling gill-box. The principle of these machines is the same as of those which precede the comb. The fallers are generally provided with finer pins. In the first gill-box fourteen to eighteen ends of sliver from the comb are united into one and run into a can. In the second four to five ends from the first gilling are united into one and wound into a ball, called a top.

\((ii)\) Doubling and Drawing.—In the drawing-boxes, of which there may be from five to nine, the top is converted into roving. The drawing-boxes have a series of drawing and guide-rollers and a bobbin-and-flyer attachment. At the back of the drawing-boxes are frames which hold several bobbins of slubbing or tops. The slubbing passes through the drawing-rollers and is then given a slight twist
by the bobbin-and-flyer attachment. This twist is put in merely to facilitate the handling of the strand in carrying it from one machine to another. When the slubbing passes through the rollers the twist is removed. The real function of the drawing-boxes is drawing. The last drawing-box is called a roving-frame, and delivers the strand much reduced in size and slightly twisted.

(iii) Spinning.—This is the last process in forming the yarn. For this system it may be done on the cap, flyer, or ring spinning-frames.

(b) French System.—For the French system the following operations are required:

(i) Gilling.—One operation of gilling, in a can gill-box as with the Bradford system, follows the comb.

(ii) Back-Washing.—The sliver is next passed through a machine called a back-washer. This has two bowls for the washing-liquor at the back, a series of drying-cylinders, and a gill-box with the usual fallers. The slivers are washed free of oil in the bowls, are dried by passing over the drying-cylinder, and straightened and united into one end in the gill-box.

(iii) Gilling.—Another operation of gilling, in a balling gill-box as with the Bradford system, follows. This straightens the fibres, winds the strand, and makes a back-washed top, also called a dry top.

(iv) Doubling and Drawing.—In the drawing-boxes, of which there are nine or ten, the slubbing, or top, is made into a roving. Several strands are made into one, much reduced in size. The drawing-boxes differ from those used by the Bradford system in that (a) they have, in addition to the usual series of drawing and guide rollers, a small cylinder set with pins, called a porcupine, which acts much as do the fallers in the gill-boxes in keeping the fibres straight as the strand is reduced in size; and (b) in place of the bobbin-and-flyer attachment they have two oscillating aprons which receive the strand as it is delivered by the rollers and condense it, but do not twist, as the oscillating apron of the woolen card-condenser does not twist.

At the back is the creel, or rack, for the slubbing, several
strands of which pass through a guide-plate to the guide and feed rolls, then over the porcupine and through the front rolls. All the drawing is done between the porcupine and front rolls. By these rolls it is delivered to the two oscillating aprons, from which the strands are passed through guides and wound on spools placed side by side.

(v) Spinning.—This is the last process in forming the yarn. For this system it is generally done on the worsted mule but may be done on the ring spinning-frame.

3. Special Processes for Woollen.—Fewer processes are required for woolen yarn than for worsted.

(1) Scouring.—This operation is the same as for worsted.

(2) Drying.—This operation is the same as for worsted.

(3) Burr-Picking.—The work of scouring and drying does not extract the burrs, which are in most wools. As they cannot be allowed to remain, the wool is put through a burr-picker. This has an apron-feed, a picking-cylinder, and one or more burr-cylinders with burr-guards. The picking-cylinder, revolving rapidly, lashes the wool into the burr-cylinders and the burrs are struck off by the burr-guards.

(4) Mixing.—This process is for various purposes: (a) to secure a desired color; (b) to secure uniformity of fibre; (c) to regulate the cost of the finished product by introducing inferior grades of wool, shoddy, etc.

The mixing is done on the floor. Various layers in the right proportions are made. In feeding this mixture to the picker, care is taken to remove the material from the side of the pile to secure all the different kinds of fibres. The mixing-picker is in general action like the duster. It has cylinders, which are set with hooks rather than teeth. The mixed fibre is delivered to the machine by feed-rolls, and after the cylinders have done their work the fibres are thrown into a chamber called a gauze-room. The picker is always used, even if no mixture is to be made, as it prepares for carding by opening up and shredding the fibres. Oil is applied from overhead to the wool at this time, to facilitate the carding operation. More oil is used for woolen than for worsted, but the object is the same.
(5) Carding.—The fibres for woolen yarn go from the mixing process to a set of cards of which there are usually three. These are called breakers—first and second breaker and finisher. Their purpose is to open and clean the fibres. The principle is in general like that of the worsted card, but there are various differences in the detail. The breakers have more workers and strippers, and consequently each machine does more carding, which is a necessity, as the fibre goes directly to spinning from the cards.

The fibre is delivered by an automatic feed to the first breaker, passes over the big cylinder, and is delivered by side drawing as a sliver. It may be fed to the second breaker and to the third by either of two methods: the traverse, in which it travels without winding, or the creel-feed, in which it is wound. Both methods are to produce uniformity of product. The ring doffer is used on the finisher. This doffer, with the condenser (an oscillating apron), delivers the fibre in a small roll, without twist, called roping, or roving. The ends are wound on a big spool called a jack-spool and are ready for spinning. (For detail in Carding, see page 51.)

(6) Spinning.—The woolen-mule is usually employed for spinning woolen yarn which requires spindle-drawing.


(1) Twisting.—Twisting, if used, follows spinning. The general method is the same for all yarns, both worsted and woolen, but different twisting attachments are used. The twisting-machines are like the upright spinning-frames except that they are without drawing-rollers. The cap, the flyer, and the ring attachments are all used, the choice depending on the kind of yarn. In the twisting operation one or more single yarns from spinning are combined for strength or to secure some special effect.

(2) Weaving.—The preparation of the warp and the filling for the loom and the process of weaving are in general the same for both worsted and woolen.

(a) The filling yarns require no special treatment. If they are not on bobbins suitable for the shuttles they are rewound and are then ready for spinning. Filling-bobbins
are always wound a space at a time rather than end to end, as the yarn is thus delivered more easily.

(b) The warp requires more preparation. The bobbins from the spinning or twisting are set in a frame. From them the yarn is wound as desired on a big spool called a dresser-spool. From the dresser-spool the yarn is drawn through two guides resembling reeds, the second guide finer than the first. It is then wound in sections on a big reel. These sections are in turn wound on the warp-beam as the design requires. Tension, rather than a guide, is used in this winding. The warp-beam is turned by power and the tension on the yarn turns the reel, which delivers the yarn evenly. An even tension is exceedingly important in winding a warp-beam.

(c) The weaving may be done in the plain harness-loom, in those having attachments, or in the Jacquard, as the design demands.

Woolen and worsted yarns are made into a great variety of materials, which include all kinds of weaves from the plain to the very elaborate. The different twill weaves are much used for both, because they give the beauty of design which is required by worsteds as well as the firmness which is needed in the finishing of the woolens.

(3) Finishing.—Great variety is possible in the finishing of both woolens and worsteds. Each finish requires many processes, certain of which are necessary for all materials. Beyond these certain necessary processes the number and kind employed depend entirely on the effect the manufacturer desires and the amount of time and expense which can be given to securing the desired effect.

Worsted fabrics depend for beauty on the yarn and the weave, and much attention is given to enhancing the merits of both. In woolen fabrics both the yarn and the weave are frequently entirely concealed by a surface finish, toward the securing of which all processes are directed.

(a) Perching, or Inspecting.—After any material is taken from the loom it is carefully inspected by being drawn over a perch in a strong light and all its defects are marked.
(b) Burling.—Most materials have knots and bunches of threads where ends have been joined. These are drawn to the wrong side by the use of burling-irons.

(c) Mending.—All the defects marked must be repaired, all broken threads must be joined, and any missing threads replaced; otherwise the design will not be complete. Woolens require less careful mending than worsteds, as the defects are usually covered by the finishing. Any specks of vegetable matter which may have got in during manufacture are looked for and removed.

(d) Fulling.—The chief characteristic of wool is its quality of felting. This quality is made use of in the finishing of both the woolens and the worsteds. In general, the processes to which either kind of fabric is subjected for felting are much the same, though they do not serve the same purpose for both and are done in a different degree for different materials.

(i) In the worsted industry felting is used for the fabrics called unfinished worsteds. The chief purpose is to give softness to the weave and flexibility and firmness to the cloth. Worsted felt less than woolens because their fibres have been straightened and paralleled. They are also subjected to the fulling process for a much shorter time than woolens.

(ii) In woolens the purpose in felting is to make the cloth sufficiently strong, firm, and thick to stand successfully all the finishing processes required, such as napping or gigging and cropping. Woolens have great felting quality because their yarns are softly twisted and their fibres are interlaced. They are subjected many hours to the fulling process. Woolens are woven much longer and somewhat wider than is required for their finished size. Occasionally a woolen material is made to shrink half its length. As they shrink in length and width they naturally become much thicker. For this reason woolens are usually woven rather loosely; otherwise, as the fulling takes place they become boardlike.

Fulling is done in a large machine which is fitted with rollers and a trap to regulate the shrinkage in length. The
shrinking of the fabric is caused by the action of warm, soapy water on the fibres and their subsequent compression. The warm water softens the fibres, they become more interlaced, and are pressed closely together by the action of rollers. In woolen the fabric is so solid that its weave is practically concealed. Very many times, if a woolen fabric is made of a poor yarn and loosely woven, flocks—wool waste from some of the finishing processes—are added to the back while the fulling is going on. This gives weight and sufficient substance to make a good surface. If carefully done it does not impair the value of the goods, but it is too often resorted to in order to cover an inferior foundation, in which case the flocks usually drop out and leave a very shabby surface.

(c) Washing.—Fulling is followed by washing and rinsing to remove all the milling agents which have been used. The ends of the material are sewed together and careful scouring done.

(f) Gigging and Shearing.—This is a process in which the fibres by various means are brought to the surface to form a nap or pile. The amount of nap raised depends entirely on the effect desired. Unfinished worsteds when ready for market usually show but little nap, while woolens often have their surface completely covered with nap. Wire gigs, brushes, and teazles are all used. The teazle is a vegetable growth which it is difficult to imitate successfully in metal. Revolving cylinders are set with teazles, wire pins, or brushes, and as the material passes over another cylinder, placed at the right distance, the exposed surface of the material is continuously brushed by these and the nap evenly raised. The gigging or teazling is followed usually by careful brushing which in turn is followed by shearing or cropping to secure the required length of nap. This is done by a shear which has revolving knives and is followed by brushing to remove the stray fibres. Many materials are napped several times and have generally a corresponding number of shearings and brushings.

(g) Steaming, Crabbing, Brushing, and Pressing.—All these processes are used to give the desired finish to ma-
terials. The steaming and boiling methods which give lustre are accomplished by the use of steam or hot water and rollers. For either method the material is stretched tightly over the rollers. If it is to be steamed the rollers have perforations through which the steam is blown. If it is to be boiled the material passes through boiling water as it is wound from one roll to another, or it stands while rolled for several hours in the boiling water. To all these finishes much brushing and pressing may be added. These give additional lustre and more careful finish.

(h) Tentering.—In drying, the material must be made to conform to a certain width and must also be carefully stretched smooth and straight. This is done by tentering. For instance, broadcloth has a regulation width of fifty-four inches; it may come from the milling process uneven in width. To remedy this it is, while still wet, stretched into shape on a frame. It is attached to this frame by hooks which catch in the selvage. The selvages of many materials show evidence of this process in the small holes made by the hooks.

(i) Inspecting.—All materials are very carefully inspected after the finishing processes.

5. Usual Finishing Processes for Worsted.—The following processes may be required in the finishing of aworsted fabric: inspecting; burling; mending; scouring; fulling (for unfinished worsteds); washing to remove the soap; crabbing (the cloth is wound on a roll and placed in the crabbing-machine; it is passed through rollers, through boiling water, and is wound again; by this process the cloth is set); dyeing (if it is to be piece-dyed); crabbing again; tentering; steam-brushing (the material is wound on a perforated cylinder and steam is blown through both cylinder and material); specking (cutting off any specks); shearing on face and back; pressing by rollers; dewing; water blown on it (somewhat like sprinkling of laundry); drying; inspecting.

6. Usual Finishing Processes for Woollen.—The following processes may be required in the finishing of a woolen fabric ("face goods"): inspecting; burling; mending; fulling in grease; washing; rolling and stretching through
water (left to stand twelve or eighteen hours to remove creases, much like crabbing for worsted); drying; napping to raise pile (by wire gig); shearing; napping and teazling; blow-steaming (wound on a perforated cylinder and steam blown through to set the fibre); cooling (while stretched); dyeing (if it is to be piece-dyed); wet-gigging or brushing wet; extracting (water taken out); brushing (wet or dry—wet gigging may be done); tentering; steam-brushing (steam warms it); shearing (double or single—depth can be regulated); steam-brushing; sanding and polishing; pressing (a press acts like an iron); inspecting.

Besides these there are special finishings, some of them employed in making a woolen look like a worsted and vice versa. Methods of finishing change constantly as fashion changes and requires new effects in materials.

7. Substitutes Used in the Manufacture of Wool.—There are various substitutes which are used both with and in the place of good wools in the manufacture of so-called wool materials. These are used because there is not enough good wool produced to supply the great demand for wool fabrics of all kinds. If only good wool were used the supply would be so limited and the prices so great that the materials could be had by only a few and those the very wealthy. This use of inferior grades and substitutes lessens very materially the expense of manufacturing fabrics and makes possible the furnishing of woolen materials at prices within the reach of the general public. The adulteration of wool is, like the weighting of silk, frequently overdone.

The substitutes are (1) cotton; (2) wool—reclaimed wool, fibres from materials like sloddy, and waste wool.

(Noils from the combing process, flocks from the finishing processes, and pulled wool, which is taken from slaughtered sheep, are sometimes included in this list but should not be.)

(1) Cotton.—Because of the cheapness of the cotton fibre and the fact that in manufacture it can be made to resemble wool it is much used—

(a) In wool materials, in combination with wool of various grades. It may be introduced in the fibrous state dur-
ing blending or used in the yarn form, either by itself or combined by twisting with wool yarns. Cotton yarn is frequently used as warp. For example, it is always used in mohair and alpaca fabrics both because of the difficulty of weaving mohair warp and filling and because it gives a less harsh fabric.

(b) In cotton materials which have the appearance of wool and are frequently called wool. Many materials, such as outing flannel, duckling fleece, canton flannel, and the cheaper blankets are made entirely of cotton fibre but are given the wool surface by teasling and gigging.

(2) Wool.—The wool substitutes are frequently classified in different ways—

(a) Shoddy.—This term includes all the materials which are to be remanufactured and used in the woolen industry. It is really the shredded fibre ultimately obtained by subjecting various kinds of rags, cloth, and yarn to a shredding or tearing-up process. The materials used may be either old or new and are, in general, all kinds of rags, materials which have been worn and discarded, clippings of new materials, and those which come from cuttings in tailors' shops, etc.

The term wool extract is frequently applied definitely to the fibres coming from rags and waste which are made of both cotton and wool. In order to obtain the wool the material must be carbonized to destroy the cotton. This process is used when necessary with all shoddy.

Preparation of Shoddy.—All the fabrics which are to be used again in wool manufacture must be reduced to a fibrous state. These fibres are used alone or they may be mixed with the clean wool in the blending process. Shoddy is used only in the manufacture of woolen yarns. It cannot be used for worsted yarn, but a woolen yarn made of shoddy may be combined with a worsted yarn.

(i) Sorting.—Before any manufacturing process is attempted all the shoddy materials must be sorted according to color and to kind; that is, new or old. The different kinds may require slightly different treatment.

(ii) Washing.—This frequently follows sorting.
(iii) Carbonizing.—When carbonizing is required it is usually done in rag form. In this process all the rags which have any cotton mixture are subjected to acids which extract the hydrogen and oxygen from the cotton and leave carbon to be dusted out. Several different operations are required.

The material is put in a cage and placed in a tank containing acid and water. It is soaked from ten to thirty minutes, according to the kind of material. From the cage it goes through three or four operations which extract the liquor and dry the material. The first is the hydro-extractor. This takes out the excess liquor, which is saved for use, and leaves the rags somewhat moist. The second machine is a drier, in which more water is dried out at low heat. In the third machine there is intense heat, which concentrates the acid and removes the water. Neutralizing follows to remove all acids.

(iv) Oiling.—All materials should be oiled and then left in piles to soften. This applies to all rags whether carbonized or not.

(v) Picking.—The machine for this operation is called a shoddy-picker. It has a travelling-apron, feed-rolls, and a picking-cylinder. In it the rags, both old and new, are torn to shreds; that is, they are practically reduced to a fibrous form. Several layers of rags are placed in flat, thin sheets on a travelling-apron which carries them to the feed-rolls. The feed-rolls pass them on to the picking-cylinder which is set with steel and iron pins. The feed-rolls go at a slower speed than the picking-cylinder, and because of this and the action of the pins the rags are shredded and reduced to a fibrous condition.

(vi) Dusting.—The carbonizing duster follows. It has the same general principle as the regular duster. It removes the dust or carbon from the fibres which were subjected to the carbonizing process while in the form of rags. After leaving the duster the fibres, by a blending process, are mixed in the desired quantity with the raw wool fibres and then pass through all the steps of manufacturing required in the making of a woolen fabric.
(b) Waste Wool.—This includes two kinds of wool fibres: first, from the worsted industry, those which are so mixed with burrs that they are thrown out by the burr-guards on the licker-ins of the worsted cards; second, from the woolen industry, the waste wool mixed with burrs which comes from the burr-picker.

(i) Removing Burrs.—The burrs in both kinds of fibre are reduced to powder or carbon by crush-rolls. Carbonizing and neutralizing as for shoddy are necessary for some kinds of waste wool—when the vegetable matter cannot otherwise be removed.

(ii) Dusting.—The carbonizing duster follows. It is the same as that used for the fibre of carbonized rags or cloth. After leaving the duster the fibres are ready for the mixing or blending process.

The character of the various woolen fabrics manufactured is discussed under Fabrics.

III. Silk

Silk, like wool, is an animal fibre. It comes from the cocoon of the silkworm, of which there are for manufacturing purposes two general kinds—the cultivated, called the Bombyx mori, and the wild, such as the Tussah. The cultivated worm feeds on the leaves of the mulberry-tree, the wild on the leaves of the oak. The fibre of the silkworm is unlike any other fibre in that it is several hundred yards in length and so does not have to be joined and twisted to make thread of sufficient length to use in weaving. Several strands are twisted together, however, to give more strength and thickness. The silk fibre consists of two parts—the inner or true fibre, called fibroin, which is not soluble in water, and the gum coating, called sericin, which is readily soluble in hot water and soap. The important characteristics of the fibre are its softness, fineness, elasticity, lustre, and endurance.

The life of the silkworm is short and busy. The eggs, usually laid in summer, are kept for some time in a cool place and hatched in the spring when the leaves of the mul-
berry-tree are green and tender. The worm at birth is about one-eighth of an inch long but begins eating at once and increases rapidly in size. During its life great care must be taken as to food, temperature, cleanliness, and unusual noise. As it continues eating and growing it sheds its skin. This occurs four times in its short life of thirty or thirty-six days, until the worm is finally about three inches long and much lighter in color. At the end of the moulting period its hunger lessens; it shows signs of restlessness and a desire to climb. Twigs are provided, and soon the worm finds a desirable spot to which it attaches itself by throwing out a little silk which hardens or dries and holds the worm in place. Spinning now begins. By a waving motion of the head and a circular motion of the body, as if making the figure eight, the worm begins throwing out from two openings underneath its mouth two thin threads of silk which unite and form one. This gradually encloses the worm and forms the cocoon. The outside threads of the cocoon are usually rough and broken but the inner is a long double thread varying from five hundred to thirteen hundred yards. The spinning takes three days, and as it ceases the worm gradually changes into a chrysalis, which if allowed to live would become a moth and escape, injuring the silk. To prevent this the cocoon is fumed; that is, it is heated sufficiently to stifle the chrysalis. After fuming, if care is taken, the cocoon may be kept indefinitely.

Before any manufacturing processes are begun, cocoons are usually sorted and classified for color, texture, and general condition. Each cocoon has two kinds of silk—the long, inner, continuous fibre, called raw silk, and the outer, shorter, and often rougher fibre, called spun or waste silk. These require very different treatment in manufacture.

1. Processes for Raw Silk.

(1) Reeling.—Usually over one-half of the silk in a cultivated cocoon is reeled into skeins, or hanks. Preparatory to this the cocoons are put in soap and water sufficiently warm to soften the gum and are then brushed. This brushing removes the short outer floss and finds the end
of the long filament. Several of these filaments, according to the size of the thread desired, are united, passed through guide-eyes, and wound on a reel. The water must be kept at even temperature throughout the process to keep the gum softened. Hand reeling is a simple process, but steam filatures are generally used in which the reels are run by power. Care must be taken in uniting the filaments, which are not of equal size their entire length, in order to make as even a thread as possible.

(2) Throwing.—The next process for raw silk, after reeling, is called throwing. It includes various operations which convert the raw silk into threads suitable for warp and filling for weaving.

(a) Several different kinds of silk thread may be made in the throwing process. (i) Singles, used for either warp or filling in thin materials. They are made by twisting a single strand from the reel to make it stronger and firmer. The amount of twist given depends entirely on the finished product intended. Chiffons, for instance, require a hard twist. (ii) Tram, used generally for filling, is made by slightly twisting two or more single untwisted reeled threads together. Usually there is just enough twist given to hold the strands together. This keeps the strand soft and makes a bulky, lofty filling and produces lustre. (iii) Organzine, used for warp, needs strength, and consequently it is made by combining with a left-hand twist several single strands which have already received a right-hand twist or vice versa. The number of threads and the amount of twist depend on the required strength of the thread and the desired appearance of the finished product. There are usually fourteen or sixteen turns to the inch in the singles used, of which two or more are combined. In this combining more than three twists must be used. (iv) Twist, which is made in the same general way and closely resembles organzine but has fewer twists.

(b) The operations included in the throwing process are as follows:

(i) Washing or Soaking.—Most of the silk to be thrown is first soaked to soften the gum.
(ii) **Drying.**—Drying is done by placing the skeins first in a hydro-extractor and then hanging them for drying in a room heated by hot air or steam.

(iii) **Winding.**—The silk is prepared for doubling and twisting by transferring it to bobbins. This is done by means of a machine resembling a swift or reel. In winding, care is taken to make the thread smooth and of even size. To accomplish this it is passed from one bobbin to another through a cleaning-machine which removes any irregularities.

(iv) **Doubling and Twisting.**—These processes depend on the kind of thrown silk required; for instance, singles are not doubled but go directly to the spinner, which does the twisting with the bobbin-and-flyer attachment; tram, on the contrary, is made by combining silk from several bobbins on the doubling-machine, and is then twisted; while organzine is twisted, doubled, and then twisted again in the opposite direction.

After the throwing, if the silk is to be skein-dyed, it must be wound from the bobbins into skeins and boiled to remove the gum.

2. **Processes for Spun or Waste Silk.**—This term includes all silks which cannot be reeled and are not suitable for throwing—the silk around the outside of the cocoon, which was used to hold the worm to its twig; it is strong, uneven, and rather lustreless; the outside layers of the cocoon; the first silk spun, which it is impossible to reel; the last spun, which is too fine and weak; short fibres from pierced and damaged cocoons; and waste from reeling and throwing.

(1) **Mixing.**—Because of the varying quality of the waste silk it must be carefully mixed to get an even product.

(2) **Boiling and Schapping.**—Raw silk can go through all the processes of manufacture except dyeing without having its gum removed; waste silk cannot. There are various ways of freeing the silk of its gum. The two generally used are boiling, the English method, and fermentation, the Continental method.

By the first method, boiling, the waste silk, in open mesh
bags, is put into a soapy water which is allowed to come to the boiling-point. Constant stirring is necessary. The gum is softened and passes out through the meshes. Another bath, with less soap, follows, and the silk is dried. By this method very little gum is left and the silk is much lighter in weight. In schapping, the silk is put into vats of tepid water and allowed to remain without motion for several days. A process of fermentation takes place and the silk is practically freed of its gum. This leaves a certain quantity of gum in the silk, which is an advantage for some materials such as velvets. Washing and drying follow, as in the boiling method.

The processes of manufacture for waste silk are similar in many ways to those used for cotton.

(3) Inspecting and Cleaning.—Because much of the waste is gathered up in mills and from the surface of the cocoons, it has mixed in it straws, hairs, and grasses. It is looked over and these are picked out by hand.

(4) Conditioning.—After the gum is removed the silk is very dry and a certain amount of moisture must be added; otherwise the necessary processes are not possible without breaking the fibre.

(5) Beating and Opening.—The beating opens up the fibre, softens it, and makes it flexible; the opening straightens and parallels the fibres for the combing.

(6) Combing.—In this process the short fibres and any foreign matter which may still be mixed with the fibre are removed, and at the same time the fibres are somewhat straightened and paralleled. The waste silk fibres are of different lengths. Before they can be combed satisfactorily they must be made regular in length by some method. There are two general ways of doing this. The first is by choosing and grouping the fibres of even length. This method requires time but saves any waste of fibre. In the second method the fibres are wound on a grooved cylinder, the grooves being as far apart as the desired length of the fibre. After the winding is completed a knife is slipped into the grooves to cut the fibre. This gives even length but many short waste ends.
The actual combing is done in a machine which has a comb and several book-boards. These latter are two-hinged boards which close like a book. Half the length of the fibres is enclosed in the book-boards; the other half hangs free so that it comes in contact with the combs. After it is combed the fibres are reversed and the other half combed. This removes the short fibres, which are called noils, and further parallels the long ones, which are called tops. Noils are combed twelve or thirteen times. Each time the combing produces both top and noils, the fibres of which with each combing are shorter. Those fibres nearly equal in length are combined for each of these combing operations.

(7) Preparing and Drawing.—From the combing the silk is fed to gill-boxes. These work like the worsted gill-boxes which have drawing-rollers and fallers. The rollers are often set farther apart, since the silk fibre is longer than the wool. By them the silk is made into a continuous sliver, which goes on to the drawing-machines, where several slivers are made into one and sufficiently attenuated to form roving.

(8) Slubbing.—The roving-machine has rollers and a bobbin-and-flyer attachment. The roving is drawn out and given a sufficient twist to prepare it for the spinning.

(9) Spinning.—This is done, as in cotton or worsted, by the mule or by the cap or the ring spinning-frames, the choice of machine depending on the kind of yarn desired. The mule and ring are in most general use.

(10) Doubling and Twisting.—In these processes two or more threads from the spinning are combined and given twist enough to hold them together. The machines used are like the upright spinning-frames but have no drawing-rollers.

(11) Gassing.—This process removes any loose fibres from the twisted yarn by running it through a gas flame or through a platinum V-shaped slot electrically heated. After this is done the yarn is wound, according to use, on bobbins if for warp; on quills or small bobbins if for filling.

3. Processes for Both Raw and Spun Silk.

(i) Weaving.—This is the same for both raw and spun silks. For it some preparation is necessary.
(a) The filling yarns are wound on bobbins suitable for use in the shuttles.

(b) The warp yarns are transferred by various steps from the bobbins to the warp-beam. In this transferring, sizing is generally added to strengthen the yarn. If fine yarn is used thin paper is very frequently placed between the different layers as it is wound on the warp-beam. This prevents tangling and assists in maintaining an even tension when the warp is unwound during weaving. Silk warp yarns are frequently printed with a design before they are woven. This is done as on the woven fabrics by roller-printing, in which a different roller is necessary for each color. In the weaving a plain filling yarn is used, resulting in softer colors and a somewhat blurred design. This method is very frequently used for ribbons. A great variety of weave is found in silk fabrics, from the plain, in such materials as taffeta and China silk, through the twills and satin weaves, to the brocades, which are the product of the Jacquard loom. Many cored materials, such as the poplins and bengalines, have the plain weave and are frequently a combination of yarns of two different fibres. Cotton is used in the cheaper qualities for filling, while wool is sometimes used to give the desired weight and effect.

(2) Finishing.—The same general methods are employed for both kinds of silk. Many times the yarns are finished partially before weaving; the processes are in general to give strength, weight, smoothness, and gloss to the yarn.

Before raw silk is dyed, whether in piece or skein, the gum must be removed from the fibre by boiling. In this process the silk loses weight. To make up for this loss weighting is usually added, the kind used depending chiefly on the color of the dye. For much of the weighting metallic salts are used, salts of tin or iron. If used in excess they affect the wearing quality of the silk, as they are themselves affected by light, air, and time. Some crystallize when exposed to the air and light and cut the silk fibre so that it breaks easily.

For the woven material there are many finishings, mechanical or made by the use of dressings: the pressing and
calendering for good silk, the dressing or sizing for poor silk. There is also that larger class of special finishings, such as moiréing or embossing and polishing, which also includes dressings of many kinds. These special finishings change with fashions, new ones appearing each year. The character of the various silk fabrics manufactured is discussed under *Fabrics*.

For artificial silk, see *Other Lesser Textiles*.

**IV. Linen**

Linen is a vegetable fibre. It is expensive, and consequently adulterants and substitutes are often used. They are, however, because of certain properties of the linen, less satisfactory in the case of this fibre than in many others.

Linen comes from the stalk of the flax-plant. It is the bark which lies between the inner woody core and the outer bark and because of this is called a bast fibre. The fibre is long, varying from twelve to twenty inches. It is straight and has a long, cylindrical tube with lengthwise markings which look like fine black lines. At intervals there are also cross-markings which help slightly in keeping the fibre together in the spinning. It is composed of cells held together by a vegetable gum called pectin. In addition to length the fibre has various other valuable qualities such as strength and lustre.

Flax is pulled and not cut, as in this way greater length of fibre is obtained. This is done by hand, since no suitable machine has yet been invented. In preparation for manufacture it requires entirely different treatment from that given cotton, wool, or silk. The beginning processes are for the purpose of (a) breaking up and removing the bark and woody tissue and (b) separating the short fibre, called tow, from the true fibre, called line.

1. **Processes for the True, or Line, Fibre.**

   (1) *Rippling.*—When flax is pulled it has all its leaves and seed-pods, which, after the plant dries, must be removed. This is done by hand, by drawing the ends of the stalks through big combs.
(2) **Retting.**—This is one of the most important processes, and if not well done it may injure the fibre. It begins the freeing of the bast fibre from the bark and the woody core by decomposing the resins which unite them. There are various ways of doing this; the most usual are by dew or cold-water retting.  
(a) **Dew Retting.**—The fibres are spread on the grass, exposed to sun, rain, and dew. From two to five weeks are required for the decomposing of the gum. This method is used chiefly in Russia.  
(b) **Cold-Water Retting.**—For this there are two general methods: the use of stagnant water, in which the flax is placed and left for several days or weeks undisturbed, and the use of slow-running water—a less offensive method—not always possible to secure but giving a good result. The latter method is much used in Belgium, to which country the flax of other countries is frequently brought for retting. Retting is sometimes done twice.  
(c) Other methods, which have been tried to shorten the length of time required, include the use of hot water or chemicals. None of these have been successful to the present time.

(3) **Drying.**—After the retting the flax is dried in the open air, then tied in bundles and left standing in the air until the time for breaking and scutching.

(4) **Breaking.**—After the retting has decomposed the uniting gums the woody matter must be broken up and removed. The breaking, which was formerly done by hand, by a series of slabs, is now usually accomplished by several fluted rollers moved by machinery through which the flax passes.

(5) **Scutching.**—The broken material is removed by placing the flax within reach of a revolving wheel in which wooden knives or beaters are mounted. These knives strike off the woody part and begin the separation of the bast tissue into fibres. Aside from the long fibre, which is a product of this process, there is a certain amount of waste or short, tangled fibres, called scutching tow, which is used for cheaper threads and strings. At this point the work of the farmer is finished and the product is sold.

(6) **Hackling.**—This is a process closely resembling the combing of other fibres. It cleans, disentangles, combs, and
parallels the fibres, separating the long, or line, fibre from the short, which is also called tow. It splits what seems one fibre into several and produces fibres of uniform diameter as well as of uniform length. Hackling is done by hand or machine, or both. There is usually a certain amount of hand hackling or roughing before the fibre goes to the machine. The process is generally repeated many times. Finer combs are successively used as the fibre becomes finer and cleaner. Hackling by hand is expensive and is more often used when the finer qualities of yarn are required. When done by machine the strands of fibre are held in place and combed by needles which are set in revolving aprons. The tow catches in the needles and is held by them until brushed off.

(7) Sorling or Classifying.—Before preparing for spinning the flax must be arranged according to quality. This is done by hand. In doing it machines like the hand hackles are used. More short fibres are removed and the longer ones paralleled, subdivided, and cleaned; the product is often called dressed line. In this process, if fine linen is to be made, the fibre is sometimes cut to secure the best section for the yarn.

(8) Gilling.—After securing the line fibre the first process in preparing it is done by a machine called a spread-board. In this machine the fibre is paralleled, subdivided, and joined to form a continuous strand. The spread-board is like the gill-boxes already described as used for other fibres; that is, there are feed-rolls, fallers, and draft-rolls. The process is rather more difficult for flax because of the greater length of the fibre and its stiffness and irregularity. The flax is fed to the machine in tresses, which differ in thickness and width according to the desired product. A usual width is about four inches. The ends of the flax are overlapped, and by the drawing of the rollers and the action of the fallers, which keep the fibres straight, a continuous sliver is made which is run into a can.

(9) Doubling and Drawing.—This is done in a series of drawing-boxes. The series is frequently composed of a machine called a doubler, three drawing-frames, and a
roving-frame. The first machines used are much like the gill-boxes; they attenuate and even the slivers which come from the gilling process by uniting and drawing out from two to ten or twelve of them. These slivers are fed from the different machines into cans. The roving-frame, the last machine in the series, has the rollers and fallers, but in addition it has a bobbin-and-flyer attachment. The sliver is still further reduced and attenuated by the rollers and fallers and is also given a slight twist by the flyer and wound on the bobbin.

(10) Spinning.—The fibre is now ready for the actual spinning. Fly-frames are used because of the smooth straightness of the flax. The spinning may be done in one of three ways: in dry frames, damp, or wet. These fly-frames are like the old machines, with rollers and the bobbin-and-flyer attachment. They have the bobbins at the back, which deliver the roving to the two sets of rollers, the receiving and the draft going at different speeds. From the rollers the drawn-out roving is twisted by the flyer and wound on a bobbin. For dry spinning the feed and draft rollers are set about one foot apart and the work proceeds in the usual way. If the spinning is to be damp the strands, after being drawn out by the receiving and draft rollers, come in contact with a roll turning in cold water which moistens the yarn. If, however, wet spinning is to be done, the drawing-rollers must be set close together—the distance between being shorter than the length of the fibre—and the roving must actually pass through water almost boiling before coming to these drawing-rolls. This softens the fibres and makes them more supple. It also gives a smoother yarn, as the vegetable jelly in the fibre is softened by water, hardens again, and forms an outside coating. Too hot water, however, is injurious. All yarn spun by damp or wet spinning must be made into hanks or skeins and dried at once. The wet spinning is generally used for the finest yarns, the damp for the next grades, and the dry for the coarsest.

(11) Twisting.—This process may follow spinning in preparation for weaving. Wet or dry twisting may be
done; the wet makes a smoother yarn. For this the ring and the bobbin-and-flyer attachments are used. The spinning-frames give single yarns which are usually combined by twisting to give more strength or to secure some special effects in the weaving. Greater strength is more often necessary when the yarn is to be used for warp.

(12) Weaving.—Weaving for flax is more difficult than for cotton because the fibre is not elastic and breaks easily. The warp yarns are sized to make them smoother and give them strength for the drawing in and weaving. All varieties of looms are used, and we find a corresponding variety of weaves from the plain of dress linens through the geometric designs of huck and bird’s-eye to the elaborate damasks.

(13) Finishing.—There is much less variety in the finishings used for linens than for the other fibres. Those used are chiefly to add lustre by polishing and weight by sizing or dressing. For polishing, a liquid like starch is applied and the material passed over hot rollers. Other finishes are given by pressing, calendering, and mangling. There is also a process, called beetling, by which the threads are beaten flat and softened. The yarn frequently goes through this process before weaving to soften it for any subsequent processes. Beetling, whether done in the yarn or on the fabric, gives a closer weave and increased lustre. The surface of the fabric is smoother because the threads are flattened and are less distinct and separate. It gives a leathery feel to the fabric.

The best class of linens need very little dressing. Some of the cheaper grades—those in which the weave is poor or a substitute is introduced—are rather heavily sized to cover defects and thus appear a better quality than they are.

Many linens are left their natural color and are stronger. Bleaching, unless very carefully done, weakens the fibre. Linen may be bleached or dyed in the yarn or in the fabric; sometimes in both. Linens do not dye easily and do not hold dye particularly well.

2. Processes for the Short Fibre, or Tow.—The short fibre, or tow, is separated from the long during the scutch-
ing and hackling processes. It is used by itself and in combination with the long fibres. The processes of its manufacture are somewhat different from those of the long fibre. It is beaten and shaken in a beater, to clean and open it up, and then carded to disentangle the fibres and continue the cleaning. The card has the same big cylinder and workers and strippers as are used for wool, but the card clothing is heavier and coarser, owing to the coarseness of the tow. The carding-machine delivers the tow in the form of a sliver. This is doubled and drawn and made into roving ready for spinning by the drawing and roving frames, as is the line fibre. The spinning is also the same as that of the long fibre. It may be dry, damp, or wet and is done by the bobbin-and-flyer attachment.

The character of the various linen fabrics manufactured is discussed under *Fabrics*.

V. Other Lesser Textile Fibres

1. Ramie.—Ramie is a vegetable fibre. It comes from the stalk of a plant belonging to the family of stingless nettles. It is a bast fibre, is strong, long, lustrous, and non-elastic, like linen. The plants are cut, not pulled, and the leaves and branches are removed. The different countries in which ramie is grown have different methods for its preparation. Sometimes the bark is stripped off while the stalk is green; sometimes the plant is allowed to dry and the bark retted by dew or water.

Before the fibre is ready for spinning it must be put through several processes. First, decorticating, a process for removing the bark while it is still wet; second, degumming, which requires care, as the gum can be removed only by the use of chemicals. When carefully degummed it is soft, lustrous, and silky. The fibre, after being immersed in the chemical, is boiled, washed, dried, and sometimes bleached. To soften the fibre it is passed through fluted rollers which make it flexible without breaking it. It is then put through gill-boxes and made into what is called filasse. The gill-boxes disentangle and straighten the fibres
ready for combing. Combing gives two kinds of fibres, as in worsted: the long fibre, called tops; the short, called noils. Both of these are spun, but the tops make the finest and strongest yarn and a better grade of material.

The use of ramie has been tried in the manufacturing of a great variety of materials; it is generally combined with other fibres. Efforts have been made to improve its processes of manufacture, but as yet its use has not become varied. To date it is not generally successful except for Welsbach burners. As a fibre for dress materials it is found that it does not stand twisting and does not wear well.

2. Jute and Hemp.—Such fibres as jute and hemp need be considered only by those interested in house furnishing, as they have, so far, proved too heavy for use in dress materials.

3. Mineral Fibres.—The mineral fibres, asbestos and tinsel, are so little used as to deserve but passing notice. This is especially true of asbestos. Tinsel, made into fine wires, is, however, introduced into dress fabrics. It is frequently seen in novelties and in gauzes which are used for trimmings and for evening wear.

4. Artificial Silk.—There are various kinds of artificial silk, nearly all of which are made from cellulose. The principal varieties are nitrocellulose, cuprammonium, and viscose. There are others, but they are not now widely enough used to warrant discussion here. Artificial silks resemble real silks in appearance but their properties are quite different. Until recently they have had serious disadvantages: they have been difficult to dye, were likely to disintegrate in washing, and were inflammable. Improvements have been and are constantly being made, however, and most of these difficulties have been practically corrected.

One general process of manufacture is this: cellulose is dissolved by treatment with chemicals and forced through capillary tubes into another chemical which hardens or sets it. Other processes are being attempted and may prove equally successful.
Artificial silks have high lustre but are brittle and inelastic. They do not cover in weaving as well as real silk and are much heavier. They are inexpensive as compared to real silk and are coming more and more into use. They are made into hosiery, underwear, and sweaters, and also into a variety of dress materials, all of which include many kinds of weaves. They are found in combination with wool, cotton, and silk. In many materials they are woven in small dots or figures to form the design.

5. Spun Glass.—The use of spun glass in wearing apparel has been attempted but has not been considered successful.

III. Bleaching, Scouring, and Dyeing

Both yarns and fabrics may be bleached, scoured, or dyed, according to the requirements of the finished product.

I. Bleaching and Scouring

All fabrics are scoured or washed after leaving the loom and before the finishing is done.

Bleaching and scouring sometimes precede dyeing to remove any objectionable substance in the fibre. If materials are not to be dyed the bleaching and scouring is much more carefully done, as its purpose is then to give good color to the product.

Bleaching, as it is generally done to-day, requires the use of chemicals and consequently weakens the fibre somewhat; for this reason unbleached cotton and linen fabrics are stronger than the same quality of fabric bleached. Linen is more affected than cotton. Fabrics bleached by continued exposure to the weather are not injuriously affected.

II. Dyeing

Dyeing is the art of coloring textile and other materials in such a way that the colors cannot be readily removed by the influences to which they are likely to be subjected; that is, water and other cleansing materials, wear, light, and sun.
In dyeing, the coloring matter is first soluble and becomes insoluble while it is being absorbed by the fibre.

(1) Dyeing may be done at different periods or stages in the manufacturing of the fibre; that is, (i) in stock—in the loose state after washing and before any of the mechanical processes; (ii) in the slub—during the mechanical processes, the exact stage differing with different fibres; (iii) in skein—after the spinning; or (iv) in piece—after the weaving. The time of dyeing depends on the fibre and on the kind of product desired. When dyed in stock the colors are thoroughly absorbed by the fibres and are considered permanent. Skein-dyeing is used for specific purposes. It is less often done than stock or piece dyeing. Piece dyeing is for materials of solid colors.

(2) Of the four most important fibres, wool dyes most readily, in general, and gives to the color depth and fulness. Silk follows, and because of the smoothness and transparency of the fibre its color is more lustrous than that of any other. Cotton does not dye readily and its colors usually lack brilliancy or depth. Linen is even more difficult to dye; while its colors are richer than those of cotton they are not usually lasting.

(3) Cotton, wool, silk, and linen do not react in the same manner in the dyeing processes; consequently different methods and different kinds of dyes are used for different fibres. The same fibre often requires a variety of treatment, differing according to the color used. For much of the dyeing a mordant is necessary. This is a substance which has an affinity both for the coloring matter and the fibre. It varies, depending on colors and fibres. It prepares the fibre so that the dyestuff may be precipitated into it in insoluble form.

(4) Dyestuffs may be divided into two general classes: (i) artificial, which includes coal-tar products, and (ii) vegetable, of which madder and indigo are well known.

(5) There are special kinds of dyeing, such as resist, cross, and discharge dyeing.

(a) Resist dyeing is the process which treats part of the yarn so that it will remain unchanged when subjected to
another dye bath. This is used often in striped material. (b) Cross dyeing is done in the piece in materials which have both cotton and wool fibres. Cotton will not take wool dyes; in consequence it may be used to give a white stripe or plaid in colored materials. (c) In discharge dyeing the material is also piece-dyed a solid color; then some of the color, in the pattern desired, is removed by chemicals.