generate a certain compression among the co-fibres, we shall now find that we are able to extend the mass considerably farther without breaking, and so by continued drawing and twisting we may attenuate the sliver until it become a fine thread. There are two circumstances which limit its extensibility. The first is that state of it when many of the fibres which compose it end together at the same place, and which it is one of the objects of carding, and the purpose of some of the after processes, to prevent. The second is when the friction produced by the twisting becomes so great that the fibres will sooner break than slide on each other.

The operations, then, to be performed by the spinning machinery, are, to extend the mass of sliver as it comes from the preparatory machines, by repeated operations, or *drawings,* as they are termed, into a narrower and nar rower ribbon ; to twist this ribbon into a loose thread or *rove,* to enable it to bear greater extension ; and, further, to extend this rove to the last degree of attenuation re quired, twisting it, at the same time, so *hard,* that, when the operation is finished, and the thread perfectly formed, the fibres will sooner break through, than separate, by sliding on each other. All these operations are, however, more or less mixed up with each other in practice. Thus, the carding engines, besides disentangling the fibres, draw the broad sheet of loose filaments into a narrower and more compact sliver ; the drawing-frames extend this into a still narrower ribbon ; in the roving-frames the drawing still proceeds, and by an additional apparatus the sliver is twist­ed ; and this drawing and twisting are carried on together in the spinning-frame and in the mule-jenny until the completion of the thread.

The manner in which the drawing is effected may be conveniently represented by a figure. Let *a a* in the figure represent a pair of rollers, which are called retaining rollers; let these revolve in the direction of the arrows with a given velocity, and receive between them the sliver *b d;* they will thus impart to it the rate of motion of their own surfaces ; let *c* *c* be an other pair of rollers, which are called drawing rollers, revolving with twice the speed of *a a,* and receiving be tween them the sliver. Imparting to it now their own motion, they will cause it to move forward twice as fast as it is yielded by *a* *a,* which it can only do by the fibres sliding asunder. If, therefore, a given length of sliver be passed through the roller, it will be drawn out to twice its original length, and its sectional area will be but half of what it was. The drawing rollers have here been sup posed to move twice as fast as the retaining rollers, but their relative speed may be in other proportions. Thus the drawing rollers may move three, four, or five times faster than the other pair, and extend the sliver to three, four, or five times its original length. This difference of speed is termed the draught of the machine, and a machine is said to have a draught of two, three, four, five, or six, as the speed of the surface of the drawing rollers is so many times greater than that of the retaining rollers. It is obvious that, to effect the lengthening of the sliver, the distance between the drawing and retaining rollers must be somewhat greater than the average length of the fibres which compose the sliver. For were the distance less than this, the consequence would be disruption of the fibres themselves, from both rollers having hold of the opposite ends of the same fibres at the same time. But the distance may be too great, which would tend to make the fibres separate entirely at the middle point between the rollers, or at least to make the greatest attenuation take place there.

It is obvious, too, that the amount of extension which a single sliver can endure must be small, from the danger of

the ends of many fibres occurring at the same place. Hence there exists a necessity for laying many slivers of the first drawing together, for the second drawing, and many of these again for the third drawing. This laying together of the drawings, which is termed doubling, possesses the advantage of ensuring greater equality in the thread, from the inequalities of the separate drawings contemperating each other. The oftener this doubling is repeated, the more compact and equal, or *level,* the thread will be, and the more capable of enduring attenuation from the interspersion of the endings of the fibres.

As an example, in figures, of the effect of the drawing and doubling processes, suppose the velocity of the drawing rollers to that of the retaining rollers, or, in other words, the draught of the machine to be as 5 to 1, let the length of the sliver before drawing be 1, and its density 1 ; after the drawing we shall have the length increased to 5, and the density diminished to ∙2. Suppose a doubling consisting of 8 of those new drawings to be put through the rollers, we shall have a new sliver formed, length 25, density ·32 ; and the result of this doubling being repeated four

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times, the ratios being the same, that is in figures, 8/5 × 8/5 × 8/5 × 8/5 = 4096/625 = 6·5 will be a length of 625, and a density 6∙5 ; that is to say, there will be 6∙5 times as many fibres in the same space as there were originally, and the length will be increased to 625, this length of 625 being made up of 4096 separate slivers, or ends, as they are termed.

Such is the process of drawing without twist, in its simplest form, and as it is applied to cotton, wool, and silk waste. In flax spinning the nature of the material renders a more complicated apparatus necessary. Each fibre of flax, on minute examination, will be found to be made up of a number of smaller parallel filaments bound together. The separation of these bundled filaments is partially ef­fected by the hackling process ; but it is evident, that the thread is not capable of its greatest degree of attenuation, until the total separation of the filaments be completed. For this reason, a hackle, which shall separate the filaments, is an essential part of the drawing apparatus for flax ; and, in the repeated doublings of the slivers, a succession of machines is used, in which the hackles are gradually finer.

From the length of the fibres of the flax, the rollers re quire to be at a considerable distance from each other, and the hackles are placed in the interval between them. They are fixed to an endless chain, working over rollers, and their points are made to move through the sliver, with a speed a little greater than that of the retaining rollers. They thus have a double action. Entering the sliver immediately on its emission from the retaining rollers, and moving faster than it does, they split down the bundles of the fibres, and allow the sliver to be ex tended by the rollers. As they proceed onwards, the action of the drawing-rollers makes the extending sliver move many times taster than the hackles, and, by this means, straightens and lays parallel those fibres which may happen to be doubled, or to lie obliquely in the sliver. This ingenious apparatus is called the Gill, from the name of its inventor.

The process which succeeds these repeated drawings, whether made by the simple rollers or by the gill, is twisting the sliver into a rove. For this purpose, an addition of a bobbin and flyer is made to the drawing machine. The bobbin is made to revolve with such speed, as to wind up the rove as fast as it is yielded by the last pair of rollers, and the flyer with so much additional speed as to give to the sliver the desired twist while moving between the roller and the bobbin. As the diameter of the bobbin