it is said, "A reel so constructed as that the circumference of a skein wound upon it shall be of a certain known admeasurement, is made to perform a given number of revolutions, usually 400, when the skein is removed and accurately weighed. The comparative weights of silk, whereby their fineness is denoted, are estimated in weights called deniers, 20 of which are equal to 16½ grains." Mr. B. F. Cobb, Secretary of the Silk Supply Association, in his "Treatise on Silk," also gives the number of revolutions of the reel as 400, but the weight of the denier he gives as "200 of which are equal to 16⅓ grains." Probably the 200 is intended for 20, but it is remarkable that in neither of the two works is the circumference of the reel given. In Macclesfield 530 deniers are equal to one ounce, and 530 yards the standard length to weigh. Again, the denier is often described as equal to two grains. Dr. Ure, in his "Philosophy of Manufactures," says he understood it to be equal to 0·693 of an English grain, but upon testing a denier weight he found it to be equal to 0·833 grains. This latter would very nearly approximate to the weight given by the "Cabinet Cyclopædia," which would make the denier equal to 0·825 grains. While Mr. Simmonds, in the Appendix to the "Philosophy of Manufactures," says, "the custom of the trade is to reckon 32 deniers to a drachm, and that the standard of silk measure is *about* 400 yards; that length of a single filament of China cocoons will weigh two deniers, and of French or Italian two-and-a-half." If the drachm here mentioned is the apothecaries' drachm, then the weight of a denier would be 1·875 grains; but if it be the drachm avoirdupois, the weight of the denier would be 0·854 of a grain, or a little heavier than the weight found by Dr. Ure, and that given in the "Cabinet Cyclopædia." But the former would nearly approximate to the weight spoken of as "two grains." Which of the two is correct it would not be easy to say; probably each may be correct as used in two separate districts, for, as before mentioned, scarcely any two districts calculate on the same principle. If we take, for instance, against the weights just given the Macclesfield weight, in which 530 deniers are equal to an ounce, if the ounce is avoirdupois, then the weight would be 0·8245 of a grain, or as nearly as possible corresponding with the weight given in the "Cabinet Cyclopædia," and by Mr. Cobb; but if the weight be apothecaries' (which is not probable) the weight would be 0·905 of a grain. It may, I think be pretty safely assumed, that the Macclesfield weight is the correct one, more especially as there is some show of reason for it, because 530 yards being the standard length reeled, and 530 deniers being equal to one ounce, whatever number of deniers 530 yards weigh the fractional part of an ounce is at once indicated. And as all the weights given approximate so nearly to this it is probable that they have the same common origin. In this, as in many other things, it will be found that the oldest authorities are the most reliable, because, as years pass on, changes take place, by almost imperceptible degrees, but collectively those changes amount sometimes to an alarming item; and the origin of the system having become lost in antiquity there is no means of checking or remedying them, therefore the nearer we get to their origin the more reliable will our authority be found to be.

Having glanced at some of the various methods of estimating the counts of yarn of different kinds, we may now examine into the readiest methods of ascertaining what is the count of any yarn. There are two distinct methods of doing this, one is by the use of ordinary weights, and the other by the use of weights or apparatus specially prepared for the purpose. One of these apparatus and certainly a most convenient one, is what is known as the "quadrant." This "quadrant" is a modification of a lever balance, one end of which is made to assume the form of a quadrant or quarter circle, and is so graduated that when a given number of yards are placed at the other end of the lever a pointer indicates on the quadrant what is the count of the yarn, or how many hanks would be equal to one pound. This is no doubt a very ready method of ascertaining the counts of yarn, but as there are so many different methods of indicating counts there must of necessity be as many different arrangements of quadrant. Then it must be advisable to have some ready method of ascertaining the counts of yarn by the use of ordinary weights. Supposing we are dealing with cotton yarn, we know in the first place that as many hanks of 840 yards each as there are in one pound arvoirdupois is the counts of the yarn, but as it may not be convenient to weigh a pound of yarn some other plan must be adopted. One pound avoirdupois is equal to 7000 grains troy, therefore, if we divide 7000 (the number of grains in one pound) by 840 (the number of yards in one hank) we shall obtain a weight which will answer to one yard of length, thus $\frac{7000}{840} = 8\frac{1}{3}$ grains. Consequently if one yard of yarn weighs $8\frac{1}{3}$ grains, one hank of that yarn will weigh one pound, so that as many yards as weigh $8\frac{1}{3}$ grains so many hanks will weigh one pound, or that will be the counts of the yarn. Example: If 20 yards weigh $8\frac{1}{3}$ grains the yarn will be 20^s, or equal to 20 hanks per pound. In spun silk the same weight will apply, as the hank is 840 yards as in cotton, the only difference being that already pointed out, viz., that in twofold spun silks there are the same number of hanks per pound as in single yarns, but in cotton twofold yarns there are only half the number there are in singles.

If we are dealing with worsted the same rule will apply, only, that the worsted hank being 560 yards we must divide 7000 by 560 to obtain the standard weight. Thus, $\frac{7000}{560} = 12\frac{1}{2}$ grains, so that as many yards of worsted as will weigh 12½ grains there will be hanks per pound. By this method it will be found to be a very easy matter to ascertain the counts of any yarn, even if only a very small quantity be available for the purpose of testing. If it be found that sufficient accuracy cannot be obtained by testing so small a quantity (though in a majority of cases a sufficient degree of accuracy will be obtained) then the length reeled may be increased, and the weight increased proportionately. Thus, a rap may be reeled (of cotton or silk 120 yards, of worsted 80 yards), then as one rap is equal to one-seventh of a hank, 1000 grains will be equal to the one-seventh of a pound, so that whatever part of 1000 grains one rap weighs or whatever number of raps are required to weigh 1000 grains, that number of hanks will weigh one pound.

In estimating the counts of woollen yarn by the wartern, as already pointed out, whether six, seven, or ten pounds be taken as the standard weight, whatever number of yards weigh one drachm, that number of skeins (each skein containing as many yards as there are drachms in the wartern) will weigh a wartern, so that it is an easy matter to ascertain the counts of woollen yarn on this principle.

There is yet one other matter connected with the counts of yarn which requires to be dealt with. In speaking of twofold yarns it has been stated that a twofold cotton, worsted, or woollen would have only half as many hanks per pound as the indicated counts. Thus a twofold forty yarn would only give twenty hanks per pound. In all cases where the two threads which are twisted together are of the same counts it is an easy matter to ascertain the weight the yarn will be when doubled, by simply dividing the counts by two; but when the two threads are not the same it is not quite so easy a matter to ascertain what counts the yarn will be. For example, if we twist a thread of 44^s and a thread of 36^s cotton together it would appear as though the counts of the twofold yarn would be just the same as if the two threads were 40^s, because one is as much finer than 40^s as the other is thicker, as indicated by the numbers. And further, we may say in twofold 40^s there are 80 hanks in two pounds, therefore there must of necessity, when the two are put together, be half that number in two pounds, and consequently 20 hanks in one pound; also, if we put 36^s and 44^s together there will be 80 hanks in two pounds (this would be perfectly correct) consequently there must be when doubled half that number in two pounds, and therefore 20 hanks in one pound, exactly as in twofold 40^s. Then let us see what are the facts of the case. One hank of 40^s will weigh 6·4 drachms, therefore when two are put together they would weigh 12·8 drachms, or equal to the one-twentieth of a pound. One hank of 36^s will weigh 7·11 drachms, one hank of 44^s 5·82 drachms nearly, then the two together would weigh 12·93 drachms, instead of 12·8 as in the previous case, consequently the 36^s and 44^s twisted together would give a yarn having only $19\frac{4}{5}$ hanks per pound. This result may be arrived at by other and shorter methods. I have illustrated by this method for the purpose of showing the reason. Another method is to divide the highest count by each count in succession, and then divide the highest again by the sum of all the quotients, and the answer will be the counts of the yarn for any number of threads; thus, $\frac{44}{44} = 1$, $\frac{44}{56}$ 1·22, then $\frac{44}{2\cdot22} = 19{\cdot}8$, or $19\frac{4}{5}$ the counts. Another and still shorter method is to divide the product of the numbers by their sum, and the quotient will be the counts of the doubled yarn; thus $44 \times 36 = 1584$ $44 + 36 = 80$, then $1584 \div 80 = 19{\cdot}8$, the counts of the yarn.

The same rule will apply if any number of threads be twisted together, and for any kind of yarn by treating them as a series of doubling.* Of course in

*More particulars in this subject, as on all calculations, will be found in the "Treatise on Textile Calculations."

all these methods no allowance is made for take-up in the twisting of the threads, as this would vary not only in different yarns, but also in the same yarns, according to the amount of twist which might be put in them, so that the allowance for twist being a variable quantity, it must be left to practice to determine what allowance must be made for it.

Having now glanced over the various methods of reckoning the weight of yarn, we may proceed to give a few examples of calculating the quantity of material required for producing a given make of cloth.

The general mode of procedure is first to ascertain the number of threads in the warp and the counts of yarn, and then the number of picks per inch and the counts of weft.

We will begin first of all with a cotton cloth. We will suppose the cloth to be 24 inches wide, and to contain 1600 threads of say 2·60 warp. The length of warp is 60 yards to make a 54 yard piece; then the calculation will be as follows, $1600 \times 60 = 96{,}000$ yards. This 96,000 yards divided by 840 yards per hank, $96{,}000 \div 840 = 114\frac{2}{7}$ hanks, which being 2·60^{s} (or equivalent to 30^{s}) is a fraction under 3 lbs. 13 oz. weight. Then as to the weft; the cloth is 24 inches wide, and has 60 picks per inch of 1·20^{s} cotton weft. If the width of the piece be multiplied by the picks per inch it will give the number of inches of yarn required to make one inch of cloth, which of course will be equal to the number of yards required to make one yard of cloth, thus $24 \times 60 = 1440$ inches of weft in one inch of cloth, or 1440 yards of yarn in one yard of cloth. The piece is 54 yards long, then $1440 \times 54 = 77{,}760$ yards of yarn in the piece. Then $77{,}760 \div 840 = 92\frac{4}{7}$ hanks of 1-20^{s}, gives 4 lbs. 10 oz. of weft, or a total weight of cloth of 8 lbs. 7 oz. In calculating the cost of weft 5 per cent. is usually allowed for waste, or sometimes more, according to the quality of the yarn.

We will now suppose that the cloth, instead of being woven with cotton weft, is woven with worsted. Of course, the calculation for the cotton warp still remains precisely the same, and the method of ascertaining the quantity of weft is the same so far as ascertaining the number of yards in the piece. Then, instead of dividing the number of yards by 840 to ascertain the number of hanks, we divide by 560, which is the number of yards in the worsted hank, thus $77{,}760 \div 560 = 138\frac{6}{7}$ hanks of worsted weft. After adding the percentage for waste the cost may be calculated according to the price per gross, or it may be reduced to the weight and calculated per pound.

The method of calculating for worsted or any other kind of warp is precisely on the same principle. The only difference in calculating for any kind of material consists in the difference in the weight and length. For instance, if we compare the above calculations with a woollen calculation, in the warp we find we have 96,000 yards of thread. Instead of reducing it to hanks, supposing we wish to reckon by the Yorkshire skein, we divide it by the number of yards in the skein, and then by the weight of the yarn (so called) we shall get the quantity of yarn required. Thus $96{,}000 \div 1536 = 64{\cdot}435$ skeins, then 1536 yards is the representative of one skein for 6 pounds, consequently if the yarn be 30 skein the calculation will be, as $30 : 62{\cdot}435 :: 6 = 12{\cdot}487$ pounds.

If calculating for two-fold yarn the same rule must be observed as for cotton or worsted yarn, viz., half the length as for the same counts single, thus $2\text{-}30^s$ would only count as 15^s, &c.

It would be an easy matter to fill pages with examples of calculations of various cloths and materials, but the few examples here given, if carefully examined, will be found to contain all that is necessary for a general knowledge of the system of calculating for any class of goods, and the student, after acquiring a knowledge of the principle of reckoning the counts and weights, may easily adapt them to the particular method of counting in his own district, therefore, I shall content myself with giving a few examples of patterns which by reason of the warp not being regular in the slay (as in stripes, where some portion is more crowded in the slay than others) contain more warp than the indicated sett of the slay represents, and other examples which may be said to be outside of the regular system of calculations. It would be a mere waste of time and labour to compile a series of calculation tables, which would not be of the slightest use, except in one particular district.

In making calculations for cloths which are not of the same colour throughout, or where some portion of the cloth is finer or closer in the threads, the work becomes a little more intricate, but still the same principles underlie throughout, and it becomes only a question of proportion in one form or another. Suppose we have a warp consisting of black and white arranged in stripes across the piece, and that the black is present in the proportion of two parts to one part of the white. Then if the warp contains, say 1890 ends, there must be 1260 ends of black and 630 ends of white ; or if there are a number of colours present, it will be still a question of proportion ; or perhaps the matter will appear in a more practical form if we divide the total number of ends in the warp by the number of ends in one complete pattern ; this will give the number of patterns in the full width of the piece. Then multiply the number of patterns by the number of ends of each colour separately, and this will give the number of ends of each colour required in the warp. One thing should be very carefully attended to in arranging stripe patterns, that the two sides of the piece (especially for goods which must be joined side to side when being made up for the purpose to which they are to be applied) shall be the same, so that if one side be joined to the other no break will occur in the pattern, or if the pattern be for shawls, or for any other material which may not have to be joined together at the edges, the two sides should be made alike for appearance sake, otherwise the piece will look very odd and one-sided. Therefore a little care should always be bestowed upon the arrangement of patterns of this description, so as to preserve this uniformity. That being done, the calculation is as has been pointed out, merely one of proportion. Sometimes fabrics are arranged with one portion of the warp very much finer in the reed than the other portions. Even in this case the calculation is simply one of proportion, but the working is slightly different to the previous case, because not only the number of ends of each colour may be different, but the total number will be affected just in the degree to which the crowding in the reed is carried. Suppose a slay has thirty reeds per inch, and that one portion of the warp is drawn two threads in a reed, and another portion four threads in a reed, the readiest way will be to divide the total number of reeds in the width of the piece by the number of reeds occupied by the pattern, then multiply the number of patterns so obtained by the number of ends in the pattern, or, if there are several colours, by the number of threads of each colour; the product will be the number of threads required. If the cloth is to be 30 inches wide, and there are 900 reeds in the width of the piece; then say the pattern occupies 25 reeds —16 reeds with two ends in each, and 9 reeds with four ends in each — $900 \div 25 = 36$, then 16 reeds with two ends in each will be equal to 32 ends by 36 patterns, or 1152 ends. Then 9 reeds with four ends in each, will be equal to 36 ends by 36 patterns, or 1296 ends, or a total of 2448 ends. If the two stripes are of different colours we have at once the number of ends required of each colour; or if there are a number of colours in the pattern the principle will be the same. In all cases of calculation for warps this method will be found both ready and correct.

If the cloth has to be checked the weft will require to be calculated in a similar manner ; first find the total, then the proportion of each colour as they exist in the pattern.

There are numerous short methods of calculating adopted by those engaged in the different branches of the trade. It may be worth while to point out one or two of these, but they are not adapted for general practice, and it is not a difficult matter for any one to make a short method for himself, still an explanation of the system upon which some of these short methods are founded may be of some little service to the student. In some cases manufacturers in making their calculations for materials allow a percentage for waste in the calculation, instead of adding it afterwards. For instance, in calculating what weft will be required to weave a piece of a given width and length, and a given number of picks per inch, a certain allowance will be made to cover waste which will be made in weaving, and the natural shrinkages of the yarn. This allowance will be on the average about 5 per cent., in some cases more, in some less ; then the calculation is made so as to cover this allowance. A short method may be adopted of making this calculation if the pieces are of one uniform length, say 48 yards. Then a constant multipler and divisor may be found which will give the hanks with any percentage allowed at once. Suppose we wish to allow five per cent. for waste, multiply picks per inch, width of piece in inches, and nine into each other, and divide by 100 ; the quotient will be worsted hanks required to weave a piece, with five per cent. added for waste. Thus, piece 30 inches wide, 60 picks per inch, 48 yards long, $\frac{30 \times 60 \times 9}{100} = 162$ hanks. This will be found very ready in practice, because dividing by 100 simply means placing the decimal point before the last two figures, or, as in the illustration here given, cancelling the cyphers.

The reason why this method gives five per cent. allowance may not be apparent at first sight; I will endeavour to explain it. If we add five per cent. to 48, the sum will be 50·4. If we multiply 50·4 by 100 and divide by 560 (the yards in a hank) the quotient will be 9, so that having multiplied picks per inch by width of piece, multiplying by 9 and dividing by 100 is exactly equivalent to multiplying by 48 and dividing by 560, and then adding five per cent. In the same manner keeping 100 for a constant divisor, a multiplier may be found for any length, or for any allowance. Warps may be calculated in a similar manner. In some classes of goods the value is estimated according to the weight per square yard, and very frequently only very small samples of cloth are available for calculating from. In cases of this kind the weight and value may be readily found by weighing a square inch. Suppose a square inch weighs 12 grains, then a square yard weighs 35·55 ounces. This calculation is as follows;—Multiply 1296 (inches in square yard) by grains weight of square inch, and divide by 437·5 (grains per ounce); the quotient will be ounces weight per square yard, thus $\frac{1296 \times 12}{437·5} = 35·55$ ounces per square yard.

Numerous other short methods might be given, but as each would merely apply to the system of calculation in use in any particular district, the above will be sufficient to show the principle upon which they are arranged, and the student will have little difficulty in making short calculations for himself.

COLOUR.

In the manufacture of fancy textile fabrics the distribution and arrangement of colour is of no less importance than a judicious selection and arrangement of patterns, consequently a knowledge of the principles upon which the science of colour is founded, and of the laws of harmony, is of the first importance to the designer.

The science of colour teaches the nature and causes of colours, their distinctions, their relations to each other, their classification, the mental effect that attend them, and the causes and laws of their harmony.

It also includes the modifications of colours arising from varying sensibility of the eye, and the peculiarities of colour visions which are found to exist in different individuals. It enables the eye to distinguish and recognise the different hues in their various tints and shades, and to acquire a correct judgment of the constituents of colours, upon which their effect in any composition depends; it improves and directs the natural taste, and aids the student in arranging as well as appreciating good compositions of colour.

The whole subject is full of interest and beauty, and an acquaintance with it adds extremely to the pleasure to be derived from the contemplation of natural objects and scenery, as well as works of art; and it has one advantage, perhaps, over any other branch of natural philosophy, it teaches us in a remarkable way to distinguish between sensations and their causes, and not to judge hastily according to the appearance of things; and as the chief difficulty of the student of colour arises from this, it is necessary to call his attention specially to it, to guard against those misconceptions which might otherwise very much retard its progress.

Then, first of all, what does the science of colour teach us ? It teaches that colours are simply and purely sensations, excited by the action of light on the nervous tissues of the retina, which forms a screen at the back of the eye ; and a little reflection and observation must convince us that they must be so, since they are only seen by the aid of the light and vary considerably with different kinds of light.

But when we look at an object we see so clearly the colour on its surface at a distance from us, and that colour under the ordinary light of day is so constantly the same, that it is difficult to believe it is not some inherent quality of the surface, belonging quite as much to the object as the form which we see, and this belief, which is certainly a common one, is with some persons so strong that it is extremely difficult to make them understand the difference between colours (properly so called) and the colouring matter or pigments which are known by the same names.

To enter fully into the science of colour, and to trace all the sensations to their ligitimate origin, would be sufficient for a volume, and indeed should be dealt with and studied as a science, quite apart from any other subject, before its laws and teachings are applied to any branch of industry ; but as it is not possible for every one whose business may cause them to require some knowledge of the laws of harmony to study the subject so thoroughly, it becomes necessary to give the leading features of the subject in as concise a form as possible, thereby enabling them to acquire such information upon the subject as will be of some assistance to them in their daily avocations, and also assist them to a higher appreciation of all the beauties which nature so lavishly displays before them, as well as all that is high and noble in art.

Then, to return to our subject, it has been said that colours are sensations excited by the action of light. Whenever, therefore the term light is used to express a sensation, it must be understood and accepted as a general term, including each and all of the colour sensations, and when we say that light is composed of certain colours, we intend to convey that under certain conditions it excites one or all of those sensations of colour. For instance, it is said that a ray of solar light is composed of an indeterminate number of variously coloured rays, which simply means that a ray of solar light has the power of exciting sensations cf colour, according to the conditions under which it is presented to the eye, or to the condition in which the eye is prepared to receive it.

These colour sensations may be divided into simple and compound sensations, the eye being so constituted as to be capable of three simple or elementary sensations of colour, except in the case of some individuals, in whom some of the sensations are deficient, this deficiency being commonly known as colour blindness.

These colour sensations are beautifully revealed and may be accurately analysed by means of the prismatic spectrum.

The three simple or elementary sensations are best described and understood by the terms of red, yellow and blue.

The simple sensations are never excited separately on any part of the retina, but always accompany each other in a greater or less degree, thus causing the endless variety of colour which we observe.

When all are excited at once with an equal intensity on the same part of the retina, the result is the sensation of white.

The theory of colour established by Sir Isaac Newton, and adopted by Sir David Brewster and others, was that light was composed of seven different colours. The experiments which led to this conclusion were conducted by Sir Isaac Newton in the following manner :—In the window shutter of a darkened room he made a hole about a third of an inch in diameter, behind which, at a short distance, he placed a prism, so that a ray of the sun's light might enter and leave it at equal angles. This ray, which before the introduction of the prism proceeded in a straight line, and formed a round spot upon a screen placed a few feet from the window, was now found to be refracted, appeared of an oblong shape, and was composed of seven different colours of the greatest brilliancy, imperceptibly blended together, viz., violet, indigo, blue, green, yellow, orange and red. This is what is termed the solar or prismatic spectrum.

The theory thus said to be established was that the white light of the sun is composed of several colours, which often appear by themselves, and that white light may be separated into its elements. Sir Isaac followed up his experiments by making use of a second prism, by making a hole in the screen upon which the spectrum is formed, opposite to each of these colours successively, so as to allow it alone to pass, and by letting the colour thus separated from the rest fall upon the second prism he found that the light of each of the colours was alike irrefrangible, because the second prism could not separate any of them into an oblong image, or any other colour than its own ; hence he called all the colours simple or homogeneous.

From this it would appear that light is composed of seven primary colours ; bur Sir David Brewster, in a communication read to the Royal Society of Edinburgh, in 1831, showed that white light consisted only of three primary colours, red, yellow, and blue, and that the other colours shown by the prism are composed of these. This theory receives its first suggestion from the fact that each of the other colours are placed between those two of the primaries whose admixture will produce it. A discovery made by Buffon, and frequently illustrated by succeeding philosophers, also tends to strengthen this theory. If we look steadily for a considerable time upon a spot of any given colour, placed on a white or black ground, it will appear surrounded by another colour. This colour will invariably be found to be that which makes up the harmonic triad of the three primaries, red, yellow, and blue; if the spot be red the border will be green, which is composed of yellow and blue; if yellow, the border will be purple, which is composed of blue and red; and if blue, the border will be orange, which is composed of red and yellow, in all cases making a tri-unity of the three primary colours.

The composition of the secondary colours may also be proved by following out the experiments with the prism. If two of the primary colours be separated from the rest and thrown together by means of a second prism, the result will be to produce the secondary or intermediate colours with as much purity and intensity as in the spectrum.

Another theory which was originally advanced by Aristotle, and afterwards adopted by Leonardo de Vinci, is that transient colours are more likely to be the result of the action of light upon shade than the separation of light into its elements. This theory has been taken up by Goethe, who gives his opinion in the following terms:—

"Light and darkness, brightness and obscurity, or if a more general expression is preferred, light and its absence, are necessary to the production of colour. Next to light a colour appears which we call yellow, another appears next to darkness which we call blue. When these in their purest state are so mixed that they are exactly equal, they produce a third colour called green. Each of the first-named colours can of itself produce a new tint by being condensed or darkened. They thus acquire a reddish appearance, which can be increased to so great a degree that the original yellow or blue is hardly to be recognized in it ; but the intensest and purest red, especially in physical cases, is produced, when the two extremes of the yellow red and the blue red are united. This is the actual state of the appearance and generation of colours. But we can also assume an existing red in addition to the definite existing blue and yellow, and we can produce contrariwise by mixing what we directly produce by augmentation or deepening. With these three or six colours, which may be conveniently included in a circle, the elementary doctrine of colours is alone concerned. All other modifications which may be extended to infinity, have reference to the technical operations of the painter and dyer, and the various purposes of artificial life. To point out another general quality, we may observe that colours throughout may be considered as half lights, as half shadows, on which account, if they are so mixed as reciprocally to destroy the specific hues, a shadowy tint or grey is produced."*

Eastlake observes that the opinion so often stated by Goethe, namely, that increase of colour supposes increase of darkness, may be granted without difficulty. And he also observes, "Aristotle's notions respecting the derivation of colour from white and black may be illustrated by the following opinion on the very similar theory of Goethe :—

" Goethe and Leeback regard colour as resulting from the mixture of white and black, and ascribe to the different colours a quality of darkness by the different degrees of which they are distinguished, passing from white to black through the gradations of yellow, orange, red, violet, and blue. This remark, though it has no influence in weakening

* "Goethe's Theory of Colours," translated by Eastlake. Introduction, pp. xlii and xliii.

the theory of Newton, is certainly correct, having been confirmed experimentally by the researches of Herschel, who ascertained the relative intensity of the different coloured rays by illuminating different coloured objects under the microscope by their means.

"'Another certain proof of the difference in brightness of the different coloured rays is afforded by the phenomena of ocular spectræ. If, after gazing at the sun, the eyes are closed so as to exclude the light, the image of the sun appears at first as a luminous or white spectrum upon a dark ground, but it gradually passes through the series of colours to black, that is to say, until it can be no longer distinguished from the dark field of vision, and the colours which it assumes are successively those intermediate between white and black in the order of their illuminating power or brightness, viz., yellow, orange, red, violet, and blue. If, on the other hand, after looking at the sun for some time we turn our eyes towards a white surface, the image of the sun is seen at first as a black spectrum upon the white surface, and gradually passes through the different colours, from the darkest to the lightest, and at last becomes white, so that it can no longer be distinguished from the white surface.'" *

These authorities may be considered sufficient to warrant the adoption of the theory that shade as well as light acts in the production of transient colours, or, in other words, colour is produced by the action of light upon the retina, the quality of the colour being determined by the conditions under which it is presented to the eye.

Having examined the causes of colour, or rather the conditions under which colour is seen, we may now proceed to examine colours generally and divide them into the classes to which they belong.

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* "Elements of Physiology," by J. Müller, M.D. Translated from the German by William Bailey, M.D., London, 1839.

There are only three classes of colour, and they are termed primaries, secondaries, and tertiaries, or hues.

A primary colour is a simple element that cannot be separated into parts, but may be reduced to a tint by white, or to a shade by black. The admixture of either of the other two primary colours changes it to a secondary colour.

A secondary colour is consequently produced by the combination of two primary colours. The secondary like the primary colours, may be reduced to a tint by the admixture of white, or to a shade by black, and may also by the subordination of either of their component parts be changed in tone, still generally retaining their name, with perhaps the addition of the name of the primary which predominates prefixed, as blue-green, &c. Hence arise an immense number of modifications of each of the secondary colours; of green from the yellowest to the bluest; of orange from the yellowest to the reddest; and of purple, from the reddest to the bluest.* A secondary colour cannot be changed in character, but by the admixture of its contrasting primary, or by its combination with one or the other secondaries, it becomes a tertiary or hue.

As a tertiary colour or hue is compounded of two secondary colours, and is consequently a mixture of three primaries, therefore it may be modified in tone to a much greater extent than either primary or secondary colours, such modifications being effected by the predominance or subordination of any of its component parts, as also by the power of neutralisation possessed by each of those parts upon the other two. Of these hues three may be taken as primary hues, as follows:—Olive, produced by the mixture of purple and green; citron, by the mixture of green and orange; and russet, by the mixture of orange

* It is only right to say here that the red, yellow, and blue theory is said by most of our eminent scientists to be exploded, yet in practice there is no doubt it is the one upon which most people work, and certainly work satisfactory; and for this reason has been adhered to here.

and purple. These hues are all produced by the combination of the three primary colours, which neutralise each other, the most neutral of hues being grey, the mean between black and white, or the mean between light and darkness, as the secondary colours are between two of the primaries. This colour may with propriety be termed the seventh colour.

Tertiary colours stand in the same relation to the secondaries as the secondaries do to the primaries.

From the tertiary colours given above, and which I have called primary hues, by repeating a similar process of combination and proper balancing of their relative powers, arise the secondary hues, which are known by the name of brown, maroon, and slate.

Then having determined the primary colours, and by their combination produced the secondary and again in turn having combined the secondaries and produced the tertiary, it remains to show the relation which these respective colours bear towards each other, and to examine the laws of contrast and harmony.

Having shown that white light is composed of three primary colours, it must be evident that if a colour which is the result of a combination of two of these primaries, or if a series of colours in which one of the primary colours is absent be presented to the eye, the sensation produced cannot be perfectly harmonious, being of an imperfect character, consequent upon the absence of this primary element. Thus, if green is presented to the eye, green being composed of blue and yellow, the primary element which is absent is red, consequently red is said to be the complementary colour of green ; orange being composed of red and yellow, blue is the complementary colour of orange ; and purple being composed of blue and red, yellow is the complementary colour of purple.

Before proceeding to deal with the laws of harmonious colouring it may perhaps be as well to glance at the laws of contrast. As the eye glances backwards and forwards from one part of an object to another, the consequence of the variableness of its sensibility is, that the different colours of neighbouring parts more or less modify each other. For they are sure to be some mixture of the three primary sensations, and the proportion must become altered according to the nature of the previous excitement of the eye.

These modifications are commonly termed the effects of simultaneous contrast, the general effect of which is to make the difference of two colours in brightness and hue appear greater than it really is.

If we look at the same time at two stripes of unequal tints of the same colour, or at two stripes of equal tints of different colours, placed side by side, if the stripes are not too wide, certain modifications of the sensations will take place ; in the first case the intensity of the tints will be affected, and in the second a modification of the composition of the two colours. Thus bright white subtracts whiteness from any contiguous objects, and causes their colours to appear darker and deeper than they really are, but without in any degree altering their hues. In like manner, if red and orange be placed together the red will take red from the orange and make it appear yellow. Dark green will subtract from light green, strong blue from blue, &c. On the other hand colours placed together which are complementary to each other, tend to increase their intensity. For instance, red is the complementary of green ; if they are placed side by side both colours are increased in intensity by the contiguity. If orange and blue be placed together the same result occurs, and so on throughout the scale of colours. This result may be easily understood. We have only to remember for a moment that white light is composed of the three primaries, consequently any one of the primaries will reflect its own rays and tend to create in the vision the rays of the other two, and any of the secondaries will reflect the rays of the two primaries of which it is composed, and tend to create the rays of the primary which is complementary to it. Thus green will tend to create red rays, and red will tend to create green rays, so that when placed in juxtaposition the result is to heighten the effect of both colours by the tendency of each to create the rays of the other.

Black of course seems to brighten white, and to make all other colours appear lighter and clearer in the same manner as white makes them appear darker.

Harmony of colour is one of the greatest sources of beauty, and that harmony of colour is guided by definite laws there can be no doubt, for if various colour compositions of like character are compared, no matter whether they consist of different colours, or of the same colours differently arranged, it is seen at once that some are more pleasing than others, and in whatever form we contemplate colour, whether in nature or art, the majority of those who see colours alike are quite agreed in the objects of their preference.

Colour compositions are endlessly varied in character. They may be composed of two or three colours, or they may be composed of many. The colours may meet in sudden contrast, or they may blend into each other by impersceptible gradations. The different hues may be bordered with other hues, or with white, grey, or black. The colours may be of the deepest or the lightest possible, or they may be nearly neutral in hue. They may be dark or light, or they may be a mixture of all sorts, and as some of these are found to excel in beauty, it would seem then that harmony consists in something independent of all accidental circumstances.

Certain rules for producing this harmonious arrangement of colours may be laid down. We have endeavoure to point out the necessity for the presence of all the primary colours in any composition, but those colours must only be present in certain quantities, as the circumstances under which they appear will permit. Then, first and foremost, this pleasing composition must have a leading feature, and some one of the colour sensations excited to a slightly higher degree than the rest, so as to give to that colour a force or prominence in the group. There is no doubt that the excitation of each colour sensation is attended with a certain degree of pleasure, but its cessation becomes necessary after a certain interval, and as the eye leaves this colour it must be directed to some other. In contemplating a colour composition the eye is almost unconsciously directed to its different parts in succession. The colour sensations becomes affected or relieved, according as the object sends or does not send to the eye the rays which excite such sensations, so that a composition which is complete in itself should affect the eye with all the colour sensations either jointly or separately, and in such degree as to preserve the tone of the composition. Each colour sensation must be relieved also at proper intervals, which relief may be easily afforded by the introduction of black, or by one or more shades intervening, or by regular gradations, the rule being observed that the darker any colour, the less it will require relief.

Colours which are nearly related to each other, none of which excite the colour sensations to a much higher degree than the others, always produce a good effect when placed in juxtaposition. Thus very dark colours, whatever their hue, are all congruous with black and with each other ; in like manner very light colours, whatever their hue, are all congruous with white and with each other. This may very easily be proved by reference to nature, where associations of this description are very common. Take, for instance, the gradation of shades from crimson to pink in roses, arising not only from the different colours of their parts, but also from the reflections produced between the petals, and in numerous examples to be met with in every-day life.

Colours which differ mainly in light and shade, whatever their hues, always associate well, and have a good effect when placed in juxtaposition, especially if the quantity of unneutralised light contained in both of them is but small.

Thus complementaries, and other colours which differ widely from each other in hue, may very frequently be placed in juxtaposition, and with great advantage, if these conditions are observed, such, for instance, as a deep primary, and its opposite pale, clear secondary. The most striking contrast between colours of different hues in nature are of this character, as in flowers, between the yellow and purple of the pansy, and the dark blue and light crimson in some kinds of fuchsias.

But if bright colours which are complementary to each other, or differ widely in hue are placed in juxtaposition, the effect in general is not of such an agreeable character. There is generally a certain harshness in the association of such colours, which is commonly called a discord, caused doubtless by the difficulty experienced by the eye in accommodating itself to the sudden change from one powerful predominating hue to another. When colours of this kind come together in a composition in large quantities it is difficult to avoid a glaring effect, but they may sometimes be used together in small quantities with a good effect, provided they are accompanied by neutralising colours. In all compositions of colour there should be some degree of accordance between the breadths of the spaces occupied by the different colours in the composition. These breadths should be such as the eye is capable of viewing distinctly and with satisfaction, (taking into account the distance from which it is probable it will in general be viewed) without changing its direction more slowly or more quickly than is usual in contemplating an object.

If the parts of a composition which are differently coloured are much too small they become blended together in the vision, producing the effect of some indistinct colour partaking somewhat of the hue which would be produced by the blending of the most prominent colours in the composition ; while on the other hand if the breadths are much too large so as to require the eye to move over any considerable space or angle in passing from one to another, the beauty of the composition is in great measure lost from the inability of the eye to take in readily the different parts, and thus enable the composition to make an impression on the mind of the spectator : this arising from the want of excitement while dwelling on the dark or most neutral parts, and a want of relief while it dwells on the bright parts.

Hence, in general, the breadth may be greater for colours that do not differ very widely from the medium grey, than for colours which are more nearly allied to light or darkness, or which have some very powerful hue.

Similar considerations apply to breadths of space occupied by groups of colours of a kindred nature, which have on the whole a similar effect on the eye.

Variety of colours may be introduced into a composition ; and conduce very much to its beauty, provided the conditions and laws of harmony be not contravened by their introduction. Doubtless, by increasing the number of colours differing widely from each other in character, the difficulty of assorting and arranging them in such order as to satisfy the eye with their harmony is considerably increased owing to the number of gradations and contrasts which are thus introduced or increased ; but if well arranged, a composition consisting of many colours will always far excel one containing few in beauty and continuity of charm.

For instance, if we take a pattern containing a number of equi-distant stripes of neutral grey upon black ground, and compare the effect with another pattern having equi-distant stripes of three striking colours, say, red, green, and blue, the effect of these colours will be to neutralise each other. In each case all the three colour sensations may be equally excited, each one neutralising the effect of the other, but in the first case there is no variety of colour, simply because all the three colour sensations are scattered everywhere, combining in one uniform grey, while in the second case each colour sensation is excited and relieved in turn in an appreciable degree ; the beauty arising from variety being thus made distinctly apparent.

The application of the rules of harmony must of course be restricted and guided by the exigencies and proprieties of the subject of design, and the purpose to which it is to be applied. Such considerations must obviously affect our choice, and in any case in attempting to fulfil the laws of harmony the designer will find himself hampered with various influences, which tend to make full conformity with one law, much more with all the laws, almost impossible. But a moderate compliance with sound principles produces a good effect, and if the eye is pleased with some good features in the composition, it will in general be very indulgent towards, and disposed to overlook, inevitable deficiencies.

But however thorough the acquaintance with the principles and laws of harmony, and with the true relations of colours to each other, useful as this acquaintance undoubtedly is, it does not, nor can it supersede, although it must materially assist, good natural taste and sensibility to colour, or the skill and facility of harmonious arrangement which can only be acquired by careful practice, It is frequently required in colour compositions to produce some special effect, congenial with the circumstances of the case, and for this purpose it is essential to study the mental effects which seem to attend different classes of colour, and their modes of treatment.

Colour, like music, produces different effects on the mind, and in like manner it is well known to those who have made music their study that there are three fundamental notes, viz., the first, third, and fifth of the scale, and that these notes, when sounded together, produce the common chord, which is the foundation of all harmony in musical composition.

It has been pointed out that upon the eye being fixed upon any given colour it appears to be surrounded by another colour, which is its complementary. This also applies to music; when any given note is sounded it is either accompanied or immediately succeeded by others, which are called its harmonics, this effect resulting from the vibrations or sound waves, as it results in colour from the vibrations of light, or the combination of rays.

The senses of hearing and seeing each convey to the mind sensations or impressions of pleasure or pain in the modes in which they are acted upon or excited by external objects; hearing, by such objects in their motion producing an effect upon the surrounding atmosphere, and seeing, by the action of light upon them, or, perhaps more correctly speaking, by the rays which are reflected by them through the medium of light.

It is a well-known fact that sounds when addressed to the ear in intelligible language convey to the mind a meaning, either descriptive of an idea or sentiment, or of some object which is acknowledged by the understanding. In like manner colour conveys to the mind a meaning, or produces an impression. The deepest colours impress the mind with a certain idea of solemnity and magnificence, the deepest notes of music produce upon the mind a like impression. Clear, bright colours are equally striking, but in a different way—their effect is lively; in like manner the clear, lofty tones of music seem to raise the spirits of the listener, and if well blended together, have a most exhilarating effect.

But one remarkable difference may be observed between these two classes of colours. While the deep colours are always impressive, and from their nature must always have such an effect on the mind, clear colours lose all their excellence in the presence of brighter colours. Thus what may appear to be a full white, in a composition which is equally illuminated, is obscured at once when a bright light is introduced into a part of the composition which before had been of less brilliant character.

The three primary colours produce different effects upon the mind, the intermediate colours partaking more or less of these characteristics, accordingly as one or other of these colours predominates or neutralises the effect of the other. As has just been said, the bright colours have a lively effect, which may be described as exciting, warm, advancing, while blue has a cool, retiring effect; but if we mix the lightest of the primaries with this cool retiring colour we produce an intermediate, viz., green, which has a refreshing, soft, pleasant effect.

To compare the effects of different colours in this respect, they should be reduced to the same intensity, made equal in brightness and strength, for the eye seems to estimate the effect in proportion to the whole brightness of colour.

Compositions of colour partake of the character of their predominant colours. When a variety of colours of like characters are brought together, the result is generally to give a more marked character to the composition, and this effect is considerably enhanced when the colours are so arranged that they mutually improve each other. Thus a good composition of the deep primaries with black, and with some of their deep intermediaries, or of the clear secondaries with white and some of their clear intermediaries, is far more impressive or more lively than any single colour possibly could be, and the effect is more lasting, because the variety enables the eye to contemplate it with more pleasure and less liability to fatigue. So also a combination of warm colours of various hues produces a stronger and better effect of warmth than any single colour could do, and a combination of cool, retiring colours has the same effect in that direction. Compositions of a dull or neutral character are uninteresting, and if the colours are dark the effect is even gloomy and sad, unless relieved in some degree by the manner in which they are arranged or relieved by some spark of bright, attractive colour.

On the other hand, colours differing widely in character may form compositions of the most beautiful description, presenting admirable examples of the harmony of colours, though not necessarily of a very lively or very impressive character, nor very warm, nor very cool.

The character of a composition may be affected by the number of colours, as well as by the manner in which they are put together. The fewer the colours the simpler the composition in that respect, and simplicity itself has a charm, where other causes of beauty are present.

If the colours are too numerous there is great danger lest the advantage of variety be lost in complication, confusion, and superfluity.

Sharp contrasts in colour, provided they are not harsh, tend to give strength and vigour to a composition; easy gradations, if they do not degenerate into tameness and weakness, produce soft and gentle effects, but should the gradations be of too tame a character the result is insipidity.

Then these principles which govern harmony and contrast may be reduced to definite order, or what is termed laws. It has already been pointed out what is meant by contrast, but this may be further qualified by dividing contrasts into three orders. First, what is termed simultaneous contrast, which simply means the intensifying of any colour by the presence of its complementary, as has already been shown; second, successive contrasts, or the tendency of the vision to create the complementary to that which is seen, and upon which the law of simultaneous contrast depends; and third, mixed contrasts, the tendency of the successive or created colour to blend with that of the object being viewed. Each of these laws of contrast is separate and distinct from the other, yet each is necessary for the existence of the other. Each one of the three may be fully and easily demonstrated by a simple experiment. If we take a bright-coloured object and look at it intently for some time, the colour begins to loose its power and become dim; at the same time the eye becomes fatigued, and cannot look steadfastly at the object. If we then turn our vision to another object, the colour of which is complementary to that of the first object, the eye is at once relieved, and at the same time the colour of the second object appears bright and intense. For example, suppose we take a red piece of fabric, and look over the piece from end to end, the colour may at first appear to be an excellent bright colour, but after a short time it begins to appear dull. This is the result of the successive contrast, or the tendency of the vision to create the complementary green, and of the mixed contrast, or the tendency of the vision to blend the green thus created with the red of the fabric, and so impair the brilliancy of the red. If we then lay aside the red fabric and take up a green we see the green in an intensified degree, because the eye has created a tendency to see green by the presence of the previous red, but after looking for a time at the green piece, a reaction takes place, and the eye begins to create a tendency to see red, and so causes the green to appear dull and approach a grey. Turn again to the red piece, and it will appear more intense than before. Thus we have all the sensations of contrast illustrated at once. Then from this it will be evident that the effect of any colour in a composition will be heightened by the presence of its complementary, but as will presently be shown, they must be present under certain conditions only. Again, it must also be manifest that the presence of any two colours in juxtaposition, each having the same common element, will detract from the quality of both, but perhaps in a greater degree from one than the other. If we place, for example, a red and orange, a yellow and green, or a blue and purple together, we shall find in each case that one colour will detract from the other ; or we may carry this still further, if we take a black, which appears at first sight to be a dense black, and place it in close juxtaposition with blue, we shall find that the black appears to have lost some of its density and has assumed a somewhat russet hue. This arises from the blue causing a tendency in the vision to create its complementary orange. The orange thus created mixes with the black and so produces the russet hue. On the other hand, if the black in the first place has a russet hue, if it be juxtaposed with orange or red it will at once appear as a dense black, because the blue ray is created in the vision and compensates for the russet hue on the black.

It has been said that in all colour compositions the three primaries must be present to produce perfect harmony. Then the question arises, In what proportion should they be present ? There is some slight difference of opinion as to what may be considered the exact equivalence of each, but the proportions laid down by Field are generally accepted by our most practical writers as being sufficiently near for practical work.

In the scale of chromatic equivalents as laid down by

Mr. Field, the fundamental powers of the primary colours in compensating and neutralising, contrasting and harmonising their opposed secondaries are approximately as *three* yellow, *five* red, and *eight* blue; consequently the secondary *orange*, composed of three yellow and five red, is the equivalent of *blue*, the power of which is eight. They are accordingly equal powers in contrast, and compensating in mixture, and as such are properly in equal proportions for harmonising effect.

Again, *green*, being composed of blue, the power of which is eight, and yellow, the power of which is three, equivalent in contrast and mixture as eleven, to *red*, the power of which is five, being nearly as two to one.

And finally, *purple*, composed of blue as eight, and red, the power of which is five, is equivalent in mixture and contrast as thirteen to *yellow*, the power of which is three, is nearly as four to one. And such proportions of these opposed colours may be employed in forming agreeable and harmonious contrasts, in colouring and decorative painting, either in pairs of contrasts, or several, or altogether, and also for subduing each other in mixtures.

The tertiary colour *citrine* harmonises with the secondary colour *purple*, in the proportion of nineteen citrine to thirteen purple. The tertiary colour *olive* harmonises with the secondary *orange*, in the proportion of twenty-four olive to eight orange. The tertiary colour *russet* harmonises with the secondary *green*, in the proportion of twenty-one russet to eleven green, &c.

And further, it is apparent that all compound hues of these colours will partake of their compound numbers, and contrast each according to a compound equivalence. Thus an intermediate red-purple will contrast with a like opposite green-yellow, with the power of eighteen to fourteen, and so on without limit all round the scale, and the triple compound or tertiary colours are subject to like regulations.

But there is no absolute necessity that these proportions should be exactly adhered to. Some one may be made to predominate so as to give a key tone and character to the composition.

In determining which colour shall be allowed to predominate, or give tone to the composition, due regard must be paid to the mental effect of the several colours, and to the purpose to which the composition is to be applied. It has already been pointed out that each of the three primaries produces a different mental effect. Blue conveys the impression of coolness, and appears to retire from the spectator ; blue also is nearly allied to black, or darkness. Red conveys the impression of warmth, is stationary as to distance, and is the mean between light and darkness. Yellow conveys the impression of light, and advances towards the spectator. Any compound colour will partake of these characteristics just as one of the three primaries predominates, or as it is neutralised by the presence of the others. Therefore in all compositions, to whatever purpose they are to be applied, these mental effects should be duly considered, and that one selected to give tone which will be most in accordance with the object of the composition or the purpose to which it is to be applied.

Then to return to the necessity for all the three primary colours being present in any composition, either in the form of primaries, secondaries or tertiaries. Although, as has been shown, they must of necessity be present, they need not necessarily be present in their full intensity or power, but they may be diluted or reduced to shades, tints, or hues, and in proportion as they are reduced or diluted their areas may be increased. We very rarely find either primary or secondary colours present in their full intensity, and extending over large areas, in any composition. The composition will invariably be more effective and pleasing if large areas are occupied by tertiary or neutral tints, and enlivened by brilliant flashes of colour in the form of a full primary or secondary. Nor should powerfully contrasting colours be placed in close juxtaposition to each other without the presence of some neutral to subdue or modify their effect upon each other. If we place, for instance, red and green in close juxtaposition in any composition, although they are complementary to each other, and the presence of one is necessary to the existence of the other to produce perfect harmony, yet the effect is unpleasant. Suppose we have alternate stripes of red and green, or if we have red figures on a green ground, or *vice versa*, the eye could not rest long upon them without experiencing an unpleasant sensation, the two colours would begin to swim into each other as it were, and the longer the eye rests upon them the stronger and more unpleasant will this swimming sensation become ; but if the two colours be separated by black or white, or some tertiary or neutral colour, then this swimming sensation will be entirely prevented, and yet perfect harmony will prevail. In the same manner if blue and orange be juxtaposed the swimming sensation will result, but it may be again prevented by the introduction of neutral. If purple and yellow, are placed together the effect is not quite so unpleasant, because the two colours, although complementary, are more nearly allied to light and darkness respectively. Yet even in this case the effect is much improved by the presence of tertiary or neutral colours. Therefore at all times colours which are complementary to each other should either be present in subdued form or separated from each other by the presence of some neutral colour.

In addition to this quality of modifying the effect of complementary colours, neutral colours also possess the property of modifying the effect upon each other of colours which possess the same common element. As has been shown, colours which possess the same common element, if placed in juxtaposition, have the effect of detracting from each other, but if separated by black, by white, or by neutral colour, this mutual detraction is prevented or modified. If, for example, we place blue and green together, one colour will partly destroy the other, and the point of junction of the two will be scarcely discernable; but if we separate the two by either a black or white line, we shall find the effect materially improved. In the same manner we may deal with red and orange, or with any other two powerful or bright colours, and the result will invariably be the same.

In speaking of neutral colours, the peculiar properties of gold as a neutral may be pointed out. Although the appearance of the colour of gold is decidedly yellow, yet it is one of the most neutral colours to be met with. Not only will it harmonise with any or all colours, but it will modify the effect of any two colours, or compositions of colour, upon each other. It is for this property as much as for its peculiar richness that gilded frames are so much preferred for pictures, the richness and neutrality of the colour of the gold not only tending to improve the effect of the colouring of the picture, but at the same time effectually preventing the interference in an undue degree of any surrounding colours.

Gold is a colour which is very rarely used in textile fabrics, yet it may sometimes be used with advantage, and whenever it is used this peculiar property may be borne in mind.

Then the whole theory of colour treatment may be briefly summed up as follows :—We have three primary or simple colour sensations, and in any compositions these three sensations must be excited if we have harmony, or, in other words, the three primary colours must be present either in their pure form or in a compound form. As each colour sensation is excited it must also in turn be relieved, thus implying that if any one is present in its most intense form the others must also be present in an equally or nearly an equally striking degree, either as to its intensity or its area. Colours which are kindred to each other will associate well ; but if they partake in a large degree of the same common element they must be divided or separated from each other by some other neutral colour, or by the intervention of white or black, or light and shadow. In this latter case the light and shadow need not necessarily be present in the definite form of black and white, but it may be present in the form of an admixture of light with one colour and shadow with the other. If we take, for example, two blues or two greens, or any other colours, and place them in juxtaposition, to produce perfect harmony, or an effect pleasing to the eye, one must be reduced to a tint by the admixture of white, and the other to a shade by the admixture of black, and just in the degree in which the two approximate to light and darkness respectively will their power of pleasing and producing harmony exist ; because the two colours, possessing the same common element, would tend to detract from each other but for the existence of the light and shade, therefore just in the degree in which the light and shade separate them from each other will the effect be pleasing.

If we are dealing with gradations of colour precisely the same principle will apply, whether we are gradating from light to dark of the same colour, or from one colour to another, therefore the more perfect the scale of gradation from one extreme to the other, the more equally balanced the extremes of the gradations are with each other, the more pleasing will be the effect. Then not only should the gradations be true and regular throughout, but the ends or extremes should be equally striking, and so balance or sustain each other. In compositions where gradations contrast and single colours occur, as will frequently happen, there should be a correspondence or equivalence between the parts throughout, and the grouping should be so arranged that the eye is not attracted too much to one part to the detriment of the rest. This again further implies that the whole should occupy appropriate breadths, so that the eye can take in the whole of the composition at once ; or if not, such parts as do come within the range of vision must be so arranged that they do not suffer in effect by the absence of the other, or that the eye can travel from one part to another without any great effort, so that the absence of one part from the range of vision is compensated for to some extent by the facility given for viewing the whole group. By bearing carefully in mind these rules and principles, by careful observation and practice, combined with some natural aptitude, it becomes a comparatively easy task to treat variety of colour in such a manner as to conduce to beauty and to be pleasing both to the cultured and the uncultured eye.

Occasionally restrictive conditions may occur which will have to some extent the effect of marring a composition. These restrictive conditions are various, and their effect may be different under different circumstances ; but a careful consideration of their cause and effect will enable the colourist to deal with and overcome them in the best possible manner.

SUMMARY AND CONCLUSION.

As has been fully pointed out in the foregoing chapters, weaving is simply the interlacing of threads or fibres with each other for the purpose of making a fabric which might be applied to some useful purpose, and the whole art of weaving consists in the proper interlacing of these threads or fibres, so as to be best adapted to the purpose to which the fabric is to be applied, due regard being paid at the same time to the nature of the thread or fibre used in its manufacture, and where fabrics of a fancy character are required, regard being also paid to the proper arrangement and adaptation of pattern and colours. This, as has been mentioned, is generally the work of one man for a manufacturing concern, who is known as the designer. Consequently, upon the designer devolves all the duties connected with the production of new fabrics, or new patterns upon old fabrics; and upon his knowledge, not only of the principles of weaving, but also of the nature of fibres used in the production of fabrics, the theory of colour and general art principles, and a ready facility for practical application of these principles and adapting them to the fashions of his time, will his success entirely depend.

Although, strictly speaking, the art of weaving consists in the proper interlacing of these threads, and consequently an intimate knowledge of the mechanical operations or processes to be employed to obtain the result desired, closely connected with this, and in fact almost indispensible, is a knowledge of the nature and structure of the fibres employed. Such a knowledge not only materially assists the weaver in the arrangement of the patterns for his fabric, but frequently enables him to employ materials for purposes which, but for this intimate knowledge of the nature of the material or fibre, might be entirely overlooked, or even considered unsuitable.

Treating the subject broadly, all weaving, as has been shown, is reducible to three distinct classes. Or, if we include knitted fabrics and laces, we have five classes. In the first two – plain and figured weaving – the warp threads are parallel to each other, and are crossed at right angles by the weft. The only difference between the two consists in the manner in which the threads are interwoven. In the one case the warp and weft threads are interwoven alternately; in the other, the warp and weft may pass over any number before being interwoven. Consequently plain weaving will produce a cloth of maximum strength with a minimum of material, while figured weaving is adapted for producing weight and bulk, owing to the loose way in which the threads are interwoven permitting them to be brought closer together, and consequently allowing a greater number of threads to be put in the cloth. Again, plain weaving does not permit of the ornamentation of the fabric,—but in a very limited degree—except by means of colours, while in figure weaving the fabric may be ornamented either with or without the aid of colour.

In gauze weaving the parallelism of the warp threads is not preserved as in the other two, but they are made to cross or become partly twisted round each other in the process of weaving. The result of this is to produce an open or perforated fabric. Gauze weaving possesses in some degree some of the characteristics of both the other two. By the manner in which the warp threads are made to twist round each other in interweaving with the weft considerable strength is imparted to the cloth, and at the same time the fabric may be ornamented without the aid of colour if desired. But from the very nature of the construction of the fabric nothing but light cloths could be produced.

Then, these, being the chief characteristics of the three primary classes of fabrics, the weaver must consider first which of these three, or which combination of two or more, will produce a fabric best suited to the purpose to which it is to be applied, and also to the nature of the material to be used for the production of the fabric. Not only must he consider the nature of the fibre of which his thread is to be composed, but also the character of the thread. He must know whether the thread possesses sufficient strength to bear the strain to which it will be subjected. If he desires to have a pattern visible on the fabric, he must consider whether the character of his thread is such that it will interfere with the pattern, as it will be certain to do if there is a great deal of loose fibre upon it. He must also consider, if the cloth is to be a plain one, whether this loose fibre will interfere with the threads in crossing each other, and if so, take means to prevent that interference as far as possible. All this may be summed up briefly by saying that all threads in which the fibres are laid parallel, or in which the amount of twist is such as to produce a clear firm thread, may be woven into fabrics in which the pattern must be distinctly visible, and all threads presenting a great deal of loose fibre must be used for goods in which the pattern is not desired to be visible. *See Appendix A.*

These observations refer chiefly to the simplest forms of weaving, such as plain and twill fabrics, or those having small, simple designs upon them, though they refer also in a more or less degree to all forms of weaving. For instance, if we are making a gauze cloth it would be an absurdity to attempt to make it with warp threads having a great deal of loose fibre on them, or with very soft twisted materials. Again, in making cloth it is a matter of absolute necessity not only to have the material or fibre of which the thread is composed such as will be adapted to the purpose to which the fabric is to be applied, but both the material and the construction of the thread which is to form the ground of the cloth must be suitable to the purpose.

These are the primary considerations, and they are such as can only be mastered thoroughly after long practice and close attention, but these principles being once mastered, the mere mechanical operations of weaving become a comparatively easy task.

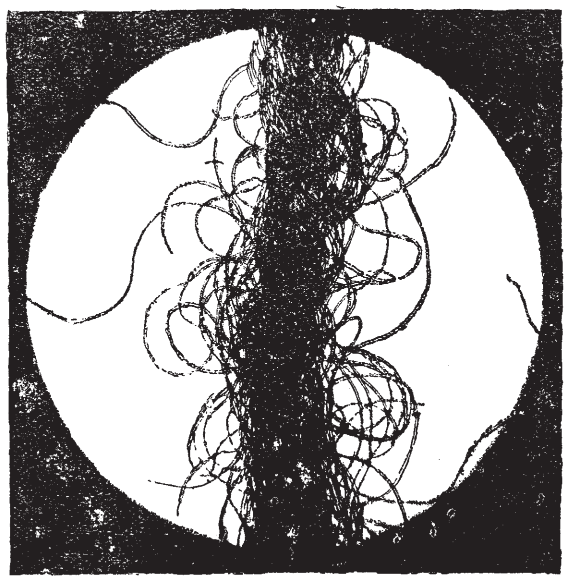
With respect to the manufacture of fancy goods much might be said, not only respecting the adaptation of the material to the purpose to which the fabric is to be applied, but also with respect to the combination of materials to produce effects, and the combination or adaptation of forms in the productions of designs, as well as upon the colouring of fabrics ; but no amount of writing could possibly supply that which can only be gained by practice and careful observation, and no rules could possibly be laid down which could supersede sound judgment, or supply taste, although one may be assisted and the other refined. The most valuable assistance will be found to be the knowledge gained by experience, and the most refining influence careful study of the choicest productions of nature and art.

With respect to the mechanical operations of weaving, the combination, interlacing, and arrangement of coloured threads, taken separately, nothing could be more simple. If we take the three movements which have to be executed in weaving, separately they are simplicity itself, yet they are in combination beautiful, interesting, and instructive. The regularity and simplicity of the movements, the ease and rapidity of their execution, accompanied by the regular winding of the cloth on one beam, and letting off the warp from another, and the ever ready stopping motions and protectors in the event of anything going wrong, bringing the whole at once to a dead stand, certainly present as beautiful and complete a machine as it is possible for mortal man to produce, or for the mind to conceive. Indeed, textile machinery from the first to the last process of manufacture presents as complete and remarkable an illustration of the inventive powers of the human mind, and the complete control and power of mind over matter, as is to be found in the whole universe, and certainly no art or handicraft exists more interesting to the earnest student than that which supplies one of the first requirements and most powerful elements of civilisation.

APPENDIX A.

THE STRUCTURE OF THREADS.

The general principle of the structure of threads has been pointed out already in my work "Design in Textile Fabrics," and also the uses to which the various classes of thread may be applied advantageously. The accompanying

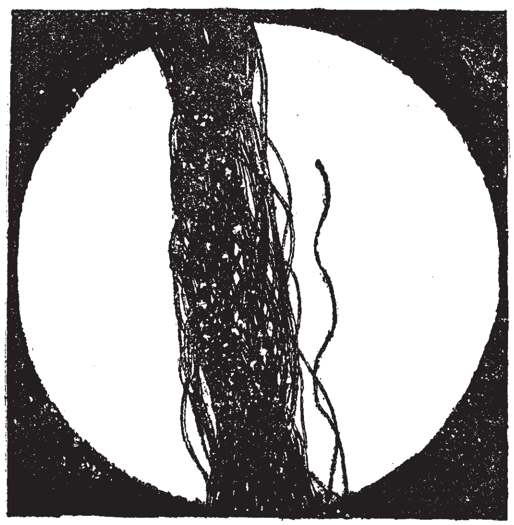


WOOLLEN YARN.

illustrations will fully demonstrate what is there pointed out. These illustrations are engraved direct from photographs of the several threads taken through the microscope and consequently their truthfulness is beyond doubt.

In the woollen thread the fibrous character is amply demonstrated and the tendency to felting in cloth made from this yarn will be easily understood. Whereas, in the worsted yarn the perfect parallel lines of the fibres is equally well shown. The counts of the yarn from which the photographs were taken were 48 skein woollen (Yorkshire count), or equal to 22^s worsted, and the worsted yarn is 24^s; and for the purpose of making a fair comparison, the quality of the wool in the two yarns respectively is nearly the same.

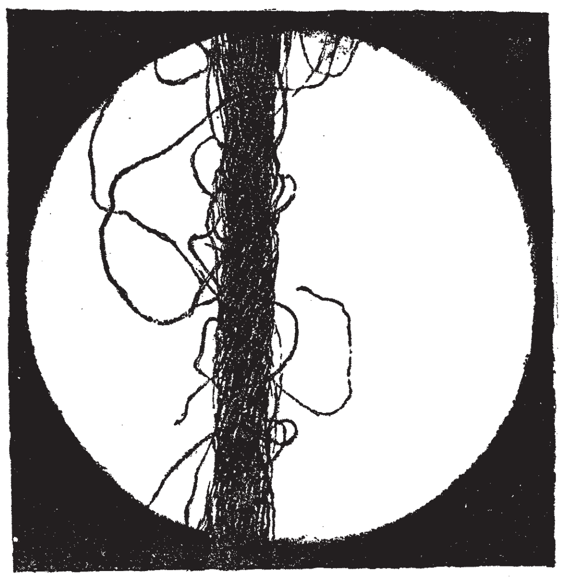
A glance at the two yarns will at once convince one of the purposes to which they may be most readily applied.



Worsted Yarn.

It will not be difficult to understand that any pattern which may be woven in the cloth will be at once lost, at least to some extent where woollen yarns are used, and that felting will be facilitated to the utmost, whereas with worsted yarns exactly the reverse is the case; the pattern will be clear, but there is nothing to assist in felting.

Turning to the cotton yarn we have one which in character comes between the woollen and worsted. The yarn here represented is an ordinary single 80ˢ carded yarn. This yarn is carded after the same manner as woollen, but afterwards goes through a "drawing" process, which not only tends to equalise the thickness of the yarn, but also to reduce the fibres to a greater degree of parallelism, consequently the thread presents an appearance something between the two already referred to, and possessing some of the characteristics of both. There is a certain amount of



COTTON YARN.

fibre projecting from it, but not so much as from a woollen yarn, and more than from a worsted yarn.

What is known as a "combed" cotton yarn has precisely the same structure as the worsted thread, the fibres being laid strictly parallel.

The silk yarn shows the fibres strictly parallel. Of course this must always be so in all "raw" silk, that is silk drawn direct from the cocoon, as they consist of continuous fibres, but spun silk is prepared practically on the same principle as cotton and will consequently present a little fibre, but not so much as cotton; owing to the fibre being longer. This illustration also discloses another feature

Silk Yarn.

of the silk thread, especially of wefts from which this is taken, viz., the very small amount of twist in the yarn, though of course for warps there must of necessity be a little more. The yarn from which this photograph was taken would be equal to about 96^s cotton.

APPENDIX B.

THE JACQUARD MACHINE, ITS HISTORY AND USE.

Reprinted from "L'Ingenieur Universel" of 1880.

It is well known to every student that all our most useful and valuable machines have reached their highest stages of perfection by slow degrees, and that although their first introduction to the world may have been the work of one man of genius, they have undergone many alterations and improvements subsequently at the hands of others. It may also be said that many of the greatest inventions are not entirely the work of the man whose name is associated with their introduction to the world, but the result of a combination of what has been done by others in the same direction. It is always an interesting study to follow the progress of a machine from its earliest birth to its latest development, and that is more especially the case when the subject of our study occupies such an important position in one of our greatest industries as does the Jacquard machine. It would not be a difficult matter to make up a volume of interesting matter in tracing its history and development, but our object will be, with the space at our command, to sketch briefly its history and use. We need not review the personal history of Joseph Marie Jacquard, or the manner in which his machine was first brought before the world. So much has already been written upon this subject that the student will have no difficulty in learning all he may wish to know about the matter from a variety of sources. The object of the Jacquard machine is to facilitate the production of elaborate designs upon textile fabrics, and for this purpose it has superseded what was formerly known as the draw loom. We may perhaps make this more intelligible to some of our readers if we say that the Jacquard represents and takes the place of a number of healds. Any one who knows anything of a loom will not require to be told how difficult it would be to crowd a few hundred healds into a loom, but a Jacquard may represent several hundreds of healds and not occupy an inconvenient space. For the purpose of showing as clearly as possible the use of the Jacquard machine, and at the same time to ascertain as nearly as we can how much of the merit of invention is due to the man whose name this machine bears, we will commence with an explanation of the draw loom, and from that point follow upwards.

Fig. 1 represents a draw loom harness. A is what is termed the harness; R the cumber board; C the neck; D is a pulley-box through which the cords from the neck are passed. These cords are continued, as shown at E and F, and beyond F are attached to a rod passed through a ring of the roof or ceiling of the workshop, this portion being called the tail or tail cords of the harness. To the tail cords are attached another series of cords G, which are carried down and attached to the floor, by means of a rod in a similar manner to the tail. These cords are called the simples, and upon them the pattern to be woven is read; that is, another series of cords I, which are called lashes or leashes, are attached to such of the simples as will raise that portion of the harness which is required to be raised to form the pattern. They are then attached by a running noose to the cord H, which is simply a fixed cord from floor to ceiling, and parallel to the simples. So far as the harness itself is concerned, the arrangement is shown very clearly, the warp threads being passed through eyes or "mails" at A, and the weights B serving to bring down such of the harness

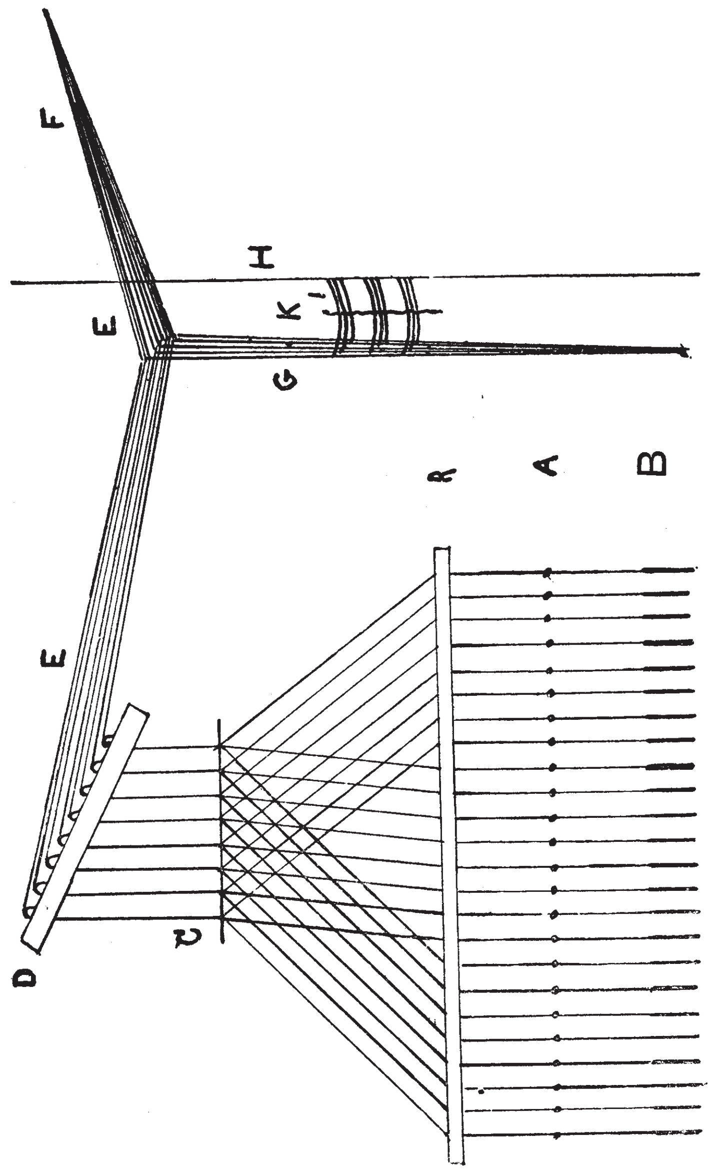


FIG 1.

cords, and with them such of the warp threads, as have been raised. Then the duty of the draw boy is to pull the lashes I in succession as the weaver throws in the weft, and so by continually drawing the cords over and over again in the order in which they are read, the warp is separated in such manner to receive the weft as will produce the pattern desired.

This then is the principle of the draw loom in its

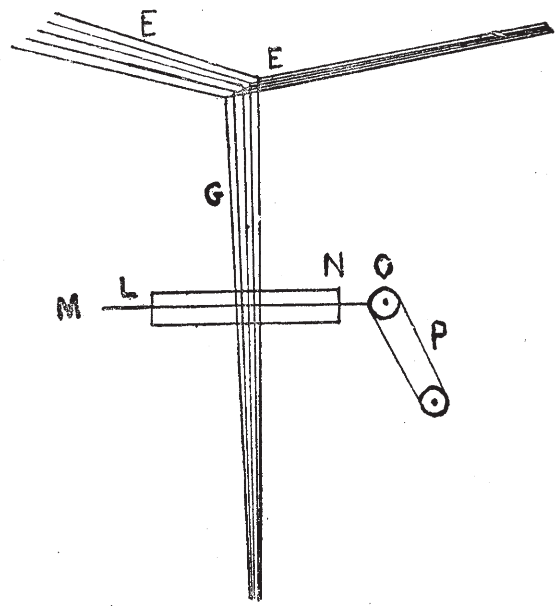


FIG 2.

simplest form. At various times machines were invented to supersede or rather to assist the draw boy in his work, but in all of them the use of the " tail " and " simple " were preserved. They therefore consisted chiefly in mechanical means of drawing the lashes or some apparatus which should take their place. The one which most nearly concerns us at present is said to have been invented by a Frenchman, M. Bouchon, in the year 1725. In this apparatus each of the simple cords passed through a long needle having an eye or loop formed near its middle. One end of this needle projected a little way in front of the board through which it passed. These needles were acted upon by a band of perforated paper, the perforations in which are made according to the pattern to be produced. Fig. 2 shows in a simple manner the principle of the apparatus. The parts lettered E and G correspond to the parts having the same letters in Fig. 1. In addition will be seen a box carrying a series of needles M, through each of which one of the simples is passed; N is the needle-board with the needle projecting through it; and O is a grooved or perforated cylinder over which the band of paper P is passed. The weights on the harness will keep the simple cords in their vertical position, and consequently keep the points of the needles pressed through in front of the needle-board; then it is obvious that if the roller O be pressed against the point of the needles, wherever there is a hole in the paper opposite the point of a needle, that needle will pass through and remain stationary. But when the paper is blank the needle will be pressed back, the simple will be drawn, pulling down the tail cord, and consequently raising the harness and the warp, which is drawn through in precisely the same manner as if the leash had been pulled by the draw boy. As each leash of the draw boy serves for one pick, if the paper is perforated in rows, as shown at Fig. 3, each row would serve for one pick in precisely the same manner. In 1728 M. Falcon substituted a chain of cards and square bar for the paper of M. Bouchon; and later Vaucansen dispensed with the tail cords and simples and made the draw bar self-acting. The harness really has to serve in the place of healds, and its arrangement is as follows:—The neck cords are numbered 1, 2, 3, &c., and to No. 1 neck a harness cord is attached and carried down through the cumber board, another from Neck No. 2, and so on until a harness cord has been attached to each neck. When this has been done we have what is termed one round or division of the harness. This is repeated as many times as will make up the desired width of the fabric; consequently whatever pattern is formed by the first division of the harness is repeated by the subsequent divisions.

We can now begin to examine the invention of Jacquard, and to estimate its value, his machine being a combination of the principles we have shown. It has been denied that Jacquard deserves any of the merit of an invention, but that he simply deserves the credit of "an experienced workman

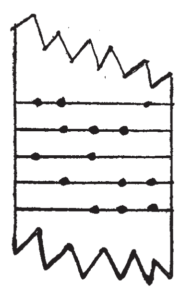


FIG. 3.

who by combining together the best parts of the machines of his predecessors in the same line, succeeded for the first time in obtaining an arrangement sufficiently practical to be generally employed." The first machine of Jacquard is said to have been completed in the year 1801, but it was some time after that when it was introduced into England. The first patent taken out for it in England was on April 11th, 1820, by F. Lambert, being "A communication from a certain foreigner living abroad," and it is described as "A new method of mounting and producing, and also of removing, preserving, and replacing the figure in weaving gold, silver, silk, worsted, cotton thread, and other laces whether made or composed of the aforesaid articles, any or either of them, or a mixture thereof." In his specification he shows complete drawings of all the parts of his machine, cards, design, &c., and explain fully the use and mode of cutting cards, and claims that the figure plates (cards) may be removed from the 'matrix block' (card cylinder) and another chain of figure plates substituted in its place, provided the width of the warp already in the loom be then suitable for the new fabrics, and the first set of figure plates being so removed may be preserved and kept for use at any future time," and he also claims that "by this invention an extraordinary and greater length of figure may be produced than hath ever been produced in his Majesty's kingdom." This is an ordinary Jacquard machine in its simplest form.

Before proceeding further we will describe as simply as possible the principle of this machine. It would be a difficult matter to conceive anything more simple in construction. It consists of a frame containing a series of upright hooks arranged in rows, each one of which serves the purpose of the tail cords shown in Fig. 1, and has attached to the bottom of it the neck cord from which the harness is suspended. Nearer the upper end of the hook it passes through the looped eye of a needle similar to that shown at M, Fig. 2. Then as the upright hook serves the purpose of the tail cord, the needle which crosses it serves the purpose of the needle and simple in Fig. 2, or of the lash J and simple G in Fig. 1. Fig. 4 will more clearly explain its arrangement. A represents the upright hooks, and B the needles through which they pass, each of them projecting a little way through the needle-board C at the front of the machine, and at their other extremity pass into the spring box D. Here each separate needle is provided with a small helical spring, which presses the needle forward and keeps the hook in its vertical position. Immediately beneath the upper extremity of the hooks a series of lifting knives are placed, their position being such as to be under the hook when it is in the upright position. To the cords E the harness is attached ; in fact they are the neck cords exactly corresponding to the neck cords in Fig. 1. The hooks are kept in position at the top by the needles through which they pass, and at the bottom by the neck cords, each of which passes through a hole in the board F, and they are prevented from turning by a grate, the bars of which rest in the lower part, that portion which is turned up being carried

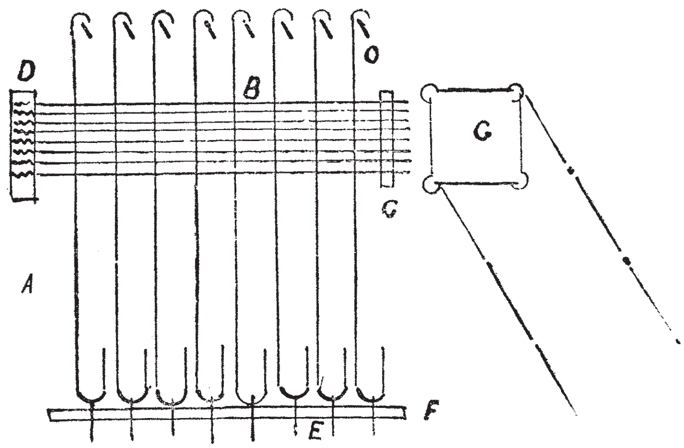
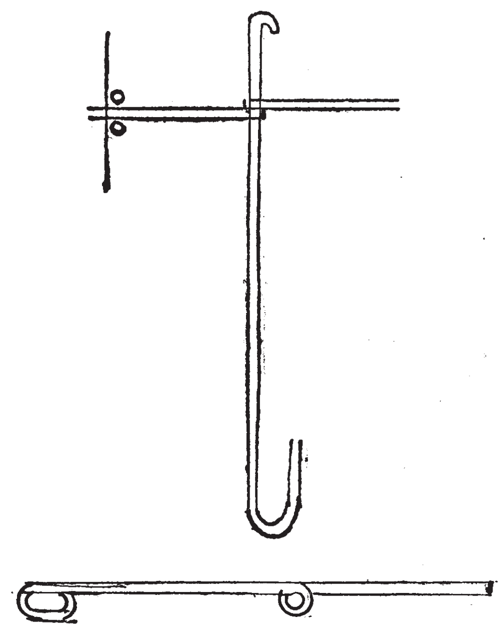


FIG. 4.

so far that the grate should never pass above it. In front of the needles is a square bar over which the cards pass, this bar being perforated with as many holes as there are needles.

If a card is placed upon this bar, wherever there is a hole in the card the needle corresponding will pass through, and the hook connected will remain stationary over the lifting knife on the bar carrying the card being pressed against the needles ; but where there is no hole in the card the needle will be pressed back carrying the hook with it, and consequently taking it clear of the lifting knife. At every pick these knives are raised, lifting up such of the hooks as have not been pressed back, and at every pick a fresh card is brought up to the points of the needles until the whole pattern is complete. This brief description represents the principle of the machine but there are details which will now require consideration. It will be obvious to the reader that some provision must be made for the lifting of the knives, for the purpose of lifting the hooks of the machine, and for bringing fresh cards in succession to the point of the needles. To perform the first of these operations the knives are firmly fixed in a block which is raised and lowered by means of a lever. In the first arrangement which was patented in England there were two of these levers employed, and the attachment came over the side of the loom. In 1821 a patent was taken out by Mr. S. Wilson, which in part refers to this matter. In previous arrangements the machine was so placed on the top of the loom that the card cylinder was towards the warp beam, but the first claim in Mr. Wilson's patent, is that the cylinder, or as he terms it the "revolving bar," shall be placed at or towards the side of the loom, instead of towards the warp beam, and so enabling him to extend the machine or use two or more machines at the same time. The second claim is that by so placing the machine the lever connected with the lifting block comes over the head of the weaver, and a cord is passed behind him and attached to a treadle "by which means the weaver is able to draw the heaviest monture and figured work without the use of a draw-boy." Another improvement which forms part of Mr. Wilson's patent consists in an alteration of the form of the needles, a loop being formed at their furthest extremity from the lifting bar, which is passed through horizontal wires and at right angles a regulating pin is passed through the loop of the needle, the extremity of the loop pressing against the helical spring which is to press it forward towards the cards as shown at Fig. 5. The cards are made to act upon the needles by being passed over a perforated bar or cylinder, which must have such motion given to it as will bring the cards into contact with the points of the needles at the proper time, and the cards must also be brought up in regular succession. To effect this the cylinder must have a reciprocating rectilinear motion given to it, and at every motion it must also make one fourth of a revolution upon its axis. Various



PLAN OF NEEDLE.

FIG. 5.

devices have been adopted for this purpose but the one in most general use is shown at Fig. 6, where the cylinder is carried near the lower extremity of a pair of Arms A, which work on a fixed centre at the top B. From the lifting block C, a rigid L shaped arm having a pulley at its extremity is carried out, and works in a curved bar D which is attached to the arms carrying the cylinder. The consequence of this arrangement is that as the block C is raised, the pulley acts on the upper side of the curved bar, so throwing out the arm, and as the block descends it acts upon the under side, bringing the arm back and pressing the card

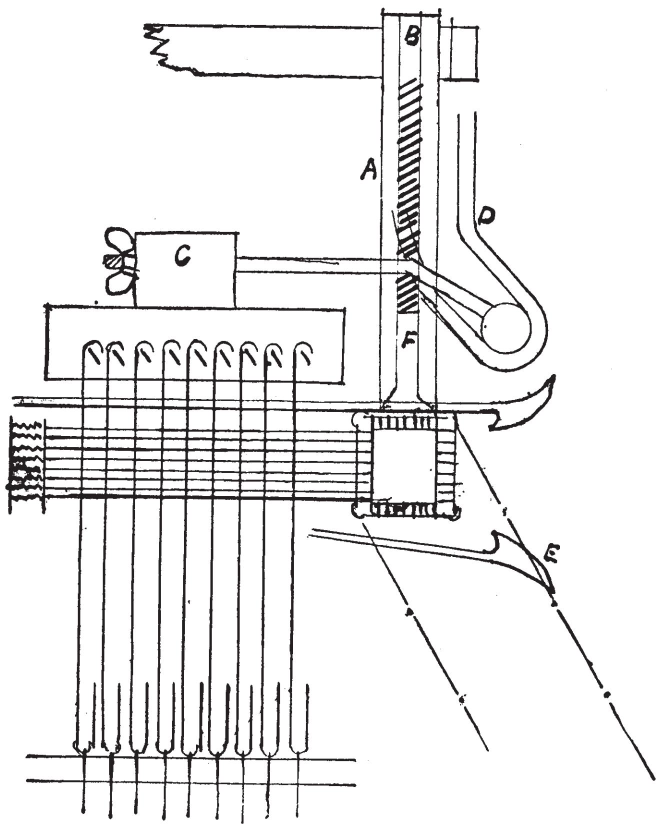


FIG. 6.

upon the point of the needles. To cause the cylinder to revolve, a pair of pawls or catches E are attached to the frame of the machine, the upper one resting upon the cylinder by its own weight, and the lower one being attached to it by a cord. As the cylinder is thrown back, the hook upon the catch takes hold of one corner of it, and pulls it over thus bringing the next face opposite the needles. The cylinder is prevented from revolving too far by the hammer F, which is kept pressed firmly down by a spring. The second catch is for the purpose of turning the cards in the opposite direction in the event of the weft breaking or running out.

We can now examine the improvements which have from time to time been made or attempted. It would be a study both curious and interesting, if space permitted, to follow all the attempts which have been made since this machine was invented to effect improvements in it, and it certainly seems very surprising that the machine of to-day so very nearly resembles the original one. Those improvements which are of value we shall notice and endeavour briefly to trace their history, and we shall also call attention to one or two attempts which have been made to adopt a new method. Mr. Wilson, the gentleman already mentioned in connection with the patent of 1821, made an attempt to alter the form of the machine in 1823. In this the card cylinder is placed on the top of the machine and the needles are dispensed with, and instead of using hooks for raising the warp threads he used an upright wire with a head formed upon it, immediately below this was placed two plates with holes corresponding to those in the cylinder, and through which the wires passed. The harness was attached to the wires in the same manner as in the previous machine, by means of neck cords: but each harness cord had a knot upon it which rested upon the cumber-board when the wire was down. The cylinder with the cards acted direct upon the needles from above, the holes in the cards permitting those which were desired to be raised to remain in their position, and pressing down (those which were required down so far that the button upon the wire would be below the two plates. The upper plate had a slight longitudinal motion given to it, so as to partly close up the holes, and both plates were caused to rise together so as to catch the bottom upon the wire, and raise the harness. As the cylinder was raised the wires which had been pressed down were returned to their places by small spiral springs.

The next attempt was by Molinard in 1833, and in his specification he claims that his invention "consists in the placing of his figuring machinery under the warp and needles, and in connecting the needles themselves directly with the warp threads in such a manner that the pattern cards are using motion given to the pattern cylinder over which they pass to act upon the lower ends of the needles." This arrangement does not seem to have proved very satisfactory, for in October of the following year (1834) Molinard took out another patent for improvements. In this he abandons the needle connection with the warp and uses "a body of needles acted upon by the rise and fall of a pattern shaft or cylinder in the way described in my former specification." And he "suspends the threads of the harness by lifting or suspension threads from the aforesaid needles, by which means one of the principle advantages of my former patent is rendered applicable to a loom for weaving figured fabrics with greater economy and facility."

In 1840 a patent was taken out by Deplanque which contained several new features. From this time, improvements in the Jacquards were numerous and some of them valuable, more especially for the use with power looms. One especially is of great importance, viz., that relating to the movement of the card cylinder. It will be easily understood that when the lifting block or griffe is raised, and the cylinder with the card is withdrawn from the point of the needles, those which are left down will return to their original position, and as that position is such that when the griffe is down the hooks are immediately over the knives, when the griffe is up they must be immediately under the knives. Therefore if the knives were vertical they would strike the top of the hook, but they are inclined to such an angle that as they descend they strike the face of the hooks, and press them back.

If a Jacquard which imparts the motion to the card cylinder with the curved bar, shown in Fig. 6 be carefully examined it will be found that the cards strike the needles before the griffe has reached its lowest point ; that would seem as if it would remove all the hooks which were not intended to rise out of the way of the knives. But it also has another effect. Many of the hooks which are already on the knives are required to be pressed back so as to be left down ; then if the card is pressing upon the needles before the griffe has reached its lowest point the hooks have not been liberated, therefore there is considerable pressure upon the needles and the card, and as a consequence proportionate wear and tear. It is obvious that the most perfect motion would be for the knives to be quite clear of the hooks before the card touches the needles, and this is best done by working the card cylinder from some source independent of the machine. The first attempt at this was made by Mr. J. Bullough in 1842, when he patented "a certain arrangement or application of mechanism whereby the 'card cylinder' is made to turn entirely independent of the lifting motion for shedding the warps." Considerable additions and improvements were made to this by Messrs. Woller and Butterfield of Bradford, in 1855. In their specification they make three claims, the first two have reference to the card cylinder, and the third to the harness. The first of their claims is "in allowing the hooks to be entirely at rest and free from the knives of the griffe, at the time when they are pressed back by the cards and cylinder;" the second, "in the means of disengaging the cylinder or swing-frame, so that the cylinder and the cards may be worked backwards or forwards, independently of the other parts of the machine." This

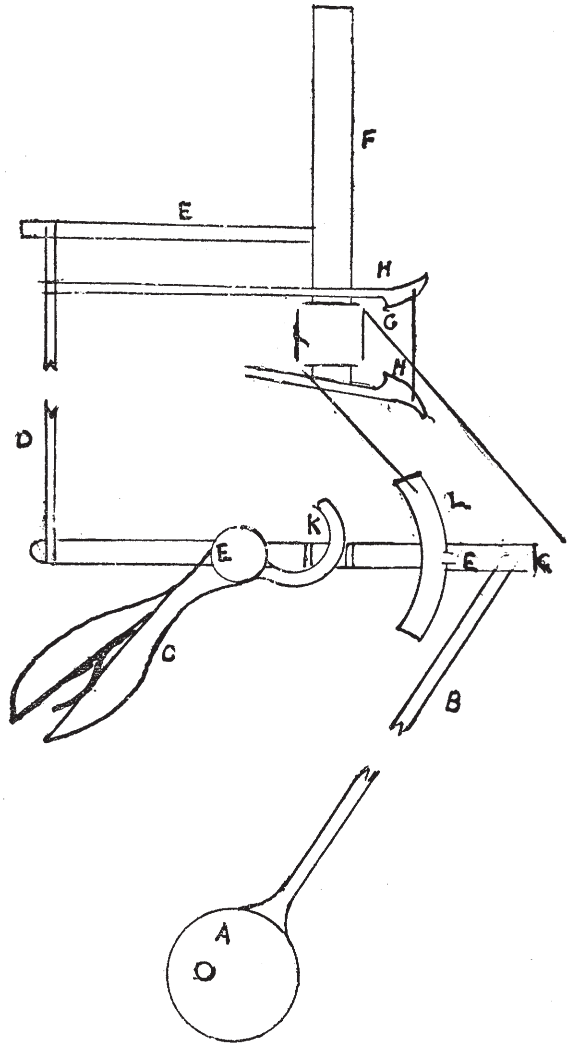


FIG. 7.

invention is of such importance that we may venture to examine it a little more fully.

In this arrangement the card cylinder is worked by an "eccentric" direct from the crank shaft of the loom after the manner shown in Fig. 7. A is the "eccentric" upon the crank shaft, the motion being communicated by means of the rod B to the lever C, and from the other arm of that lever by the rod D to the arm E. (Although we speak of C as one lever, the arm to which D is attached is quite apart from the arm C, but they are both working upon the same centre, which is a rocking shaft running across the loom behind the harness.) This arm is made fast to the swing frame F, which carries the cylinder G. It will be seen at once that as this arrangement is quite independent of the rise and fall of the griffe of the machine, the movement of the cylinder can be timed at will in relation to the movement of the griffe. The arrangements for turning the cards without moving the other parts of the machine are extremely simple. When the loom is running the cylinder is turned in the usual manner, by means of the catch H. The handle C is a split handle working upon the centre E, and provided with a spring for keeping each half in position. The movable part has at its opposite extremity an arc of a circle K upon it; and upon the fixed arm is another arc L, with a notch E. The whole of the arm is made fast upon the rocking shaft before named, and the straight arm C, to which the rod B is attached, works loosely upon the rocking shafts. When the machine is working in its usual manner a "nib" upon C falls into the notch E of the large arc, so causing the rocking shaft and the loose arm to work together, or as it were to become one. When it is desired to work the rocking shaft for turning the cards without turning the loom at the same time, the handle is pressed together raising the nib by means of K, and so removing it from the notch E; the rocking shaft is therefore disengaged, and by working the handle backwards and forwards the card cylinder will be thrown out and the cards turned over either in one direction or the other as desired, by bringing either of the catches in contact with the cylinder.

This invention has probably had a greater influence in promoting the use of the Jacquard machine with power looms than any other, because it enables the weaver to prevent broken patterns, when the weft breaks or runs out, with the greatest facility. There is no trouble turning the loom back pick by pick, until the broken one is found but the weaver simply seizes the handle and turns the cards over to the desired one without much trouble.

The third part of this invention aimed at what has often been attempted, viz., "Keeping the harness steady and free from vibration" when working. Messrs. Woller and Butterfield endeavoured to remedy this tendency by instituting springs for the loose weights, and so enable them to run their looms at a higher rate of speed. In theory this seems very feasible, but in practice it does not seem to have answered very well, for it was very soon abandoned, and the loose weights replaced, the latter retaining their position up to the present time. This is only one of the many attempts which have been made to enable the Jacquard power loom to be run at a high rate of speed, upon some of the others we shall speak shortly. We now have the Jacquard machine in such a state of perfection that it will do its work fairly well, either on the hand loom or power loom, yet in some respects there is still room for improvement. We will now point out in what direction these improvements are desirable, and some of the attempts which have been made to effect them. With respect to the vibration of the harness we have already pointed out one of the attempts to remedy it, and we are not aware of anything better having been done. Of course in the ordinary loose weight harness some provision is made for this, by making the weights work in the partitions which prevent their swinging from side to side except for a very limited distance. To enable the Jacquard power loom to attain a high rate of speed many attempts have been made, but the most successful has been the "double action" machine, though this system has its defects, and many practical men are of opinion that the increased speed is purchased at too high a price. The question is and always must be, whether the advantage gained is not counterbalanced by the disadvantages, or whether the increased speed is not gained at the cost of efficiency. Before we enter more fully into the double action machine it will perhaps be as well to inquire into the purpose it is intended to serve, and what advantages are to be gained by it. Putting the matter broadly there are two distinct objects

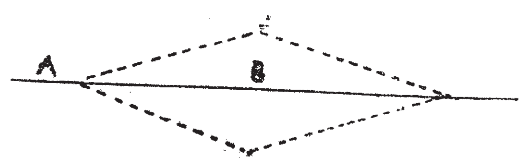


FIG. 8.

in view. One is as we have said, increased speed, and the other an improved shed, coupled with a counterpoise harness, in which the falling or sinking part of the shed would balance the rising part and effect economy in power. Then first as to the shed, that is the separation of the warp into two portions so as to permit the shuttle carrying the weft to pass between them. This may be indicated by Fig. 8, where A represents the point at which cloth is formed by the weft being beat up; the straight line B, the warp when no shed is formed; and the dotted lines B show the warp as divided into two portions to permit the passage of the whole. It will be observed that the shed is V shaped, and that the lower line is as much (or nearly so) below the straight line B as the other line is above it, or in other words, that each one is drawn the same distance—though in opposite directions—from the straight line. It will be obvious that if we consider the line B as the natural position of the warp threads when at rest, or as we may term it the line of rest, and as the shed is opened, each half of the warp is drawn the same distance from it, the work seems to be done in the most economical manner. But in the ordinary Jacquard this cannot be done. The lower dotted line becomes the line of rest, consequently to make a full shed it must travel to the top one or the entire depth of the shed. In the hand treadle and tappet power looms, the shed is always opened from the centre; in the Jacquard loom it is not always so, but only in those which have a double action. The principle of the double action appears to have been used by Mr. J. Cross, of Paisley, in his counterpoise harness for the draw loom. Also a few years later by Mr. B. Taylor, who took out a patent for a loom for weaving "figures or flowers on twilled or plain cloth," and which was "worked without any drawboy, the figures in the different articles being produced by means of barrels filled with wires arranged to the figures or flowers, in a similar manner to that of a barrel organ producing tunes." The harness is described as having a double neck, "and as one lash falls the other rises, and by the falling of one the weight assists the other in rising." This is simply the principle of the double action Jacquard. There are two necks and two hooks, each being acted upon by a separate griffe working alternately. In 1849 a patent was taken out by Mr. Barlow, for a Jacquard with "double counterpoised griffes and apparatus for simultaneously raising and lowering different portions of the suspending wires of such apparatus." This machine (Fig. 9.) contained two sets of hooks and one set of suspending wires, it had also two sets of needles, two cylinders, and two sets of cards. The two hooks A A are the lifting hooks; and B the suspending wire to which the neck of the harness is attached. The suspending wire has two nuts upon it by means of which either of the hooks can raise it. Each set of hooks is acted upon by separate sets of cards and by separate griffes acting alternately. This arrangement, as may be easily understood, was too complicated, there were too many wires. Consequently the form of the hooks was altered as shown in Fig. 10, where it will be seen that the two hooks were retained, but the suspending wire dispensed with, two neck cords being used instead. In all other respects the principle of the machine remains the same.

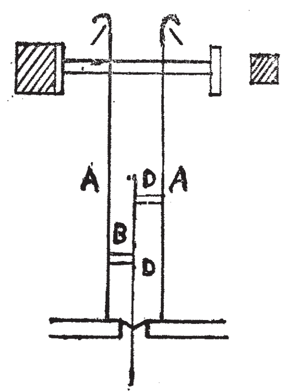


FIG 9.

The greatest alteration in the double lift machine was made by Mr. H. Crossley, in making one needle serve two hooks, and by that means dispense with one of the card cylinders. One of the great drawbacks of this kind of machine is the amount of pressure exerted upon the cards by the needles. One of the two hooks must of necessity be upon the griffe, either rising or falling when the card strikes it to throw it off. The consequence is the card has not merely to press back the spring at the back of the needle as in the single lift machine, but as the hooks cannot be both disengaged at the moment when the cards strike the needles, considerable force must be exerted on the needle and hook. As a consequence the cards used upon this kind of machine must be very strong, and under the most favourable circumstances must wear out much sooner than those used on the ordinary single lift machine.

In 1857 a patent was taken out by Mr. J. Craven, of Bradford, for "giving independent motion to the bottom or knot board, in order that a downward motion may be given thereto at the time of giving upward motion to the lifting

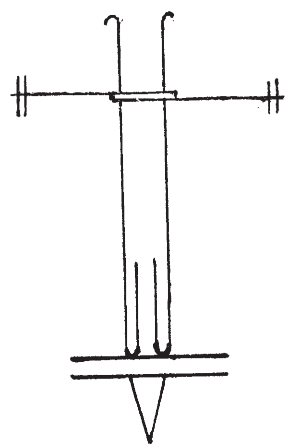


FIG. 10.

blades to form sheds." In this machine "the ordinary lifting frame and the bottom or knot board are operated by separate levers and cranks, or other means, capable of being shifted or timed to vary the times of operating the parts in relation to each other as desired." In 1859, Mr. D. Sowden, of Bradford, obtained provisional protection for a means of attaining the same object. He used "two rods or slides and one lever, and one treading rod," and claimed that he "simplified working and gained some increased speed." For some reason or other Mr. Sowden did not proceed with his patent beyond the preliminary stage. Another patent was taken out in 1876 by Mr. Ainley, of Huddersfield, and has since been largely adopted for heavy work, such as fancy woollen or worsted mantle and coating cloths. The means adopted by Mr. Ainley are extremely simple, the bottom board of the machine being carried on two arms, which are actuated by the lever which also actuates

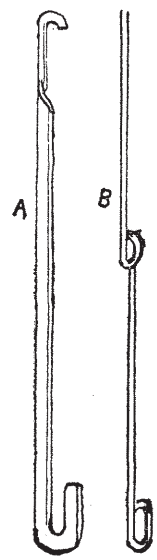


FIG. 11.

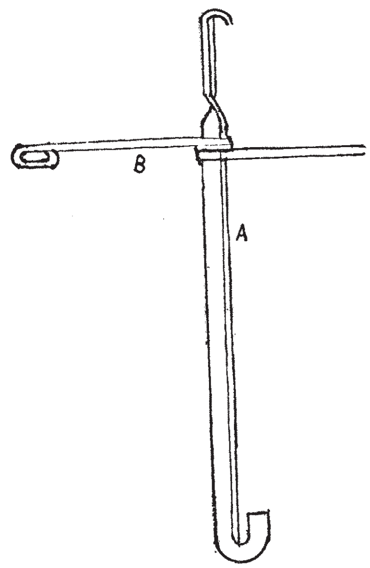


FIG. 12.

the lifting blades. Various devices have been adopted by other people with different degrees of success.

One of the most recent attempts to preserve the open shed is shown at Fig. 13, and is the invention of Mr. Robert Wilkinson, of Bradford. It is obvious that in the ordinary double lift there cannot be a full open shed in the general acceptance of the term, that is whilst the threads forming the lower half which are not required to change for the pattern, remain perfectly stationary. Those forming the upper half of the shed cannot do so; but must descend with the griffe until they meet the other portion, or about half the depth of the shed, and then return again. Mr. Wilkinson obviates this by carrying his neck cord over a pulley, and making it fast to a bar below the pulley. This pulley, over which the neck cord passes, is suspended

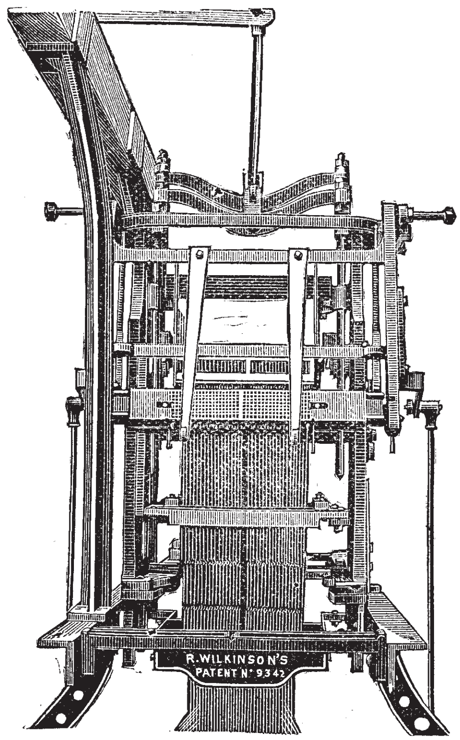


FIG. 13.

from another, then a cord is carried round this upper pulley and made fast to the two hooks of the machine, so that the cord from the hooks being made fast direct to the neck, as in Fig. 10, the two pulleys intervene. Now it must be clear that as one hook ascends and the other descends, the cord simply runs round the pulley and does not alter the position of the neck in the slightest, but as they ascend above, or descend below the point

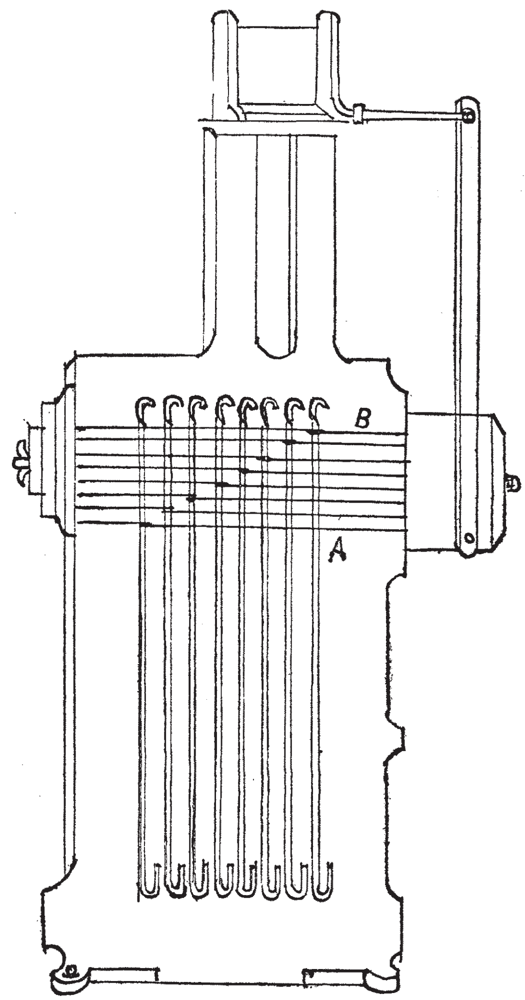


FIG. 14.

where they meet, then they alter the position of the neck and consequently of the harness, so that a perfect open shed is obtained ; all the threads forming the upper and lower portions of the shed respectively remaining until required to change for the formation of pattern.

In the early part of this article we pointed out the liability of the hooks to turn, and the consequent damage resulting. Attempts have been made from time to time to prevent this as far as possible, but the grate as first introduced seems to have outlived most of them. One of the simplest and most effective contrivances was patented in 1877 by Messrs. Dracup and Ball, of Bradford, which consists of a simple modification in the upright hook and needle. Ordinarily the upright hook and the needle are made of round wire, the eye of the latter consisting of a simple turn of the wire so as to form a complete loop. In this arrangement the upright hook is made of flattened wire, and the eye of the needle instead of being a single loop is a double one, that is, the wire is carried twice round, so as to present greater surface to the hook. In Fig. 11 A is the upright and B the needle. In Fig. 12 they are shown together, ready for putting in the machine, and Fig. 14 shows the interior of the machine with the hooks and needles placed in position. It will be at once apparent that the wire of the upright hook being flattened, and the eye of the needle elongated and presenting a double surface to the hook, that it will be a matter of impossibility for the latter to turn round, as it would if it were round, in fact it is bound to retain its proper position, and the use of the grate is entirely dispensed with. This arrangement also possesses one or two other advantages, which in practice are worthy of some consideration. The hook is, near the top, twisted half round, thus presenting greater wearing surface to the griffe, and the needle, being double at the eye, presents greater wearing surface to the hook, though this may perhaps be slightly counterbalanced by a little more friction from the flat hook, and the fact that the needle has to keep it in its proper position. Again, by dispensing with the grate the bottom of the hook does not need to be turned so far up, and consequently it is a much easier matter to replace a neck cord when required. There have been more attempts to accomplish what this patent aims at. One which certainly possessed considerable merit consisted in making the hook a double one as shown at Fig. 15. When the hook was at its lowest point the portion A rested upon a rod, in fact the hook was so proportioned that the rod at A caught the hook before the griffe at B had left it. This and several others did their work in a fairly satisfactory manner, but could scarcely compare for simplicity and general working advantages with the flat wire hooks.

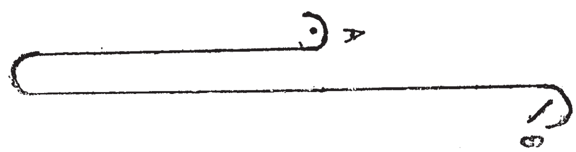


FIG. 15.

We may now turn our attention for a short time to the arrangement of Jacquard machines for special purposes. For damask weaving, for instance, some modifications become necessary, so as to enable the weaver to produce large and elaborate figures with a minimum of Jacquard power. Many figured fabrics known by the name of damask are formed by what is technically termed warp and weft twilling, or satin. For example, we may take a linen table-cloth, the ground of which consists of warp, and the figure weft, satin. To non-technical readers this would be more readily expressed by saying that as the pick is thrown in, there are say four-fifths of the warp raised in the figure. In the ordinary way of weaving every thread of a pattern is worked separately, consequently in some of the large patterns the extent of the Jacquard required is enormous. To reduce the machine to the lowest point a modification of the harness was early introduced, and

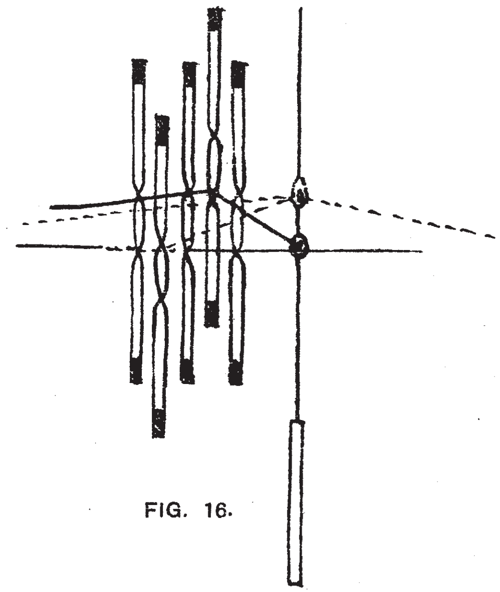


FIG. 16.

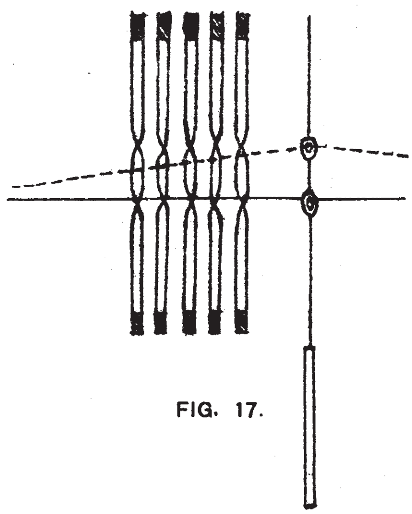


FIG. 17.

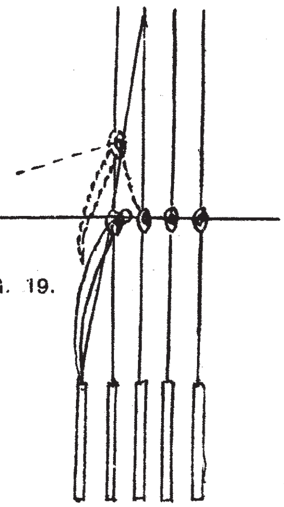


FIG. 19.

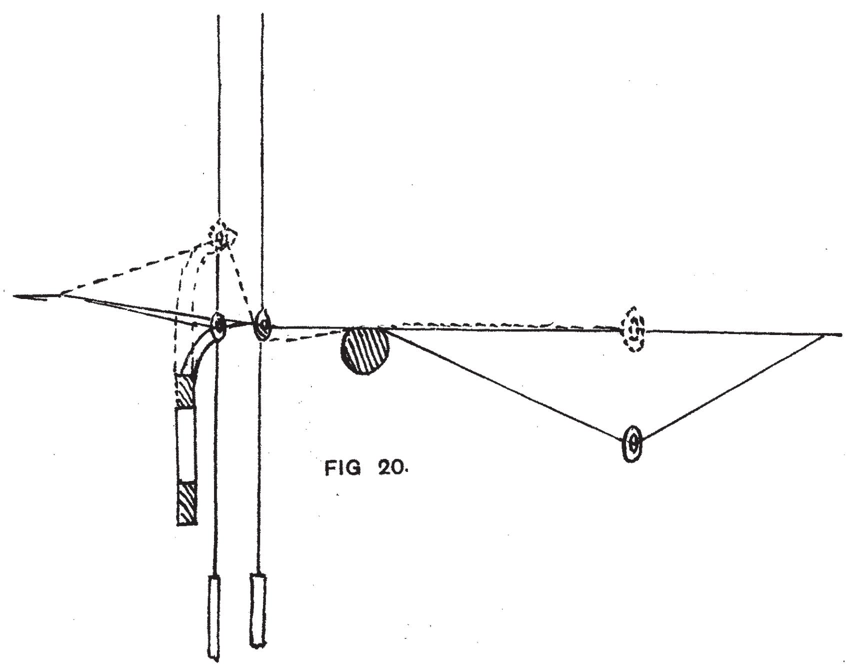


FIG 20.

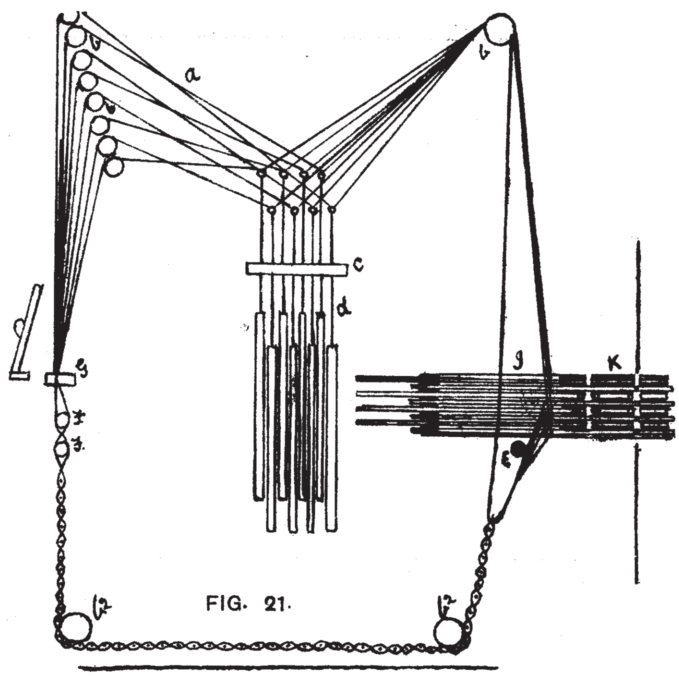


FIG. 21.

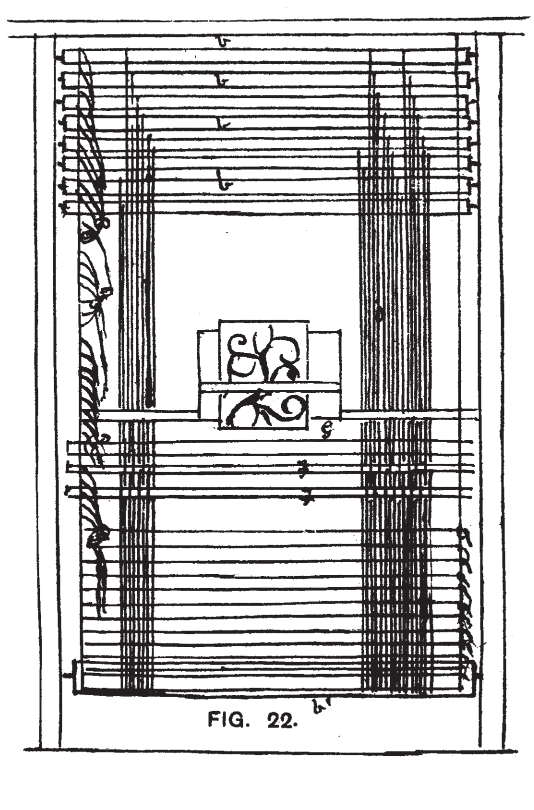


FIG. 22.

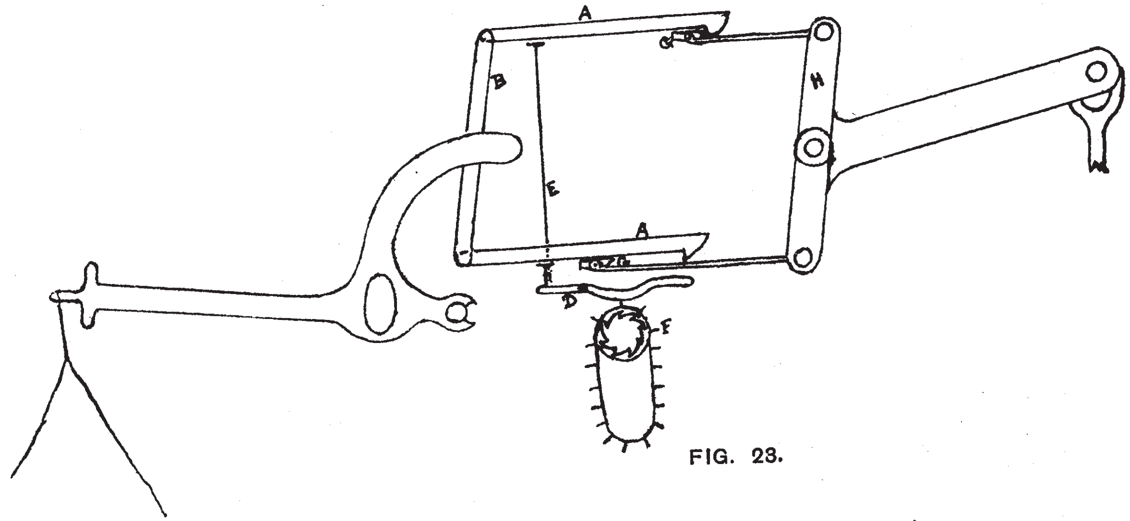


FIG. 23.

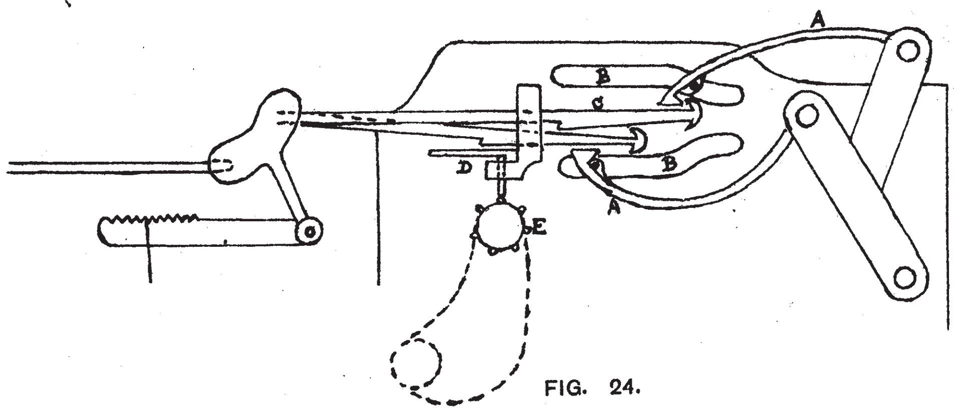


FIG. 24.

was known by the name of the "compound" or "pressure" harness, the principle of which is briefly as follows:—We will suppose that it is desired to produce a pattern, the extent of which will occupy 2000 ends. Instead of using a machine containing 2000 hooks, we may use a machine which will contain say one-fifth of that number, 400. Then as we attach only one harness cord to each hook, it will be necessary to enable us to put in the full number of threads, to pass five threads through each mail or eye of the harness. Then to all intents and purposes these five threads become as one so far as the harness is concerned, and although we have the 2000 threads the limit of our pattern would be 400; but we now proceed to subdivide the five threads. In front of the harness we place five healds, and through each one is passed one of the five threads, which are passed through the mail of the harness. We have then the work divided into two distinct portions, viz., figuring and twilling, the first being performed by the harness, and the twilling by the healds. Representations of this arrangement are shown at Figs. 16 and 17. In Fig. 16 all the healds are shown as being stationary, and the warp threads in both the lower and raised positions by the harness. In Fig. 17 the healds are shown as in work, one raised, and one depressed. Then if the harness is in the lower position one thread out of the five will be carried up by the healds, and if in the raised position one thread will be depressed, so that weft or warp satin—or twill—surface may be made at once. It may now appear at first sight as though the figure would have a very coarse appearance from the fact that five threads must be raised or depressed at once by the harness; and so it might if the picks are arranged in fives, that is, if one card served for five picks. But each card may serve for one pick only, and thus form the pattern as clear and perfect as if each thread had a separate harness cord, because no matter how much or little of the harness may be raised to form the figure the healds have precisely the same effect in forming the pattern on the ground. The eyes or mails of the pressure healds are made considerably longer than those of ordinary healds, so as to allow of the proper formation of the shed. Of course the number of healds may vary according to the twill or satin of the ground—thus for a five thread satin five pressure healds would be used, and five threads through each mail of the harness; for an eight thread satin eight healds would be used, and eight threads through each mail of the harness, and so on. From this it will be seen that whatever number of threads are passed through the mail eye of the harness they must all be actuated at once, and the picks may be either single, or one card may serve for several, which will be kept from passing into precisely the same shed by the twilling healds. The saving effected by this arrangement must be obvious, and in hand loom working is comparatively easy of application, and although it has been very largely applied in power looms, yet the combination of healds and harness is undesirable where it can be avoided. Machines have been invented, and considerable ingenuity displayed, for the purpose of dispensing with the healds. If by actuating five threads at once and keeping each pick separate, we can produce the pattern we desire, it must be evident that if we actuate each thread separately, and change the figuring arrangement every five picks, the result will be the same. This principle was in use upon the draw loom before the introduction of the Jacquard, one cord being made to serve for four, five, or eight picks, according to circumstances. A patent was taken out in 1859 by Mr. J. Shields, of Perth, for the application of the principle to the Jacquard. The chief part of this invention consisted in "an arrangement of apparatus for working or actuating a greater number of upright wires or needles, than has hitherto been the case by one horizontal needle, without the necessity of the latter being in parts or sectional portions. In this way the improved Jacquard accomplishes, by the aid of a harness only, all that is at present being done by a harness and a comb, or what is ordinarily known as 'pressure' harness."

Described briefly, this invention consisted of two sets of horizontal needles, one being of the ordinary kind,

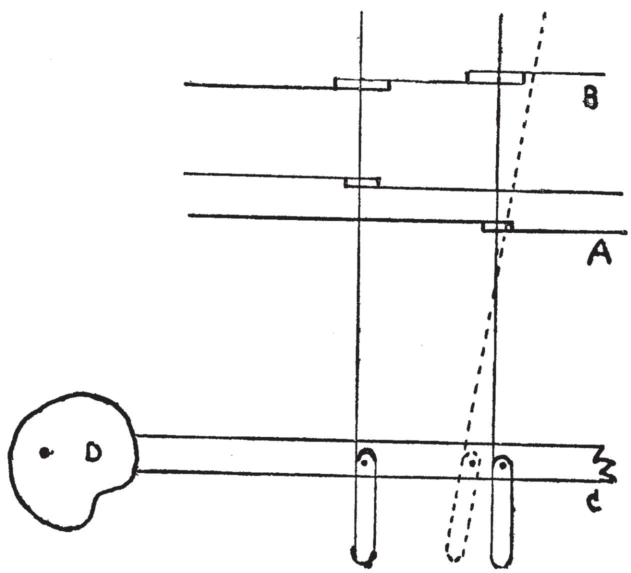


FIG. 18.

carrying one upright hook through the eye ; the other placed above, having a series of elongated eyes, and being capable of carrying any desired number of upright hooks. This arrangement is shown at Fig. 18, A being the single eyed needles ; and B the elongated ones. Below the needles each upright wire has a long loop formed at the bottom, through which a rod passes. Each rod is supported on standards C, which are actuated by a cam D. There are a series of these cams, as many as are required to form the twill, each one being connected to a separate pair of standards and arranged for the twill or satin. As the figure is formed the extra needles are acted upon by the figuring cards, the ordinary shaped needles along with the cam arrangement regulating the twilling. The figuring card cylinder is made to turn at intervals of three, four, or five picks, as may be required. It will be seen that this arrangement at once dispenses with the pressure healds, and in the same manner as in pressure working, there is no necessity for cutting the twill upon the figuring cards. This saves a considerable item in the cost of card cutting.

In the following year (1860) Mr. Shields, in conjunction with Mr. A. Shields, took out a patent for an improvement in this machine, which consisted in giving the lifting knives a horizontal reciprocating motion, to and fro, in addition to the ordinary ascending and descending motion, as employed for raising the Jacquard wires or needles. The horizontal motion was given by a differently formed cam or barrel, which acted upon the knives in such a manner as to cause them to take up such of the hooks as were required to form the twill, the figure being formed, as in the previous case, by the cards. Another claim was the turning up of the hooks at the bottom, the turned-up portion resting against a fixed bar and so causing it to act as a spring, similar to that shown in Fig. 15. Another machine which seems to be a combination of some of the best features of the two already described, was more recently patented by Mr. Barcroft, of the Bessbrook Spinning Company, County Armagh, Ireland. In this machine, which is very compact, each needle acts upon three, four, or five uprights, as desired, and one card may serve for any number of picks. The lower part of the hook is formed into a long loop, through which a twilling bar is passed, in the same manner as in Shield's first patent. The lifting knives are made movable, so as to be free to turn clear of the upright hooks when required, and are acted upon by a small barrel which is pegged according to the twill required, so that in this, as in Shield's machine, the figure is formed by the cards, and the twill by the barrel, each thread passes through a separate mail, and each card may serve for several picks.

The application of the Jacquard machine to lace weaving is a marvel of ingenuity and a most interesting study, but it scarcely comes within the range of this article to deal with.

Many attempts have been made to supersede the use of cards for the Jacquard; in some instances by the application of electricity, and in others by the use of a continuous band of paper. The inventors have been so sanguine of the success of their devices that patents have been taken out, but as yet none of them, so far as we are aware, have come into general use. Some of them have been applied to a great many machines, but their superiority over the cards not having been fully established they have gradually fallen into disuse. One of the latest of these is the "Benson Patent Jacquard," manufactured by the Benson Patent Jacquard Company, Limited, of Belfast, in which a continuous band of paper is used, and although the application certainly deserves credit for ingenuity, it has not proved a success.

We have given a tolerably fair view of the Jacquard machine in the various stages through which it has passed, and the form in which it now appears. A stranger on first seeing one of these machines at work upon a loom would probably conceive the notion that it was a strangely blended mass of wirework, cordage, and mechanism, but after a brief but careful examination chaos is reduced to simplicity. After comparing the design upon the paper with the design upon the fabric, and following the connection of the cards with the warp threads, all wonder at the charming patterns which can be produced at once gives way to admiration of the beautiful simplicity of principle by which the results are attained, and the immense value of this machine to the manufacturer of fancy textile fabrics is at once recognised.

Another special form of harness now calls for attention. In weaving fancy gauze it is necessary that doups shall be formed in one way or another, so that each set of threads forming the gauze shall have a doup of its own. In the original mode of working, the doup was formed in the harness as shown at Fig. 19, that is, a loose slip was passed through the mail eye of the harness, and the thread passed through the loose slip after passing through another mail eye. The loose slip had its own weight and a cord carried from the weight through the cumber board and attached to the ordinary harness cord through which the crossing thread had been passed, so as to ensure its being always lifted when the thread was lifted by the ordinary harness cord, and avoid any risk of breakage in the warp, or undue strain, so that by this means the working of a gauze harness was not so difficult a matter as one would suppose at first sight. Of course in this, as in all other work, proper care would have to be taken in arranging the harness to have due allowance made in the boring of the cumber board, to ensure the requisite degree of fineness, and also in the arrangement of the design on paper, and take into account the doup hooks as to preserve the proper form of figure, and ensure the threads being raised in the required order, but with a sufficient knowledge of Jacquard work, and of the principles of gauze formation, neither of those points would give either the harness builder or the designer much trouble.

In many cases the loose slip would be carried through two eyes in the mail, so that in the event of the warp thread breaking, the slip would retain its position, so as to facilitate the replacing of the thread. A modification of the system is now in vogue, but instead of each slip having its own weight, the whole series are placed on a heald shaft in front of the harness, as shown at Fig. 20. In this there is considerable saving effected, as the slips are very liable to wear out even with the best management, and the cost of re-douping a harness is a somewhat serious matter, whereas when they are all on one shaft it is both simply, easy, and cheap, and the difference in working is simple that instead of each individual weight being lifted when required, the whole shaft may be raised at every pick if necessary, and those threads which are lifted by the harness will have no weight on them, and those which are not raised will not be affected in anyway by the raising of the shaft.

An important addition was made to this harness by a Mr. Aldred, in the way of facilitating the easing of the warp threads when crossing was taking place. Whenever this occurs, the warp going through the doup must be slackened by some means to compensate for the extra length required for the crossing. This is accomplished by having behind the ordinary harness, what may be termed a slackening harness, as shown at Fig. 20. This consists of hooks placed behind the ordinary hooks, and which may be actuated by the same needle as actuates the doup hooks, so that both shall rise at the same time. The mail eye of the slackening harness is placed below that of the ordinary harness a distance about equal to the depth of the shed. The warp is passed over a rod as shown, and so adjusted that whenever the doup rises, the slackening harness will rise also, and give off sufficient warp to compensate for that taken up in crossing the other thread or threads, and of course is carried back as the warp descends in the usual manner; generally the weights upon the slackening harness should be somewhat heavier than the ordinary ones, so as to bring back the warp with certainty.

The arrangement is very simple and ingenious, and at the same time effective.

The question of card cutting now comes up, and upon that comparatively little need be said, as it is merely a mechanical operation which would be more thoroughly mastered by a few hours practice than any amount of reading. The object of course is to cut the cards so that they shall act upon the needles of the Jacquard to produce the required pattern. As has been said the hooks of the machine are arranged in rows, and the paper upon which the design is made is ruled to correspond; that is there are small divisions corresponding to the warp threads in one direction and with the weft in the other. Then there are thick lines at intervals corresponding with the number of hooks in a row of the machine, and the divisions corresponding with the warp threads of necessity correspond also with the hooks, so that when a small square is marked on the paper to indicate the lifting of a warp thread, it also indicates that a hole must be cut in the card, consequently each square of the design paper corresponding with a row of hooks must be read in succession from the design to the card, and the holes cut according to the marking for the pattern.

There are several methods of doing this work: one by what is known as the "piano" machine. This consists of an arrangement of vertical punches, their upper ends in a kind of box, and the lower ends over the card to be cut. In this box there are keys with horizontal spindles placed immediately over the head of the punches. By means of treadles the box is raised and depressed, and whenever a hole is to be cut one of the keys is pressed inwards on the top of the punch so that as the box is brought down it forces the punch through the card. The card cutter has his design placed on a stand in front of him with a lath numbered to mark the line or pick he is reading, and as he reads each row in succession he works the treadles and pushes in the necessary punches, and so cuts row after row of the card until all is completed. The card is caused to travel from end to end under the punches by means of a small carriage which grips one end of it, and by means of a rack and catch arrangement moves forward a distance equal to the space allotted to one row of holes at each movement of the treadle, so that the punches must always come down exactly at the proper place. To assist the card cutter in knowing exactly where the card is, or at what row it stands, a cord is attached to the carriage and brought over pulleys so as to lie on the reading desk in front of him. What is termed a "bob" or small piece of coloured material is made fast to the cord at one point, and a "gauge" or marked lath, having divisions upon it corresponding to the distance travelled by the "bob" is placed parallel with the cord, so that as the carriage moves it draws the "bob" forward and enables the reader to see as he goes along what row the card stands at, and consequently what row he should be reading from the design. By this simple arrangement the work is made much easier, and the risk of error reduced to a minimum.

Another arrangement of reading machine is shown in section at Fig. 21, and front elevation at Fig. 22. This consists primarily of a series of endless cords *a*, carried over pulleys *b b* at the top, and *b′ b′* at the bottom of the frame, between the rollers *b b* the cord dips down towards a cumber board *c*, another cord *d* with a ring at the top is suspended from *a* and passed through the cumber board, and is provided with a weight at the bottom. At E, is placed a comb or rack which divides the cords into eights or twelves according to the number of hooks in a row of the machine, and below that are lease rods F F, into which the cords are leased singly. Down each side of the frame are stout cords running round the pulleys *b b*, *b′ b′* and made tight; to one of these a series of cords are made fast after the manner of the cords in the old draw loom. The reader takes a seat in front of the lease rods with a design in a rack above them, and commencing at one side he runs his fingers rapidly through the cords in the lease rod, at the same time passing the fingers of his left hand under such cords as correspond with the warp threads indicated on his design as are required to be raised, and over those to be left down, and having done this, he threads one of the strings from the side cords into the lease he has in his left hand, thus literally weaving the pattern on the cords of the machine. As he does this the cords *a* are pulled down, thus bringing what might be termed the weft threads under the rollers *b' b'* and to the opposite side of the machine. The cords *a*, or the warp cords as they might be termed, now pass through the eyes of needles *i*, these resting in a needle board at one end, and at the other in a punch plate. This punch plate contains as many punches as are required, or corresponding with the number of hooks in the machine. Another plate is now placed in front of this punch plate into which the punches may be passed, and from which the card may be cut. Below the needle boxes and plates a sliding carriage is fixed to carry a roller. The roller *e* is now inserted into the lease formed by the first cord, and placed in the steps of the sliding carriage and by the movement of a lever is drawn forward so as to pull the cords and force the punches out of one plate into the other, so that every punch corresponding to the required pattern is brought into the plate, for cutting the cards. In fact the whole operation is a simple repetition of the work of the draw loom, only that cards are cut which may be used on the Jacquard machine which takes the place of the drawboy at the loom. When the first card is cut the process is repeated until the whole design is completed.

For some classes of design this is a most expeditious mode of working for two, or even three persons can be working at the same time on one design, one reading, one drawing the punches into the plate, and changing the rollers, and the third working the cutting machine. After each card has been cut the punches are pressed back into the punch plate by a comb before the next cord is drawn.

The stamping machine itself consists simply of a travelling carriage in which the cards are placed between two perforated plates, the plate with the punches is placed on the top of these, and the whole passed under a roller which presses the punches through the card, and so produces the necessary perforations. In many cases both the machines described are dispensed with and the punches are inserted in the plate with the fingers, reading from the design in the same manner as when machines are used, and it is certainly astonishing how rapidly the work can be done by an experienced hand. In the worsted district probably more than ninety per cent. of cards cut are worked in this manner, very few card-cutters, in fact ever having seen a reading machine.

When it is required to reproduce a set of cards, as is invariably the case when a number of looms have to be set to work on the same pattern, a machine known as the "repeater" is brought into use. This machine is made in several forms, but briefly it consists of a punch plate similar to that just described, a series of long needles, similar also to those in the reading machine, but simply having a spring upon them instead of a cord passed through them. The card to be "repeated" is placed upon a card cylinder at the back of the needles, and by means of a lever, generally worked by a treadle, is pressed up to the needles and so presses the required punches out of the stamping plate into the receiving one, thus retaining in the stamping plate those corresponding with the holes in the card and ensuring an exact reproduction. When this is done, ten, twenty, or any number of cards are cut from the same plate according to the number of sets required. When the requisite number have been cut the punches are pressed back into the plate by the "comb" in the same manner as that described.

In the best machines many of these parts are made automatic so as to save time and labour, but the principle is the same in all of them. There are now continuous card repeating machines in the market, which will go on repeating continuously, and at one movement, cut a card without the necessity of removing the plate from one machine to the other. These no doubt effect a saving of time and labour in certain cases, but many manufacturers prefer to keep to the old system of repeating.

Attention may be turned now to dobbies or shedding motions. These are really an extension in one form or another of the chain tappets just mentioned, and also may be said to be intermediate between tappet shedding and the Jacquard machine. The machine assumes such a variety of forms that to attempt to describe them all would be a mere waste of time, but the leading features of a few may be referred to. Reference has already been made to the different methods of shedding, but something more may be said to enable us to arrive at something like a clear conception of what is required for good work, and how work of different kinds may be best performed. Putting the matter broadly there are the three distinct orders of shedding mentioned at the commencement of the lessons on shedding, and it has been shown that for the great bulk of work the open shedding, such as is obtained by the tappet is undoubtedly the best, though for some purposes one of the other two systems, viz., centre or bottom shedding, may be the best. However this may be, the most strenuous efforts have been made by loom makers to produce dobbies for open shedding, except for special purposes. The first machine, which may be mentioned, and probably one of the most successful, is what is known as the Hattersley machine, (Messrs. George Hattersley and Son,) and which has been copied over and over again with only a very thin veil to distinguish the copy from the original. This machine consists of a series of levers most ingeniously arranged. First are the catches A, A, Fig. 23, each attached to one end of a lever which in turn is fixed at its centre to a peculiarly shaped lever C pivoted as shown, and from the extreme end of which the heald is suspended, so that in those two levers and catches the principal part of the work lies. Under the catches A, are placed a series of fallers D, which are made the medium of communication between the lags and the catches, the upper series being worked by means of the upright wire E, and the lags passed over the cylinder F. Two draw bars G, G, work in grooves in the frame of the machine and are connected by rods, as shown, to the arms of the lever H, this in turn being actuated from the lower shaft of the loom by means of a crank and connecting rod.

A glance at the details show that whenever a peg in one of the lags passing over the cylinder F, come to the top it must lift the faller, and through it the catch corresponding to it, and the movement of the cylinder in bringing the lags to the top corresponds in time with the movements of the draw bar, so that by the insertion of the pegs a system of selection is adopted as to which hook or catch shall be acted upon, and of course through the medium of the levers B and C, which heald shall be raised. In the movement of the draw bars one point may be noticed, they meet each other in the centre of their stroke, and of course as the pegs come up if a heald is required to be raised or depressed for a second or third time its hook is transferred from one draw bar to the other, and consequently from the peculiar form of the levers C what is almost equivalent to an open shed is obtained. One of the chief features of the machine is its extreme simplicity, at the same time one of its drawbacks for some classes of goods has been the use of springs to bring the healds down, but for some years back it has been made as a positive motion machine for certain classes of goods.

Another form closely akin to this in its general principles of working is that of Mr. Geo. Hodgson, the details of which are shown at Fig. 24. In this it will be seen that there are draw knives A working in a groove B, the grooves being so formed as to cause the draw knives to move towards and from the central line alternately. In this machine there is only one catch C for each heald, and this communicates through a lever directly with the heald, as shown. The catch C rests upon a tumbler D, which is raised at will by cards or lags placed in the cylinder E. But this tumbler has another function, on the under side of the catch C, there is a notch as shown, and placed in such a position that when the catch is drawn back by the draw knife it will rest just over the end of the tumbler D, the result of this arrangement is that if the heald is required to remain up for a number of picks the tumbler will hold it there, and if required to remain down or at the extreme, it may rest equally well, so that this is really an open shed machine, the healds remaining at their highest or lowest point for any length of time required for the patterns. This machine works also with weights or springs. There are many other machines now in use where the open shed is obtained with positive motion.

The details of Hattersley's and Hodgson's have been given to illustrate simply the general principle of open shed, mainly because they were amongst the first of their kind in the market.

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