The "Westminster" Series

TEXTILES

TEXTILES

BY

A. F. BARKER, M.Sc.

WITH CHAPTERS ON

THE MERCERIZED AND ARTIFICIAL FIBRES, AND THE DYEING OF TEXTILE MATERIALS

BY W. M. GARDNER, M.SC., F.C.S.

SILK THROWING AND SPINNING

BY R. SNOW

THE COTTON INDUSTRY

BY W. H. COOK

THE LINEN INDUSTRY

BY F. BRADBURY

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PREFACE

In the following pages practically the whole range of Textiles comes under review, with the exception of certain very special branches, such as Trimmings, Hose-pipings, Beltings, etc. It is hardly to be expected that such a wide field can be satisfactorily covered by one writer, however well he may have been trained and whatever may have been his opportunities of gaining practical experience and insight. Thus, although I alone am responsible for the great bulk of the work, special chapters by recognised authorities have been introduced. Professor Gardner is responsible for the chapters on "The Mercerized and Artificial Fibres" and "Dyeing"; Mr. R. Snow for the chapter on "Silk Throwing and Spinning"; Mr. W. H. Cook for the chapter on "The Cotton Industry"; and Professor Bradbury for the chapter on "The Linen Industry." That these chapters add much to the practical value of the treatise will at once be conceded.

The authors hope that this work may prove of value to those who require extensive but accurate information on the whole range of the Textile Industries; that the technicalities dealt with in the work will serve well the practical man in his every-day difficulties; and finally that the student desiring an all-round knowledge upon which to soundly base his later special knowledge will here find that which he seeks.

ALDRED F. BARKER.

THE TECHNICAL COLLEGE, BRADFORD,
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List IV.—Importation of Colonial and Foreign Wool into the United Kingdom from

	1800.	1810.	1820.	1830.	1840.	1850.	1860.	1870.	1880.	1885.	1886.
New South Wales (with Queensland, bracketed, 1800–1880)	658	83	213	3,998	25,820	51,463	46,092	142,588	224,777	217,119	265,181
Queensland										104,361	84,065
Victorian	—	—	—	—	—	55,378	78,186	209,038	306,817	317,152	360,731
Tasmanian	—	—	180	4,005	11,721	17,468	16,731	17,039	23,653	21,681	21,463
South Australian	—	—	—	—	3,484	11,822	23,554	68,679	109,917	115,108	130,628
West Australian	—	—	—	—	—	1,046	1,992	5,260	9,211	14,427	16,862
New Zealand	—	—	—	—	—	1,502	17,870	106,660	189,441	237,875	260,912
Cape and Natal	—	15	29	—	3,477	19,879	55,711	124,050	190,614	182,168	227,289
Total Colonial	**658**	**98**	**422**	**8,003**	**44,502**	**158,558**	**240,136**	**673,314**	**1,054,430**	**1,209,891**	**1,387,131**
East India and Persian	—	—	—	—	7,611	9,704	62,226	44,090	112,716	93,699	118,525
China	—	—	—	—	—	—	119	337	1,672	3,426	2,393
German	1,170	2,221	14,609	74,496	63,278	30,491	19,681	16,459	28,119	9,700	12,005
Spanish	30,318	2,976	17,681	8,218	5,273	2,105	4,199	1,583	14,603	97	15,766
Portugal	9,622	16,772	475	2,319	1,569	7,361	24,503	9,287	14,356	7,634	8,589
Russian	25	868	150	1,680	11,776	9,758	22,150	18,474	45,417	63,368	65,027
Turkey, Egyptian & N. Africa	76	676	380	29	5,492	11,896	17,545	17,607	49,853	32,199	60,079
Peruvian & Chilian	—	601	25	64	40,004	39,731	69,068	64,173	52,876	65,691	49,927
Buenos Ayres & Montevideo	—	—	—	—	—	3,841	5,058	11,122	9,852	8,728	12,440
Falkland Is. & Punta Arenas	—	—	—	—	—	—	—	—	4,700	6,909	6,614
Italian & Trieste	84	683	334	14	4,055	1,536	719	832	2,565	928	1,574
Sundry	487	349	1,479	3,995	2,519	3,041	15,172	16,643	35,973	14,990	22,422
Goats' Wool	—	—	—	—	—	13,139	11,915	14,196	57,449	52,457	76,690
Total Bales	**42,440**	**25,244**	**35,555**	**98,818**	**186,079**	**291,161**	**492,491**	**888,117**	**1,484,581**	**1,569,717**	**1,819,182**

	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.
New South Wales	373,757	310,534	347,277	369,037	293,759	316,754	282,574	276,303	248,408	353,091	278,181
Queensland	247,330	196,481	190,372	221,972	210,970	209,784	180,095	148,548	124,401	117,353	90,135
Victorian	385,914	347,036	382,937	418,560	345,445	358,717	301,772	292,166	255,131	375,843	299,643
Tasmanian	23,644	20,794	22,458	22,655	22,567	20,495	18,917	15,770	18,225	24,316	22,112
South Australian	112,166	104,838	103,462	115,717	118,616	90,055	60,326	61,444	50,720	86,556	66,157
West Australian	25,002	18,541	26,959	24,332	34,011	26,948	26,192	27,077	26,317	31,354	39,990
New Zealand	319,615	349,061	378,991	377,934	355,257	386,635	403,397	400,137	395,693	399,691	411,284
Cape and Natal	278,476	274,616	240,606	252,062	294,253	243,848	283,115	264,569	102,268	214,522	281,670
Total Colonial	**1,765,904**	**1,621,901**	**1,693,062**	**1,802,269**	**1,674,878**	**1,653,236**	**1,556,388**	**1,486,014**	**1,221,163**	**1,602,726**	**1,489,172**
East India and Persian	141,475	131,165	162,980	163,706	185,465	172,309	154,804	133,632	142,518	109,646	106,538
China	10,091	10,873	14,971	14,765	6,216	4,022	8,813	2,781	4,151	1,775	3,960
German	4,478	5,682	1,644	4,051	4,504	9,677	8,999	7,675	9,126	6,677	4,486
Spanish	3,079	4,742	1,631	10,638	4,240	12,948	3,110	3,481	896	1,293	2,128
Portugal	9,304	8,435	9,941	9,648	12,620	16,294	7,772	8,314	5,242	9,928	10,633
Russian	63,297	27,994	30,789	34,872	32,998	60,405	39,186	32,063	28,018	14,922	12,861
Turkey, Egyptian & N. Africa	81,901	55,614	40,094	67,056	42,435	53,984	32,935	28,363	39,108	26,746	36,692
Peruvian & Chilian	67,184	72,368	68,391	62,938	66,633	67,453	60,340	72,318	70,423	61,515	61,603
Buenos Ayres & Montevideo	15,368	16,734	23,980	38,659	31,026	47,931	41,205	20,109	22,077	53,150	37,220
Falkland Is. & Punta Arenas	13,615	15,087	16,413	18,017	19,504	23,498	27,645	30,019	28,784	35,395	39,403
Italian & Trieste	841	2,760	2,897	1,683	1,438	2,138	3,547	6,042	2,768	1,866	5,567
Sundry	23,935	20,322	24,777	45,139	34,629	50,034	48,729	62,508	37,150	45,463	58,165
Goats' Wool	71,170	67,061	66,873	94,412	50,473	95,487	89,511	107,290	69,445	77,514	104,644
Total Bales	**2,271,642**	**2,060,738**	**2,158,443**	**2,367,853**	**2,167,059**	**2,269,416**	**2,082,984**	**2,000,609**	**1,680,869**	**2,048,616**	**1,923,072**

Note.—Specially prepared by Messrs. Jacomb, Son & Co., of London.

Note.—The wool production of the United Kingdom increased 30 per cent. during this period.

1887.	1888.	1889.	1890.	1891.
245,290	321,154	306,091	274,448	353,407
106,614	122,867	126,637	144,093	173,558
345,396	380,330	372,057	365,172	365,490
22,261	20,167	22,035	23,537	25,855
106,403	115,849	111,236	98,249	120,665
17,656	19,382	22,897	27,949	26,933
272,918	265,684	277,726	292,724	315,055
234,728	288,910	287,334	283,494	316,510
1,351,266	**1,534,343**	**1,526,013**	**1,509,666**	**1,697,473**
123,945	134,170	140,868	125,670	133,767
2,149	3,789	5,455	8,200	15,316
9,589	5,356	7,358	4,592	3,335
6,621	8,137	10,448	5,854	1,753
9,764	10,020	11,110	7,684	7,188
66,422	59,802	106,263	65,506	96,205
86,735	77,793	85,637	73,169	62,301
69,942	56,235	67,047	57,500	62,068
7,016	10,350	11,885	6,310	9,145
7,697	7,578	8,953	9,481	12,859
1,636	1,187	2,758	1,058	2,494
14,523	21,433	30,573	19,065	19,258
56,005	72,767	77,526	48,131	62,993
1,813,310	**2,002,960**	**2,091,894**	**1,941,886**	**2,186,155**

1903.	1904.	1905.	1906.	1907.
233,922	209,023	240,922	223,648	308,628
75,052	77,728	148,059	131,622	130,128
224,787	226,133	261,724	221,684	330,326
25,189	20,523	13,770	14,551	22,147
67,001	60,019	76,469	78,579	89,637
32,456	33,851	44,623	38,724	41,467
436,500	374,463	394,390	415,879	442,973
224,458	188,843	192,210	194,949	259,691
1,319,365	**1,190,583**	**1,327,167**	**1,319,636**	**1,624,997**
129,885	158,600	153,841	180,961	159,818
3,792	5,367	7,284	8,742	15,060
4,629	7,668	6,636	10,196	11,533
1,413	2,392	1,732	2,139	4,077
13,377	11,587	11,018	9,900	10,214
10,772	9,550	7,404	19,476	15,889
39,802	53,712	43,104	53,856	51,725
61,274	60,735	55,163	63,091	53,493
45,026	22,719	52,839	59,254	70,343
39,027	41,589	34,903	41,884	53,249
4,749	3,618	3,889	1,382	2,761
42,467	48,706	46,485	47,943	43,176
109,868	100,939	101,712	100,350	109,077
1,825,446	**1,717,765**	**1,853,177**	**1,918,810**	**2,225,417**

TEXTILES

CHAPTER I

THE HISTORY OF THE TEXTILE INDUSTRIES; ALSO OF TEXTILE INVENTIONS AND INVENTORS

THE authentic history of the textile industries has been carried so far back into the past ages by the archæological discoveries of the last hundred years that an interesting account of the evolution of these industries could readily be compiled. Such an account, however, while of interest from an archæological and historical point of view, might not be of much practical value: it would almost certainly be diffuse where concentration and triteness were desirable, and, possibly, too brief in dealing with those periods when change multiplied change, causing a rapid and extensive evolution.

A sequential history of the development of the textile industries will here be preferable, although such will naturally sacrifice a certain amount of absolute accuracy to ensure a more perfect statement of the sequence of developments; perhaps even a sacrifice of actual historic order may at times be necessary to impress the real historic teaching involved. Not that in the following pages history is to be outraged and actualities suppressed or changed out of recognition; but rather that to gain all that history should teach us a certain practical licence will be taken, its justification being in the clearness and precision thereby gained.

Throwing back our minds to the time when our ancestors were emerging from the barbaric state, we can well picture to ourselves their earliest dress as the skins of slaughtered animals. As the human race was probably evolved from the torrid-temperate zone (Central Asia), it is possible that some lighter form of wearing garment preceded the skins of animals for personal wear, But it seems very probable that the first idea of textures of real wearing value would be first thus suggested.

If any animal such as the sheep then existed, we can well imagine that the shearing of a fleece would suggest the matting together of fibres already favourably disposed for the formation of a continuous covering. Felt fabrics undoubtedly came early in the historic sequence; thus both garments and hats of felt were worn in Ancient Greece; while remains of felts can also be referred to a much earlier period. But wool being the only fibre which truly "felts," the felt industry naturally cannot go further back than to the discovery of the felting property of wool.

Wool could only be converted into a woven fabric by being spun into a "fibre-thread." Now prior to the spinning of "fibre-threads"—or yarns as we now term them—the art of interweaving rushes and other fibres or bundles of fibres of long length was undoubtedly practised, so that the art of weaving evidently preceded that of spinning in the natural evolution. Again, it is probable that the art of weaving preceded the art of felting, as it is a debateable point whether the art of felting preceded the art of spinning.

The spinning and weaving of fibre-threads or yarns are obviously most delicate processes in comparison with rush and coarse fibre weaving; but it is nevertheless true that as far back as the early Egyptian Dynasties a most refined art of weaving was practised, so much so that to-day Egyptian mummy cloths of a gauze structure are found worthy of reproduction.

Turning to the conditions under which the arts of spinning and weaving would be practised in the early days of our civilization, we come across traditional industries retained in the family. It is more than probable that in some of the ancient civilizations the textile industries became more than family concerns, but so far as we are concerned we may regard the textile industry as essentially a family industry until the home industries—developed from family industries — appeared about the commencement of the eighteenth century. This does not discount the "Trade Guilds" which flourished in many centres of industry, such being based as much upon the family as upon a more highly organized form of the industry.

So long as all industries were distributed over the country it is evident that there would neither be the need nor the incentive for large production: the incentive would rather be towards the production of better fabrics and more artistic effects. Hence the marvellous beauty of many of the fabrics which came down to us from a very early date. And it is interesting and instructive to note that up to the nineteenth century attempts to introduce machines to facilitate production invariably claimed small consideration, while new methods of producing elaborate styles were certainly more than welcome. The "draw-loom" was successfully introduced from China, but M. de Gennes' power-loom failed; Jacquard looms were in use long before the power-loom was either invented or adopted by the trade. Thus the art of producing elaborate and beautiful textiles followed civilization from the East to Southern Europe and from Southern Europe northwards. Marked indications of this line of development are still evident in the present-day organization of our industries, as will be shown later.

With the disturbance of the balance of production by the going forth of Europe's, but more especially England's, sons as colonizers would come the pressing demand for the greater production of certain commodities, of which cloth would be one. This would tend to break up the family traditions and to develop an industry organized on a larger scale, resulting in what might fairly be termed "specialized production" or organized home industries. Bringing groups of artisans together could not fail to stimulate industry and inventiveness, which in this case would naturally run on the lines of increased production. Now the Continent would naturally have shared in this evolution had it been tranquil and comparatively undisturbed as was England. But the Napoleonic wars were such a constant source of ferment on the Continent that tranquil, undisturbed England reaped nearly all the direct benefits of the very rapid evolution dating from this period.

About 1790 there commenced a natural evolution of the textile industries—spinning and weaving—the final result of which was to leave England for a long period of years practically supreme as a manufacturing country.

Prior to this evolution two kinds of spinning wheels were in use, one of which might be termed the "long-fibre wheel" and the other the "short-fibre wheel." In the case of the long-fibre wheel (Fig. 9) a sliver of long fibres was practically made up from the raw material to the right thickness by hand and then twisted and wound on to the bobbin at the same time by the action of the flyer and bobbin. The attempt to use a double-spindle wheel no doubt suggested at an early date the more perfect and automatic production of slivers which might then be spun in greater numbers by hand. Thus in 1748 Lewis Paul developed the idea of drafting rollers. That he probably got the idea from seeing rollers used for elongating or working metal is indicated by the fact that it was thought possible that one pair of rollers would do all that was necessary, elongation of the sliver presumably being thought to vary with the pressure exerted. This mistake was soon rectified, and two or more pairs of rollers adopted. Richard Arkwright now came upon the scene and, linking up the drafting rollers of Lewis Paul with the long-fibre spinning wheel, made it possible to control more than one or two spindles at the same time. Arkwright then linked up the water wheel to this machine and thus evolved what is known as the "water-frame," yielding a type of yarn known even to-day by the term "water-twist."

It is probable that the "short-fibre wheel" was employed in the spinning of wool and of cotton—cotton was then a comparatively small industry[1]—both of which were woven

[1] Year 1701:

Cotton Exports	£23,253
Woollen Exports	£2,000,000

Year 1833:

Cotton Exports	£18,486,400
Woollen Exports	£6,539,731

into fabrics known as Lancashire woollens. Spindle-draft, as distinct from roller-draft in Arkwright's machine, was here employed, the reduction of a thick carded sliver into a comparatively thin thread being accomplished by mere extension, by the movement of the hand away from the spindle point, with the aid of a little twist; then upon the completion of the drafting the necessary twist was put into the thread. The process was intermittent, as winding on to the bobbin followed this drafting and twisting. The idea of working more than one spindle would here be more difficult of realization than in the case of the flyer, as the cycle of operations was much more complex. Improvements in the preparation of the slivers would here also forward the multiplication of the spinning spindles. Thus Hargreaves invented the "jenny," which was simply a multiplication of the spindles to be worked by hand, the action being really an exact copy of the mechanical operation of spinning on the "short-fibre wheel." This was soon followed by the "slubbing-billy," in which the position of spinning spindles and the slubbings were reversed, as in the mule of to-day. The "billy" was gradually developed by such men as Kelly, Kennedy, Eaton, and many others, into the hand-mule, and finally the hand-mule was successfully converted into the self-acting mule by Richard Roberts in 1830.

Much has been made of the invention of the "mule" by Crompton. But the truth is our ideas here need considerable revision. Crompton's idea of combining the drafting rollers of Arkwright's water-frame with the spindle-draft of Hargreaves' "jenny" was simply a "happy thought." Certainly this happy thought was combined with a certain amount of resolution and skill in putting the idea into practice, but it should be noted that the woollen "mule" of to-day is not Crompton's mule at all, and in fact is not a "mule," but a "pure-bred," and all the really ingenious mechanism on both woollen, cotton, and worsted mules is not due to Crompton, but to the men mentioned above. It is further interesting to note that most of the complex mechanisms combined in the mule were known to spinners and would-be inventors prior to Roberts taking the mule in hand, but owing to their lack of power of sequential thought they all failed in devising a successful machine. It was Roberts who combined the ideas presented to him into a harmonious whole and gave to the world one of the most wonderful and ingenious machines which has ever been invented.

It will readily be imagined that the improvements in spinning just mentioned naturally resulted in a marked multiplication of yarn production. Curious to relate, however, there does not appear to have been over-production of yarn, but rather under-production of cloth. It is said of the hand-loom weavers of this period that they went about with £5 sewn in their hats, so remunerative was their art. The invention of Kay's "fly-shuttle" in 1738—an invention be it noted which could only affect production, not quality nor elaborateness of the resultant fabric—had been followed by others which brought the hand-loom up to the perfection of to-day. The word "witch"—applied to the shedding mechanism known to-day as the "dobby"—carries with it an indication of the way in which some of these innovations were regarded. The placing of two or more shuttles in movable planes or shuttle-boxes, any of which could be brought into line with the picking plane, was possibly introduced in more places than one quite independently, while "permanent back-rests," "setting-up" and "letting-off" motions had developed, so far as might be, the possibilities of the hand-loom from the production point of view.

It is interesting to note that power was practically applied to the spinning frame earlier than to the loom. Arkwright's "water-frame" was successfully run shortly after 1769, while no practical power-loom was running until about 1813. By the middle of the nineteenth century hand-spinning was fast disappearing from all the manufacturing districts, but hand-weaving is even still continued in the twentieth century. Arkwright's "water-frame" was most easily rendered automatic; the spinning-jenny or "mule" up to a certain point was soon rendered automatic, but the completion of the necessarily complex cycle of operations automatically was not accomplished until Roberts faced the problem in 1825. The cycle of operations involved in weaving being more complicated than the "water-frame" cycle, but less complicated than the "mule" cycle, would naturally have come in between but for the difficulties in obtaining a steady drive; while the development of the comb into an automatic machine came much later than the "mule." Dr. Cartwright's first attempt at a power-loom was made without the slightest reference to a hand-loom and proved a failure. His second attempt was based perhaps too much upon the hand-loom, but may be regarded as having been fairly successful. It is well to fully realize that, while the introduction of water power facilitated spinning, it did not facilitate weaving to nearly the same extent; simply because for weaving a really steady drive to ensure steady picking is necessary, and this was probably not by any means attained to in the early days of water-power driving. Later, when steam power was applied, marked improvements in steadiness were rapidly developed, with the result that practically most movements involved in ordinary spinning and weaving could be accomplished automatically from 1830 onwards. Then came the exodus from the country districts and the centralization of industries on or near to the coalfields. Thus it is interesting to note that prior to England becoming a manufacturing country the wool of England met the skill of Southern Europe in Flanders. Later a distributed industry is to be noted in England, the industry generally following the line of supply of the raw material. Still later the coal-power of Yorkshire meets the wool production of Yorkshire at Bradford, and the coal-power of England the cotton of America in Lancashire.

Attention was now turned to the more perfect preparation of the slivers of wool, cotton, flax, etc., for the subsequent spinning process. Hand-cards were early displaced by the roller hand-card, and this in turn developed into the "flat-card" and later the "revolving flat-card." The development of the card, however, was more of an engineering problem than a problem in mechanism, the style of build and accuracy of setting being the real difficulties. There is an exception to this, however, in the case of the woollen condenser. Originally cardings were left exceedingly thick and unwieldy, having to be drawn out into slubbings and then into slivers, finally to be spun on the wheel or jenny. The first improvement was the dividing of the card-clothing on the last doffer into strips of 6 inches to 8 inches wide across the doffer, so that from the circumference of, say, a 24 inch doffer 10 or 12 slubbings just the width of the card—each say 27 inches to 36 inches long—would be stripped, these strippings being piecened up on the apron of the slubbing-billy by boys and girls called "pieceners." Then what was called a "piecening machine" was added, which, taking charge of these 27 inch to 36 inch slubbings stripped from the doffer, joined or placed them into continuous slivers, which were wound on to a spindle to be placed later on the slubbing-billy.

Some time after the introduction of the piecening machine the "condenser" made its appearance. In this the last doffer or doffers were clothed concentrically with rings of card-clothing, so that the slivers were stripped continuously from the doffer, and were practically endless as compared with the 36 inch slubbings stripped from across the doffer of the old card. In the latest form of condenser the wool is stripped from the last doffer in a continuous film, and then broken up into 70 to 80 filaments by means of narrow straps or steel bands. One wonders why the idea of the ring-condenser was not sooner thought of and why it should have been so frequently tried and discarded. A little thought, however, soon clears up this point. It may be taken that wool fibres take up a more or less concentric position on the card. If this be so, then stripping the wool off the old form of doffer would result in the fibres taking a concentric position in the thread, while in the case of the condenser they would take up a longitudinal position in the thread. This, no doubt, seriously affected the subsequent spinning, weaving, and finishing properties; in fact, it is frequently stated that no fabrics equal to those made from yarn spun from the old piecening slubbings are to-day produced. Possibly the realization of this difference suggested the idea of preparing wool for combing by previously carding it. This was first carried into practice about 1847 and is to-day being largely applied even in the case of wools 8 inches to 10 inches long.

The cycle of movements in hand-combing being more complicated than the cycle of movements in carding, automatic combing naturally developed much later than automatic carding. The operations of lashing on, combing, drawing off, and the removal of "backings," of "milkings," and of "noil" were necessarily very complicated, and it was largely by the elimination of certain of these that mechanical combing was made a success. As with most other machines, the first mechanical attempts were simply imitations of the hand process. Dr. Cartwright from 1789 to 1792 brought out two forms of mechanical combs which after many vicissitudes were laid aside for many years until they both again emerged—the upright circle comb as Heilmann's comb, the horizontal circle comb in its most perfect mechanical form as Noble's comb. It should be noted, however, that it is Lord Masham (then Mr. S. C. Lister) to whom credit must be given for the creation of a practical wool comb: without his "driving-force" there can be no doubt but that the evolution of the wool comb would have been long delayed. As with spinning so with combing: the preparatory processes were of marked importance. Without the preparing or gill box and the card, mechanical combing would to-day be at least very imperfect if at all possible. The "Genesis of the Wool Comb" is given in List I.

We have now dealt with the evolution of all the important textile mechanisms with the exception of the ring and cap frames, which may finally be briefly touched on.

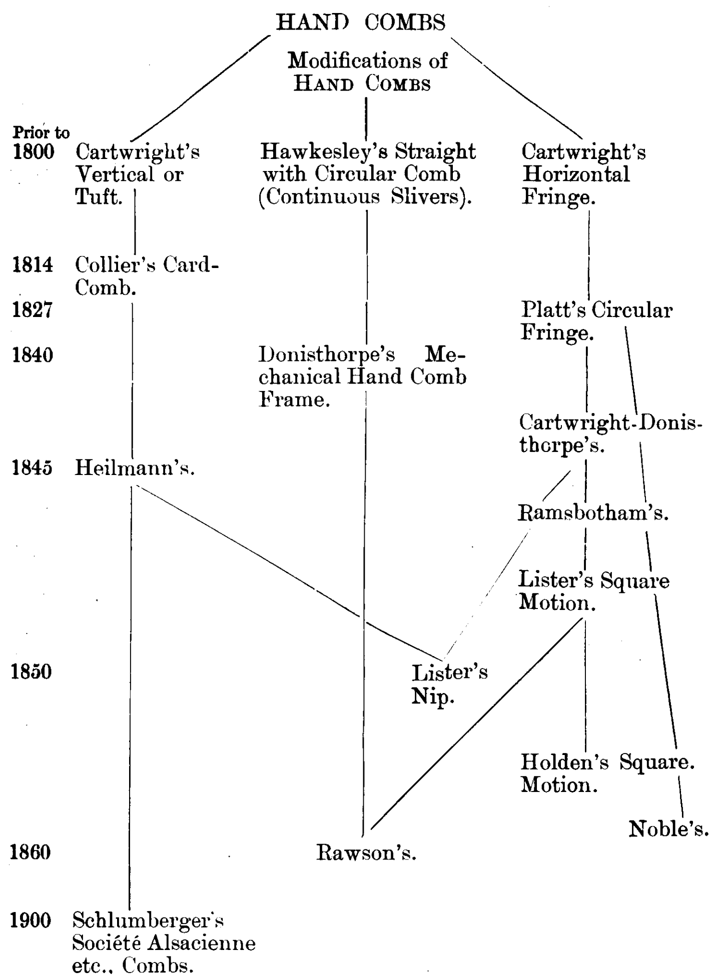
Labour, especially male labour, being very scarce in the United States, difficulties were encountered in working the heavy mules or mule-jennies needed for the production of certain yarns. Again, the questions of speed of machine and production would no doubt claim attention. Thus in 1832 the ring-frame was invented, this being readily controlled by female labour and eminently suited to the spinning of certain useful cotton counts.

Other ideas of frame spinning had naturally been tried in the States. The Danforth or cap spindle, coming to Lancashire about 1825, was condemned for cotton, but being introduced into Yorkshire was adopted as the system *par excellence* for the spinning of fine Botany yarns. It is curious to relate that the first trial of this spindle in Yorkshire was made at a very slow speed "to give it a chance." The result was that the yarn could be jerked off the bobbin or spool. It was only when the bobbin was speeded up from 2,000 to 5,000 revolutions per minute that its possibilities were fully appreciated.

From 1850 onwards—with the exception of the electric Jacquard and certain most interesting methods of pile weaving—no marked advances in the general form of the machinery employed in the textile industries are to be noted. Nevertheless, the improvements in details have been many and in some cases of surprising merit.

The development of pile weaving and of pile weaving

List I.—The Genesis of the Machine Wool Comb.



machinery may briefly be summed up as follows: The printed warp pile fabric was introduced by Mr. R. Whytock about 1832. This was followed by the Chenille Axminster —in which the colours were woven in—about 1839. From 1844 to 1850 the power wiring loom was developed in the United States and introduced into Great Britain. From 1856 to 1867 the power "tufting" or Axminster loom was developed, and finally in 1878, Lord Masham succeeded in weaving two pile fabrics face to face, the pile stretching between an under and upper ground texture being severed in the loom by a knife which traverses from side to side with this object. From 1890 to 1910 the chief innovations have had reference to the cutting of weft-pile fabrics in the loom, the introduction of the looping or cutting wires through the reed, thus doing away with the necessity for any wiring mechanism, and certain marked improvements in the mechanism for producing Chenille Axminster fabrics.

Along with these developments came the factory system. This system was no doubt evolved by the disturbance of the balance of trade due to colonization and the various inventions noted. One thing reacted upon another, production increased production, spindle stimulated loom and loom spindle, until eventually a terrible strain was put upon those actually engaged in the factory, and in many cases humanity was sacrificed on the altar of increased production, most awful conditions prevailing. Slowly, however, the position of the worker has been improved both by direct and indirect legislation. Foreign competition has no doubt retarded still further improvements being carried into effect; but the *rapprochement* of nations due to increased facilities for communication must

LIST II.—DEVELOPMENT OF THE FACTORY SYSTEM.

Development of Mechanical Methods of Manufacture.	Development of Organization culminating in the Factory System.	Development of Markets.
DISTAFF, HAND CARDS, HAND COMBS, JERSEY WHEEL, FLAX WHEEL, HAND LOOM.	1545 Principle of Interest admitted.	*Prior to* 1750.
1589 William Lee . Stocking Frame.	16th Century. Silk Mills at Bologna.	Virginia.
1650 M. de Gennes . Power Loom.	1609 Bank of Amsterdam.	West Indies.
1738 John Kay . . Fly Shuttle.	*Up to* 1690. *Entirely Domestic.*	Hudson Bay Territory.
Robert Kay . Drop Box.	1610 Water power suggested for Spinning.	Newfoundland.
1738 Lewis Paul . John Wyatt . } Drawing by Rollers (ass power.)	17th Century. Child Labour (6 years). German Spinning Schools (girls).	Gibraltar.
1748 Lewis Paul . Roller Card.	*Up to* 1730. *Combined Home, Warehouse and Mill.*	*Prior to* 1800.
1750 M. Vaucanson . Swivel Loom.	1718 Lombe's Silk Mill. (King's influence and power.)	India.
1758-59 J. Strutt . Rib Hosiery Frame.	*Up to* 1780. *Development of Domestic Industries. From Pack Horses to Waggons. Turnpike Roads. Riders for Orders.*	Canada.
1764 Jas. Hargreaves . Spinning Jenny.	1738 Wyatt and Paul's Mill driven by two asses.	Florida.
1769 R. Arkwright . Water Frame.	1750 to 1757 } First Woollen Factory: in Workhouse.	Australia.
1772 John Lees . . Improved Card.	1757 Water power fully employed.	Ceylon.
1779 S. Crompton . Mule.	*After* 1780. *Partners in London and on Continent. Agents, Factors and Brokers established. Market Days.*	*Prior to* 1850.
1785 E. Cartwright . 1st Power Loom.	1784 First Worsted Factory.	Cape Colony.
1789 ,, . Wool Comb.	1786 Cartwright employs Steam Engine.	Natal.
1790 ,, . Wool Comb, &c.		New Zealand.
1792 ,, . Wool Comb, &c.		British Guiana.
1797 ,, . Steam Engine.		Tasmania.
1789 Jas. Watt . . Steam Engine.		Mauritius.
1790 Kelly . . . Power Mule.		Malta.
Johnson . . Warp Dressing Frame.		*After* 1850.
1804 J. M. Jacquard . Jacquard Loom.		Opening up of China.
1813 Horrocks . . Power Loom.		Japan.
1823 to 1830 { Heilmann . Jordain . Risler and Dixon . Sharp and Roberts } Power Looms Comb and Mule.		Africa, &c.
Whitehead . . Piecening Machine.		

inevitably lead to a levelling up and to labour ultimately receiving due recognition both with respect to the conditions under which work is done and the pecuniary benefits derived from such work.

In List II.,[1] the concomitant early developments of Mechanical Methods of Manufacture, Organization of the Industry and of Markets, are given.

[1] NOTE.—This list was given in a different form in the article on "Wool Combing" appearing in "Technics" for August, 1904.

CHAPTER II

THE WOOL, SILK, COTTON, FLAX, ETC., GROWING INDUSTRIES

THE sources of supply of raw materials must always claim the careful attention of spinners and manufacturers, even if they have not to deal with the material at first hand. It may be questionable if all the fluctuations in price of cotton, wool, etc., can be accurately gauged by the most careful study of the economic conditions of the supply; but of this we may be sure, that a sound knowledge of the conditions of production and consumption will in a large percentage of cases enable the spinner or manufacturer to correctly judge the situation and thus avoid mistakes which otherwise would most surely be made. We must not forget that the successful man is he who makes the fewest mistakes!

About a hundred years ago most wonderful advances were being made in both wool and cotton growing. The development of the Continental merino wool trade, followed by the still more remarkable development of the Colonial wool trade, and later by the development of the South American wool trade—these and other minor but important influences have resulted in changes of momentous issue. Cotton much earlier than wool seems to have felt the coming revolution, becoming acclimatized or being further developed in the United States of America, the East Indies, Peru, and later in Egypt. It is further interesting to note that of late there has been a most decided unrest in cotton producing and consuming circles, resulting in the institution of the British Colonial Cotton Growing Association, which is at the present date (1910) threatening to again revolutionize the cotton markets. Silk also has made a remarkable advance, owing to the discovery of the possibilities of reeling certain wild silk cocoons and therefrom making a good quality of net silk. None the less remarkable have been the developments in the waste and artificial silk industries. Flax has never markedly changed its centre of gravity—at least so far as production is concerned—this no doubt being due to its being one of the fibres most easily spun by hand, and hence having been in general use prior to the industrial era. Its cultivation was much more distributed up to about 1870, but the chief centres of flax production, Ireland, Russia, Germany, Holland, and Belgium, are all old established. Other vegetable fibres, such as China grass, Phormium Tenax, etc., have from time to time appeared, and it does seem as if at last China grass has come to stay. The following sections, which must only be regarded as notes, give a broad outline of the development of the respective industries. Perhaps such notes possess a value which is not diminished but rather accentuated through their very brevity and triteness.

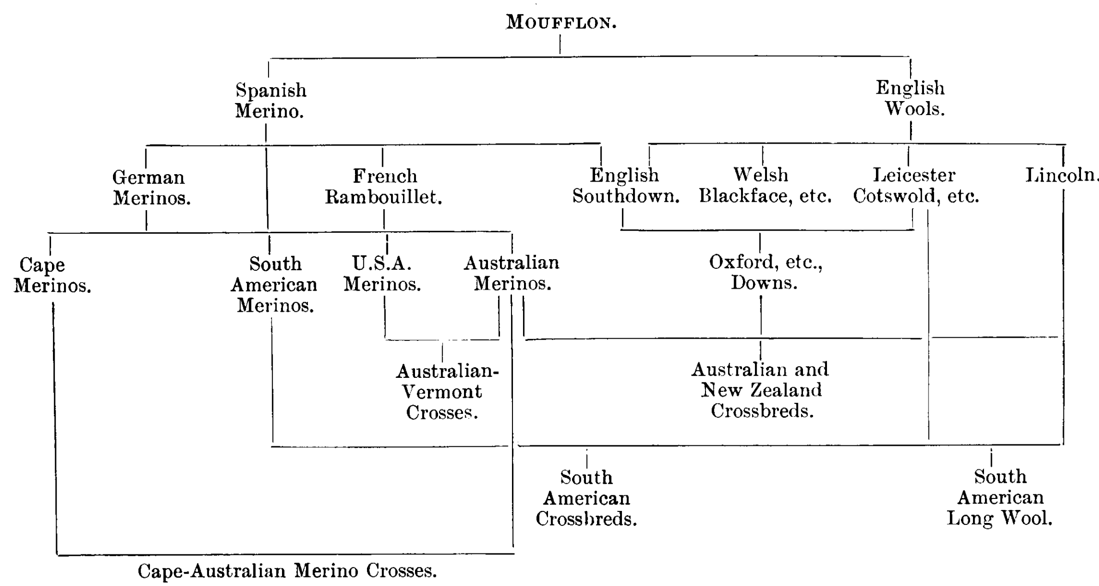
The Wool Growing Industry.—The sheep as we have it to-day is said to be a development, through years and years of selection and acclimatization, of a somewhat rough-haired animal, the moufflon, originally reared on the central plains of Asia. The evolution of the sheep was no doubt dependent upon the advancement in civilization of the peoples ultimately destined to spread not only over Asia, but

Europe and Northern Africa also. It seems quite probable that the Arabs following the north coast of Africa into Spain, took the partially developed sheep with them and by their well-known skill and carefulness, aided by climatic conditions, ultimately produced the Spanish merino, to which the merino flocks of the world owe their origin either directly or indirectly. At the same time that this evolution was taking place, the Asiatic tribes who struck northward across the central plains of Europe possibly also took with them the partially developed sheep which ultimately arrived in England, and again owing to climatic conditions became what we should now term a typical mountain sheep, from which within comparatively recent times the world-renowned English breeds of sheep have been developed by careful selection and breeding. An idea of this development is given diagrammatically in List III.

It seems more than probable that the moufflon or original progenitor of the sheep was black or brown, and it is interesting to note that there are continual reversions to this colour in some of our whitest and finest breeds—Wensleydales for example. So much has this tendency marked itself in certain parts of Australia that flocks of brown or black sheep have been established. The change in colour of the average sheep from brown to white is said to have been due to the custom of paying for shepherding with the white lambs dropped. This naturally led to the shepherds promoting the breeding of white sheep—as told with reference to Jacob in the Bible—with the final result that when the attempt was seriously made to breed pure white sheep success was soon achieved.

It is reasonable to suppose that the sheep as a supplier

List III.



Note.—Merino breeds are placed on the left, English breeds on the right, and Crossbreds in the centre.
So far as may be the history of each breed is shown vertically. Thus the French Rambouillet was probably the origin of the Vermont Merino, while the pure Spanish Merino was possibly transferred to the South American Colonies. Again, the Leicester breed is probably the most representative of cultivated English wools, etc.

of wool and mutton, was very widely distributed, and that the small quantities of wool produced would be spun and woven locally until some change upset this distributed equilibrium. So far as we can tell, the first change was due to the developed skill of the Continental workers, probably coming down the Rhine Valley and finally settling in Flanders. At least we know that the skill of the Flemish spinners and weavers was largely instrumental in creating England as a wool-growing country. The direct endeavours of several of the English monarchs coupled with Continental wars and persecutions ultimately resulted in the establishment of spinning and weaving industries in England along with wool growing. Nevertheless the centralization of industry was only partial until, as already pointed out, our colonization of new worlds, Continental wars, certain mechanical inventions, and the application of water and steam power gave rise to the factory system, which in its turn reacted upon the raw material producers and ultimately resulted in the development of the Cape, Australia, New Zealand, South America, the East Indies, etc., as the great wool-producing centres, although England still holds its own for its specially useful types of sheep. List IV. gives an idea of how these markets developed and at the same time affected the production of wool in the older wool-growing districts.

It will be noticed from these lists that the most marked development of the Botany wool trade took place between 1850 and 1880, coinciding with the development of combing machinery capable of dealing with fine short wools, and with the invention and development of the self-acting woollen mule. In fact these lists conclusively prove that the development of the growing of fine wools was largely dependent upon the invention of machines with which to work them: thus the wool comb and the self-acting mule were really the deciding factors. Of course woollen yarn had previously been spun on the "billy" and "jenny," and Botany wool had been combed by hand, but these being all hand processes were the natural but very marked limitations, and it was only when these limitations were removed that the most noteworthy advance was made—just as the development of these improved hand methods had caused a marked rise in wool production fifty to seventy years previously.

It was the wonderful direct influence of the Australian climate upon the fleeces which first called attention to Australia as a possible fine wool-growing centre. The climatic conditions, however, were not the same all over the island continent, so that later developments have taken the line of heavier sheep of a greater value from a "mutton" point of view, with a consequent development in crossbred wool growing. When wool was down at a very low price in 1901-2, "mutton" became the chief factor in the case of all lands carrying crossbred or heavy sheep—as was also the case during these years in England. A large part of Australia, however, is only fitted for carrying the lighter merino breed, and thus will never be markedly affected by the frozen mutton trade. The drought of 1897–8, however, played havoc with these merino flocks, and a shortage of merino wool has resulted, which, in conjunction with the tendency to run off wool, owing to its poor paying results, and grow mutton, has finally resulted in a general shortage of wool and especially of fine wools.

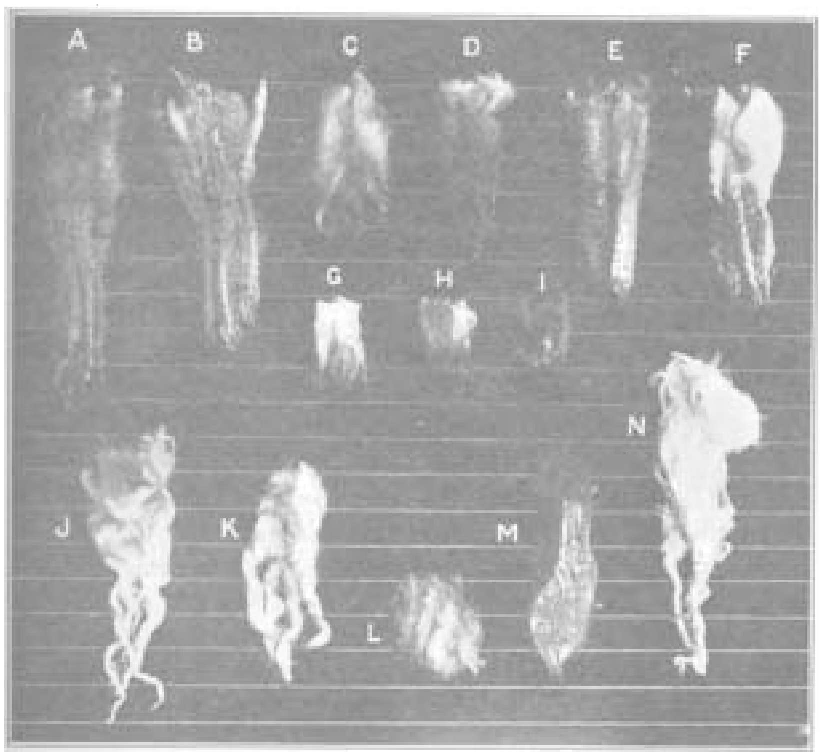


FIG. 1.—Wools and Hairs (the horizontal divisions = 1 inch). A, Lincoln; B, Kent; C, Shropshire; D, Australian Crossbred (46's); E, New Zealand Crossbred (46's); F, Buenos Ayres Crossbred (46's); G, Australian Merino (70's); H, Buenos Ayres Merino (60's); I, Cape Merino (64's); J, Turkey Mohair; K, Cape Mohair; L, Cashmere; M, Camel's Hair; N, White Alpaca. *Note.*—The presence or absence of grease on these natural wool staples has affected the colour.

New Zealand, having a climate more akin to that of England, has always produced wools of the crossbred type, merino sheep being bred in some few districts only.

The Cape has been a wool-producing country longer than

Australia, but climatically is apparently not so suited to the production of wool of good type. Of late much has been done to improve Cape wools, and they are naturally more sought after; but it seems as though it was a continual wrestling with nature.

Of recent years the country which has advanced most in wool production is South America. Originally a common sort of merino wool was grown, but now, owing to careful breeding and selection, both fine Botany and well-developed crossbred and even English wools are produced. The wool capabilities of the South American Continent are by no means exhausted, and it seems a pity that we English failed to realize the wonderful potentialities of a country likely in the near future to play such an important part in the world's history. It is principally to this country that the £1,000 Lincoln rams are continually being exported.

The United States of America very early attempted and succeeded in establishing flocks of sheep ranging from crossbreds to truly fine merinos, although, as already pointed out, they at first as colonists drew practically all their cloths from the mother country, and still take large quantities of the finer goods. That the United States is capable of producing a fine merino wool is proved from the use—rightly or wrongly—which has been made of the Vermont merino sheep in Australia. This use, however, has been made with the idea of producing a heavier fleece rather than a finer wool. America still buys English sheep and English wools, the importation of the sheep probably being necessary to correct the tendency to degenerate owing to climatic conditions.

Of the hairs manufactured into fabrics of various

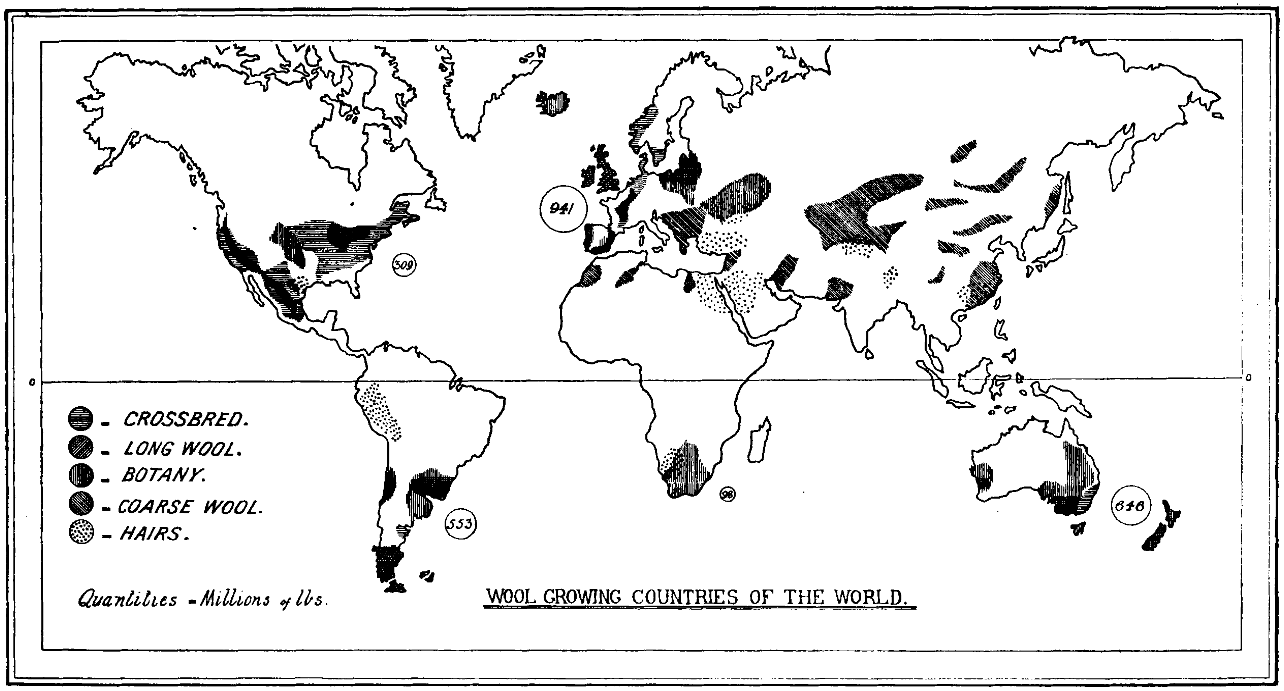

309
941
98
553
646
CROSSBRED.
LONG WOOL.
BOTANY.
COARSE WOOL.
HAIRS.
Quantities = Millions of lbs.
WOOL GROWING COUNTRIES OF THE WORLD.

Fig. 2.

descriptions, Mohair, Alpaca, and Cashmere are the most important. Horsehair, Cow-hair, Rabbits' fur, etc., are used in small quantities only and for very special purposes.

That mohair was used in England two to three hundred years ago is evident from allusions to mohair fabrics made for example by Dryden. These fabrics, and later mohair yarns (hand spun), were no doubt imported from the emporium of the East, and it was only about 1848 that supplies in quantity of the raw material commenced to come into this country. Various restrictions were at first placed upon the export of the hair, but now it is an established trade and very considerable in bulk. More stringent restrictions were placed on the export of the Angora goat, but owing to a certain amount of vacillation flocks have been firmly established at the Cape and also bid fair to become established in San Francisco and Australia. Turkey mohair still maintains supremacy so far as quality of lustre is concerned, but Cape mohair, which, by the way, is clipped twice from the goat each year, now runs it very close. The Australian supplies are not yet of much moment, while the industries of the United States consume all grown in San Francisco.

Alpaca comes from the Peruvian sheep or goat. This hair, although used in various forms for centuries by the inhabitants of Peru, claimed no special attention in this country until Sir Titus Salt discovered it and produced his famous "alpacas." The fibre is long and silky and in some respects—notably softness—is superior to mohair. Most of the so-called "alpacas" sold to-day are actually made of mohair, for, curious to relate, while the supplies of mohair have quadrupled during the past fifty years, the supplies of alpaca have almost remained stationary, as all attempts to naturalize the sheep outside Peru have failed.

Cashmere is obtained from the Cashmere goat, being the under-hair which is protected from the weather by a long coarse over-hair, and in turn no doubt serves the purpose of keeping the goat warm. This material came into notice as a useful fibre from the wonderful cashmere shawls which are so remarkable for their softness and fineness. The supplies of this material are in the hands of a select few and it is used for very special purposes. Soft, fine Botany wool is, however, frequently sold in a manufactured state as "cashmere."

Camels' hair is obtained chiefly from China and Russia. The coarser kinds or hairs are used for such purposes as camels' hair belting, while the "noil" or short soft fibre is used for blending with wools to yield special effects. The combing of this fibre, as also of Iceland wool, is very interesting, the idea frequently being to comb away the long fibres, leaving the "noil"—usually the least valuable part of the material—as a soft-handling and exceedingly useful fibre.

Cow-hair, rabbits' fur, etc., are only used for very special textures. Rabbits' fur, however, is used to a considerable extent in the felt trade.

Before leaving the wool industry reference must be made to the remanufactured materials, which briefly are Noils, Mungo, Shoddy, and Extract. The idea of using over again materials which have already served for clothing must be very old. It was not until 1813, however, that the Yorkshire clothiers succeeded in tearing up wool rags and therefrom producing a material capable of being spun into a fair yarn, especially if blended with other better materials.

The operations necessary for this "grinding-up," as it is technically termed (although in truth the operation more truly consists in a teasing out), are dusting, seaming, sorting (according to quality and colour), oiling, and grinding. Obviously hard-spinners' waste would be most difficult to reduce again to a fibre state, but machines are now made that will grind up at least anything of wool; cotton, however, is another matter. The terms mungo, shoddy, and extract refer to the original quality of the goods from which these materials are produced; mungo being produced from soft short wool goods, shoddy from longer and crisper wool goods, and extract from goods made of cotton and wool from which the cotton is removed by the "extracting" process, the remaining wool being then torn up into a fibrous mass.

To supply this trade large quantities of rags are imported into this country from the Continent, the Dewsbury and Batley districts working up a very large proportion. Quite recently the Americans made a very determined attempt to get hold of this trade, sending representatives into the Dewsbury district. They have undoubtedly been successful, although they cannot yet treat these materials quite so efficiently as the Dewsbury men. Germany has also a remanufactured materials trade of considerable moment.

The "noils" referred to above are the short fibres rejected from either English, Crossbred, or Botany wools, or Mohair, Alpaca, etc., during the combing operation. They cannot be considered as quite equal to the original material, although they are undoubtedly superior to mungo, shoddy, and extract: they may have lost a little of their elasticity, but their scale structure is not so much damaged, nor are they so much broken up.

All these materials are either used alone or, more frequently, blended with better or what one might term "carrying materials." Cotton and mungo, for example, often compose the blend for a cheap but effective yarn for the Leeds woollen trade.

The following tables, taken from Mr. F. Hooper's "Statistics of the Worsted and Woollen Trades," published by the Bradford Chamber of Commerce, give a bird's-eye view of the past and present constitution of the wool industry; similar particulars respecting the other industries are given in the special chapters devoted to them.

ESTIMATE OF WOOL GROWN IN THE UNITED KINGDOM IN 1907.

Chief Districts.	Sheep and Lambs.	Weight per Fleece.	Total Weight.
	(1906.)	lbs.	lbs.
Lincoln	993,983	9½	9,442,838
Yorks—East Riding	419,391	8	3,355,128
Devon	837,384	7	5,861,688
Ireland	3,714,832	6	22,288,992
Somerset	474,042	7	3,318,294
Shropshire	484,865	6	2,909,190
Sussex	399,001	4½	1,795,504
Wilts	468,743	4½	2,109,343
Scotland	6,994,338	5	34,971,690
Northumberland	1,067,697	6	6,406,182
Cumberland	586,432	6	3,518,592
Yorks—North Riding	683,877	6	4,103,262
Yorks—West Riding	678,876	6	4,073,256
Wales	3,586,095	3½	12,551,332
Sheep and Lambs in 1906	29,135,192	—	163,875,521
Slaughtered	11,113,187	at 3 lbs.	33,339,561
Net Clip of Wool in 1907			130,535,960

Exports of British Wool from the United Kingdom. In Thousands of Lbs.

Country.	1901.	1905.	1907.
To Russia	63	2,869	4,335*
,, Germany	1,067	2,531	3,417
,, Holland	829	962	916
,, France	606	760	936
,, United States	15,949	24,806	18,022
,, Canada	820	1,563	1,662
Totals for all Countries	20,206	35,252	31,087

* For 1906.

Imports of Wool into the United Kingdom. In Thousands of Lbs.

Country.	1903.	1905.	1907.
From France	15,781	21,338	24,487
,, Turkey	9,888	13,899	8,893
,, Chili	16,133	15,057	20,704
,, Uruguay	13,699	3,143	5,593
,, Argentine Republic	24,150	26,675	40,555
Totals from all Foreign Countries	107,049	111,764	137,133
From Cape of Good Hope	66,878	58,332	91,606
,, British East Indies	32,503	39,898	46,717
,, Australia	223,384	253,373	321,471
,, New Zealand	155,127	139,269	158,406
,, Falkland Islands	2,944	3,565	3,650
Totals from all British Possessions	492,452	503,944	622,104
Totals - -	599,501	615,708	759,237

Re-Export of Colonial and Foreign Wool from the United Kingdom.
In Thousands of Lbs.

Country.	1901.	1905.	1907.
To Germany .	79,094	82,279	89,136
„ Holland .	21,950	12,580	9,144
„ Belgium .	43,219	39,251	57,852
„ France . .	96,531	60,424	83,711
„ Italy . .	664	32	908*
„ United States	47,379	78,756	69,889
„ Canada . .	2,257	1,824	917*
Totals for all Countries	293,063	277,103	312,673

* For 1906.

Imports of Mohair into the United Kingdom.

Year.	From Turkey.		From South Africa.	
	lbs.	£	lbs.	£
1860	2,512,447	378,071	—	—
1865	5,056,037	786,915	9,609*	1,468*
1870	2,191,237	393,996	283,659	47,388
1875	5,461,832	753,907	1,079,293	89,700
1880	9,083,854	943,251	2,987,192	227,501
1885	6,828,502	607,365	5,263,813	305,196
1890	4,120,222	230,229	8,923,531	402,844
1895	11,875,640	787,964	10,354,870	492,531
1900	8,538,374	596,551	9,039,772	606,711
1905	12,524,356	807,901	12,532,482	779,967
1907	11,652,140	780,624	19,125,425	1,217,178
1908	7,460,507	477,344	17,810,975	935,702

* The first year that South Africa exported mohair in quantity.

IMPORTS OF ALPACA, VICUNA, AND LLAMA WOOL INTO THE UNITED KINGDOM.

Year.	From Peru.		From Chili.	
	lbs.	£	lbs.	£
1860	2,334,048	263,635	520,402	58,443
1870	3,324,454	388,969	563,782	65,996
1880	1,412,365	98,644	890,627	64,621
1890	3,114,336	190,703	564,606	30,694
1900	4,236,566	205,839	1,148,694	51,116
1907	4,665,738	251,236	356,068	22,452
1908	4,309,912	257,215	515,754	26,968

TOTAL EUROPEAN AND AMERICAN WOOL IMPORTS.

—	1901.	1903.	1905.	1907.
	Bales.	Bales.	Bales.	Bales.
Australasian . .	1,745,000	1,451,000	1,633,000	2,103,000
Cape . . .	217,000	234,000	209,000	287,000
Total Colonial .	1,962,000	1,685,000	1,842,000	2,390,000
River Plate . .	532,000	558,000	488,000	478,000
Total . .	2,494,000	2,243,000	2,330,000	2,868,000

The Silk Growing Industry.—At one time this industry was practically limited to China and Japan, in which countries the silkworm was rigorously guarded. Some missionaries, however, in the year 552 managed to bring some eggs to Constantinople, and eventually the industry was firmly established upon the north shores of the Mediterranean. Various attempts have been made to establish the industry elsewhere. Attempts, for instance, were made to acclimatize the worm in Ireland, and at the present moment a certain amount of success seems to be attained in Australia; but rival industries or the unskilfulness of the rearers seem to prevent the attainment of any success of practical value. The United States, perhaps, may be regarded as exceptional in this respect. Not only have they developed their own breeds, but they have established a most complete silk industry from the worm to the finished product.

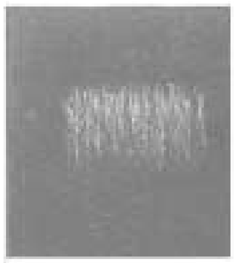
The most remarkable development in the silk industry was brought about in 1877 by Lord Masham, who, after many failures, succeeded in producing cheaply and successfully utilizing a most useful silk yarn from waste silks—old cocoons, brushings from the outside of the cocoons, throwing waste, etc. This development naturally lead to the utilization of wild silk, as tons of these pierced or spoilt cocoons—supposed to be unworkable—were available. Thus was developed the remarkable trade known as the "spun silk trade." Curious to relate, however, the latest discovery is that many of these wild silk cocoons can be reeled, as will be further explained in Chapter XV. The supplies of wild silks are not yet exhausted, as news is just to hand of the discovery of wonderful nests of cocoons in Africa (Congo State), arrangements for the exploitation of which are only just being made.

"Net" silk (silk threads reeled directly from the cocoon) comes to us in the form of what is known as "singles," a thread composed of just a few strands—say six. In the English "throwing mills" several of these singles are thrown together to make up a thread of the required thickness, with little twist if for weft, or, as it is termed, "tram," and much twist if for warp, or, as it is termed, "organzine" (see Fig. 21).

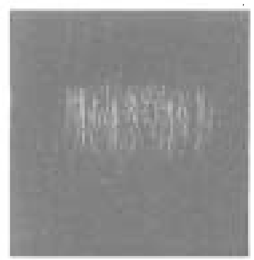
Waste silk is received in this country in three other forms, viz., wild cocoons, waste silk in the gum, and waste silk discharged. All these forms are, however, worked up on the same principle, which will be described later.

The Cotton Industry.—The cotton industry seems to be of Asiatic origin, and appears to have appertained more particularly to the Mahometan religion, as we hear of Mahomet going about with the Koran in one hand, a sword in the other, and a cotton shirt upon his back. As already pointed out, flax, being a material more readily spun, would naturally claim first attention. It seems probable, however, that India was unsuitable for flax cultivation, while the cotton plant was evidently indigenous. Thus attempts would no doubt be made to utilize this very nice-looking fibre, and eventually cloths very suitable for the Indian climate would be produced. These fabrics being shipped to Europe no doubt ultimately resulted in the cotton trade being established in various centres, but only on a very small scale. It was, as we have already seen, the mechanical era which gave life to the cotton trade and resulted in the development of the cotton-growing industry in the United States, the West Indies, Peru, the Sea Islands, Egypt, and later—under the auspices of the British Cotton Growing Association—in Africa. Our chief supplies of cotton still come from the United States. Egypt and the Sea Islands send us long-stapled cottons suitable for the Bradford trade, while Peru supplies us with a woolly cotton very suitable for blending with short wools for the Leeds and district trade.

In Fig. 3 the chief varieties of cotton are illustrated.



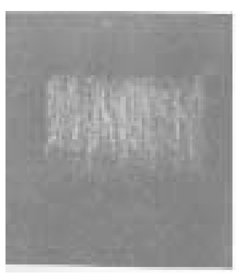
WEST AFRICAN. Gambia. from American seed.



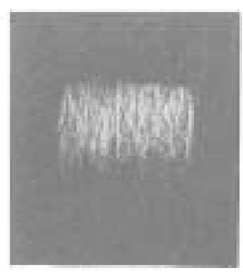
WEST AFRICAN. Lagos.

INDIAN. Oomrawattee.

INDIAN. Bengal.



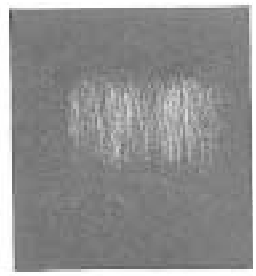
INDIAN. Broach.



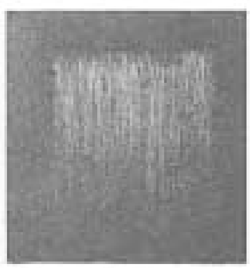
INDIAN. Tinnivelly.

FIG. 3.—The Cotton Fibres of Commerce. Scale, $\frac{1}{2}$ inch to 1 inch. Arranged and photographed by F. W. Barwick, Esq., of the Research Laboratories, Imperial Institute.

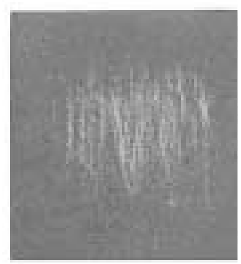
BRAZILIAN. Ceara.



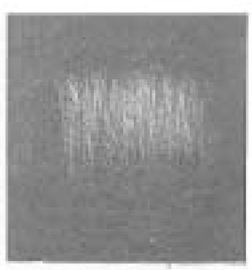
BRAZILIAN. Pernam.



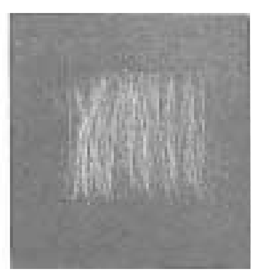
BARBADOS. Sea Island.



EGYPTIAN. Abassi.

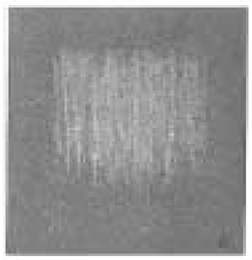


NYASSALAND. Egyptian.

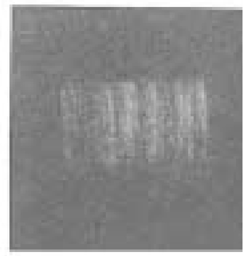


EGYPTIAN. Mitafifi.

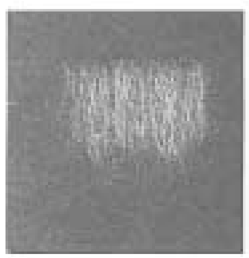
FIG. 3.—The Cotton Fibres of Commerce. Scale, ½ inch to 1 inch—*continued.*



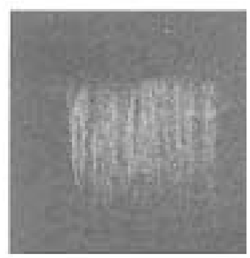
EGYPTIAN. Yannovitch.



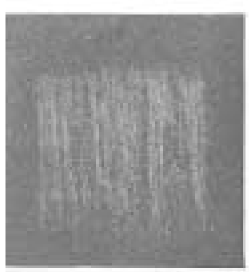
PERUVIAN. Smooth.



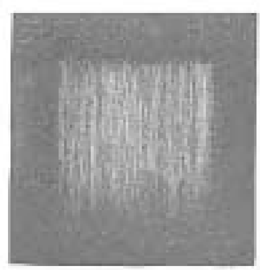
PERUVIAN. Rough.



PERUVIAN. Sea Island.



AMERICAN. Carolina Sea Island.



AMERICAN. Georgia Sea Island.

FIG. 3.—The Cotton Fibres of Commerce. Scale, ½ inch to 1 inch—*continued.*

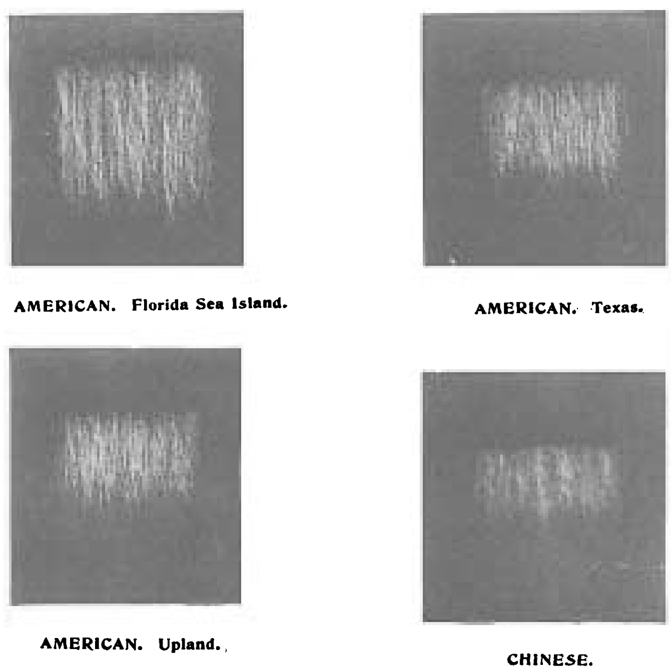


Fig. 3.—The Cotton Fibres of Commerce. Scale, ½ inch to 1 inch—*continued.*

The cotton-growing countries of the world are shown in Fig. 4, from which it will be noted that practically the torrid zone is the cotton zone. Of course soil and other conditions in part determine whether cotton can be grown, but it is evident that much heat is desirable and even necessary, and, as a consequence, that the best available labour is black labour. The United States has its "black belt," and in our attempts to grow cotton in our Colonies—and in the case of French Colonies also—it seems as though we must be largely dependent upon black labour.

The cotton fibre is produced on three varieties of plants,

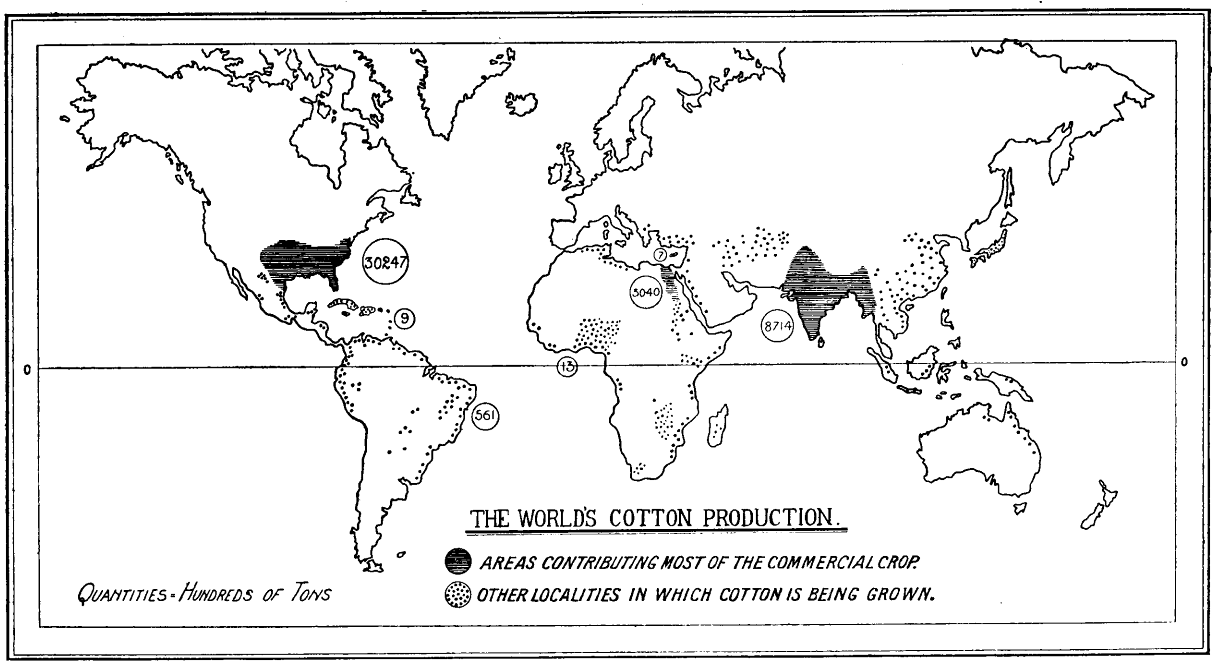

THE WORLD'S COTTON PRODUCTION.
AREAS CONTRIBUTING MOST OF THE COMMERCIAL CROP.
OTHER LOCALITIES IN WHICH COTTON IS BEING GROWN.
QUANTITIES - HUNDREDS OF TONS
30247
9
561
7
3040
13
8714
0
0

FIG. 4.

viz., Gossypium Barbadense, or the true Sea Island cotton plant, which, yielding the best type of cotton, is the original basis of much American, Egyptian, and Indian cottons; Arboreum or tree cotton, yielding a rougher cotton, coming to us from Brazil and Peru; and Herbaceum, or the variety of the ordinary cotton plant from which American cotton is largely produced.

The Flax Growing Industry.—The flax fibre is one of the oldest fibres of which we have any records. The Biblical references to flax (or linen) are numerous, and remnants of old linen fabrics are frequently coming to light in the exploration of the sites of the older civilizations. The writer has just been asked to analyse some linen fabrics dating back some 2,000 to 3,000 years. The following are the results:—

ANALYSIS OF MUMMY CLOTHS.

	To-day's Cloth. Linen.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Weight per yard, 54 × 36	8 ozs.	$12\frac{1}{16}$ ozs.	$12\frac{7}{8}$ ozs.	$10\frac{5}{8}$ ozs.	$10\frac{3}{8}$ ozs.	$11\frac{5}{8}$ ozs.
Counts of warp	1/33·5 linen	1/20·7	1/10·3 linen	1/32·7	1/21·8 linen	1/29·1 linen
Counts of weft	1/31's linen	1/16's linen	1/10's linen	1/33·3 linen	1/18·4 linen	1/23·83 linen
Threads per inch	46	60	28	84	50	80
Picks per inch	43	21	18	37	25	27
Strength of warp (single thread)	30·72 ozs.	—	2·77 ozs.	—	1·31 ozs.	1·65 ozs.
Elasticity of warp (single thread)	·36″	—	·272″	—	·524″	·478″
Strength of weft (single thread)	31·66 ozs.	—	5·01 ozs.	—	6·23 ozs.	1·7 ozs.
Elasticity of weft (single thread)	·472″	—	·374″	—	·288″	3·34″

The flax fibre, coming as it does from the stem of the flax plant, naturally requires very different climatic conditions as compared with the cotton fibre. Although its cultivation is still very dispersed, the chief flaxes are Irish, Belgian, Dutch, German, and Russian. The stems when ripe are cut somewhat after the fashion of corn, placed in the dam to rot or "ret," as it is termed, dried and "scutched," this latter operation resulting in the cortical or non-fibrous matter being separated from the fibrous matter. Dew retting is practised on the Continent, and sometimes chemical retting also; but whichever system is adopted, the idea is simply to separate the fibres from the cortical and pith-like substance with which they are enveloped with as little damage to strength, length, and colour as possible. Many substitutes for flax have come forward from time to time, but none have stood the test, with the possible exception of cotton, which seems to have made considerable encroachments during the past few years. China grass or Ramie may in the future have some influence on the flax industry, but it has hardly yet been felt.

Other Vegetable Fibres.—It is useful to obtain a general idea of all the vegetable fibres, as one cannot foretell which type is likely to come more markedly into use, or what particular type of plant is likely to yield a fibre suitable for special and up-to-date requirements.[1] In List V. the origins of the various "vegetable hairs" are given. In List VI. the physical compositions of the vegetable fibres are given.

[1] The use of Sisal hemp in the place of horsehair by the Italians is a case in point.

List VII. is a practically complete list of the vegetable hairs and fibres.

List V.—Vegetable Hairs.

Origin.	Natural Order.	Typical Example.
Entirely covering, or in part covering the seed	Malvaceæ Asclepiadaceæ Apocynaceæ Œnotheraceæ	Cotton. Madar Fibre of India. Periwinkle. Willow-Herb.
Contained in the flower .	Typhaceæ Cyperaceæ	Bullrush. Cotton Grass.
Lining interior of fruit .	Bombaceæ	Horse-chestnut. Red Silk Cotton of India.
Twigs and leaves . .	Filices Muscineæ	Ferns. Peat-moss Fibre.

List VI.—Vegetable Fibres.

(*a*) Fibres formed of Single Cells:

Ramie—disintegrated.
China Grass—disintegrated.
Flax—disintegrated (*i.e.*, too far retted).

(*b*) Fibres associated in Bundles:

Jute—unbleached.
Flax.
Deccan Hemp.
Ramie—not disintegrated.
Hemp—well prepared.

(*c*) Fibres together with Medullary Ray Cells:

Sisal Hemp.

(*d*) Fibres together with Parenchyma Cells:

Sunn Hemp.
Mudar Fibre of India.

(*e*) Fibres and Vessels:

Phormium tenax or New Zealand Flax.
Musa or Manila Hemp.
Ananas or Pineapple and Banana Fibre.

List VII.—Complete List of Vegetable Hairs and Fibres.

Technical Name.	Local or General Name and Location.	Scientific Name.
Cotton.	1. Tree Cotton	Gossypium arboreum.
	2. American, African, and Indian Cotton	,, Barbadense.
	2a. Sea Island Cotton	,, maritimum, etc.
	2b. Peruvian or Brazil Cotton	,, acuminata.
	3. Asiatic Cotton	,, herbaceum.
Kapok	White Silk Cotton of East Indies	Eriodendron Anfractu.
Semal	Red Silk Cotton of India	Bombax Malabaricum.
Silky Cotton	Down Tree of Armenia and Jamaica	Ochroma Lagopus.
,, ,,	White Silk Cotton Tree of India	Cochlospermum Gossypium.
Vegetable Silks	"Mudar" or "Yercum" of India	Calatropis gigantea. ,, procera.
,, ,,	Of Bengal	Beaumontea grandiflora.
,, ,,	"Yachan" of the Argentine	Chorisia insignis.
Flax	Flax or "Lin"	Linum usitatissum.
Hemp	Sunn Hemp	Crolalaria juncea.
,,	Sisal of India and Queensland	Sida rhombifolia.
,,	Manila Hemp	Musa textilis.
,,	Sisal Heneopien or Yucatan Hemp. (An aloe)	Agave rigida. Var. longifolia.
,,	Chinese Hemp	Abutilon, etc.
,,	Common Hemp	Cannabis sativa.
,,	Rajmahel Hemp of Northern India	Marsdenia tenacissima.
White Rope Fibre	Bombay or Manila Aloe of America and East India	Agave vivipara.
,, ,,	Istle of Mexico	,, heteracantha.
,, ,,	Maritius Hemp of South America	Fureroea gigantea.
Flax-like Fibres	Buaze Fibre of Guinea and Nileland, etc.	Securidnea longipedum culata.
,, ,,	Siberian Perennial Flax	Linum perenne.
Flax and Hemp Substitutes	Spanish Broom	Spartum junceum.
	Kendu Fibre	Apocynum Venetum.
Jute	Jute of India and China	Corchorus capsularis.

List VII.—Complete List of Vegetable Hairs and Fibres—*continued.*

Technical Name.	Local or General Name and Location.	Scientific Name.
Jute . .	Jute of Calcutta . . .	Corchorus Olitorius.
,, . .	,, America . . .	Abutilon Avicennæ.
,, . .	,, West Africa . .	Honckenya ficifolia.
Jute-like Fibres	Fibre from Lagos . .	Honckenya ficifolia.
China Grass	Tchon Ma (Temperate Zone)	Boehmeria nivea.
,, ,,	Ramie or Rhea (Torrid Zone)	Variatum tenacissima.
,, ,,	Canada Nettle Fibre . .	Laportea Canadensis.
Nettle Fibres	Tashiari (Himalayas) . .	Debregeasin Hypolenca.
,, ,,	Nilgiri Nettle . . .	Girondina heterophylla.
,, ,,		Maontia purga.
,, ,,	Ban-Surat of India and Ceylon	Laportea crenulata.
,, ,,	Ban-Rhea of Assam . .	Villebrunea intergrifolia.
,, ,,	Urera Fibre of Natal . .	Urera tenax.
,, ,,	Mamaki of Pacific Islands .	Pipturus albidus.
,, ,,	Rere of Pacific Islands .	Cypholobus macrocephalus.
Palm Leaf Fibres	Oil Palm Fibre . . .	Eloesis Guineensis.
,, ,,	Gri-gri Fibre of West Indies	Astrocary.
,, ,,	Raffia of Madagascar and Africa	Raphia Ruffia.
,, ,,	Corogo Fibre of Cuba .	Acrocomia Lasiospatha.
Special Fibres	Plantain and Banana Fibre	Musa sapientium var. paradisiaca.
,, ,,	Pineapple Fibre of East India	Ananas sativa.
,, ,,	Caraguata of Paraguay .	Bromelia Argentina.
,, ,,	Pingum of Jamaica and America	,, ,,
,, ,,	Silk Grass of Jamaica and Tobago	Bromelias or Furcroea Cubensis
,, ,,	Madaguxar Piassava . .	Diety osperwa Piassava.
Hibiscus or Mallows	Deccan Hemp. Also known as Kanaff and Ambari Hemp	Hibiscus Cannabinus.
,, ,,	Okro	,, esculentus.
,, ,,	Royelle or Red Sorelle .	,, Sabdariffa.
,, ,,	Maholtine (Africa and America)	Abutilon periplocifolium.

List VII.—Complete List of Vegetable Hairs and Fibres—*continued.*

Technical Name.	Local or General Name and Location.	Scientific Name.
Hibiscus or Mallows	Ban-ochra of India, or "Toza" Fibre of West Africa	Urena lobata.
,, ,,	Indian Mallow Hemp . .	Abutilon Avicennæ.
Leguminous Order	Dhunchi Hemp of Assam .	Sesbama aculeata.
,, ,,	Ka Hemp of China and Japan	Pueraria Thunbergiana.
,, ,,	Maln Fibre of India and Ceylon	Banhima Vahlii.
Bowstring Hemps	Konje Hemp of Zambezi, etc.	Sanseviera Guinensis.
,, ,,	,, ,, ,,	,, longiflora.
,, ,,	Pangane Hemp of Pangane	,, Kukii.
,, ,,	Neyanda of Ceylon . .	,, Zeylanica.
,, ,,	Ife Hemp of South Africa .	,, cylindrica.
,, ,,	Moorva of India . . .	,, Roxburghiana.
,, ,,	Somali Land Fibre . .	,, Ehrenbergii.

The average lengths, practical and actual, and the average diameters of the principal vegetable fibres are given in List VIII. In Fig. 5 the countries producing the more important vegetable fibres not specially dealt with here are indicated. The only fibres in these lists which call for special comment are hemp, jute, and the two forms of China grass.

Jute is the fibre from what is essentially a torrid zone plant and is largely used in the carpet industry for sackings, while hemp is not quite so much of a torrid zone plant and is more particularly used for ropes, especially for shipping, as it sinks in the water, while ropes of some other materials do not sink so readily and are thus dangerous to small boats passing by.

List VIII.—Working Lengths and Average Diameters of the Principal Vegetable Fibres (in inches).

Name.	Working Length.	Average Diameters.
	inches.	inches.
1. Agave Americana or Sisal Hemp. *Agave rigida var. Sisalana* (True Sisal hemp)	36—60	$\frac{1}{250}$ — $\frac{1}{62}$ average $\frac{1}{130}$
2. Ananassa or Banana Fibre. *Ananas Sativa* (Pineapple Fibre)	18—72	$\frac{1}{830}$ — $\frac{1}{230}$,, $\frac{1}{410}$
3. Boehmeria Nivea or China Grass	up to 11	$\frac{1}{1250}$ — $\frac{1}{330}$,, $\frac{1}{660}$
4. Boehmeria tenacissima or Ramie	ditto	ditto
5. (*a*) Common Hemp . .	48—84	
(*b*) Piedmontese or Giant Hemp	up to 144	$\frac{1}{1660}$ — $\frac{1}{500}$,, $\frac{1}{1330}$
6. Corchorus olitorius or Jute.	60—120	$\frac{1}{1660}$ — $\frac{1}{500}$,, $\frac{1}{1430}$
7. Crotalaria juncea or Sunn Hemp	72—144	$\frac{1}{2000}$ — $\frac{1}{830}$,, $\frac{1}{1250}$
8. Linum usitatissimum or Flax	24—36	$\frac{1}{1660}$ — $\frac{1}{660}$,, $\frac{1}{1000}$
9. Musa textilis or Manila Hemp	up to 60	$\frac{1}{500}$ — $\frac{1}{83}$
10. Phormium tenax or New Zealand Flax	36—132	$\frac{1}{312}$ — $\frac{1}{66}$,, $\frac{1}{104}$

China grass (*Boehmeria nivea*) has so often been to the fore as a newly discovered fibre and so often proved a failure that one hesitates to speak of it. The Chinese, however, make such magnificent textures from this fibre that its prospects cannot be regarded as other than hopeful. Whether the Indian form of the fibre, ramie (*Boehmeria tenacissima*) as it is frequently called, will ever yield such a plastic wonderful yarn and fabric as the Chinese get from

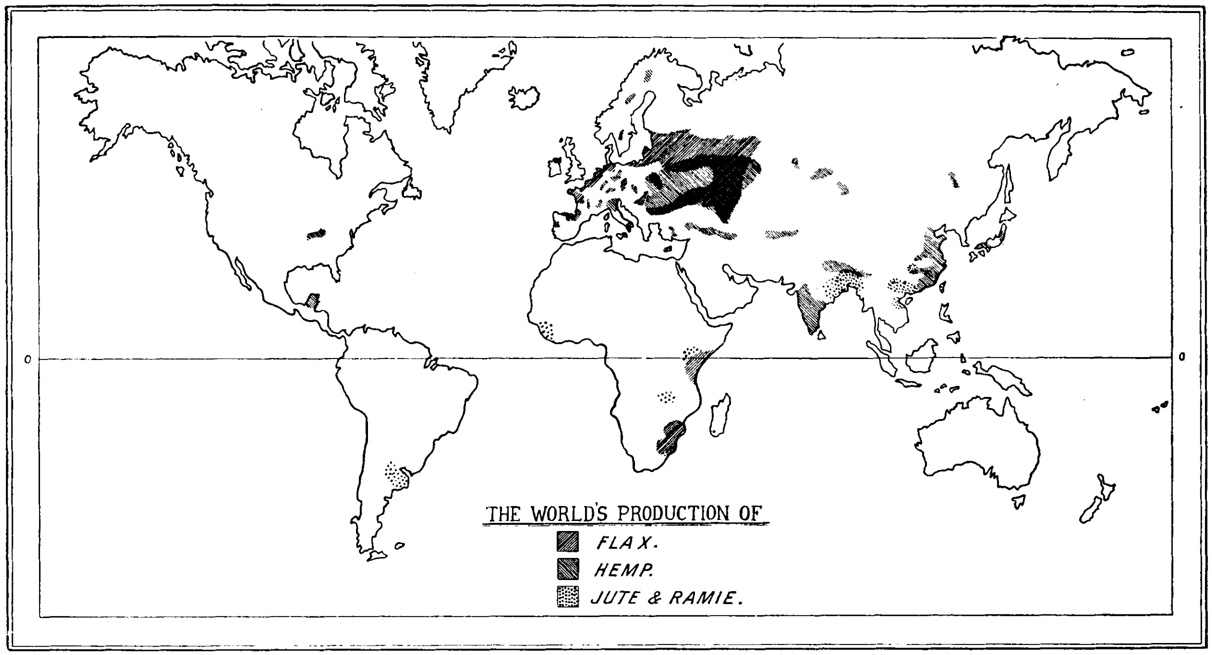


FIG. 5.

China grass (*Boehmeria nivea*) still remains to be seen. Certainly the possible need for indigo planters turning their attention to growths other than indigo should at least favour a really serious trial. The gums in China grass are the greatest difficulty, necessitating its being prepared in a way entirely different from linen; when it is satisfactorily prepared it is so silky that waste silk machinery is the most suitable for dealing with it.

At the present moment a great revival in the New Zealand flax (*Phormium tenax*) industry is taking place. Whether success will attend the endeavours being made remains to be seen, but of this we may be certain, that there are still many fibres only partially exploited, and many which have not even been touched, which in the future are undoubtedly destined to play a useful part.

Notes on the Chemical and Physical Structures of the Fibres.—The textile fibres of commerce naturally group themselves into six well-defined groups, viz., the animal fibres, the vegetable fibres, the animal-vegetable or insect fibres, the mineral fibres, the remanufactured fibres, and the artificial fibres.

Of the first class the normal wool fibre may be taken as representative. It is composed of carbon, oxygen, nitrogen, hydrogen, and sulphur,[1] and when burnt emits a disagreeable odour largely due to the liberation of ammonia, which serves to distinguish it from cotton and most other fibres. It does not burn with a flash, as does cotton, but rather shrivels away, leaving a bead of burnt matter. Wool has marked powers of causing dissociation of certain metallic salts, this forming the basis of the mordanting of

[1] In what manner these elements are combined chemists are still uncertain.

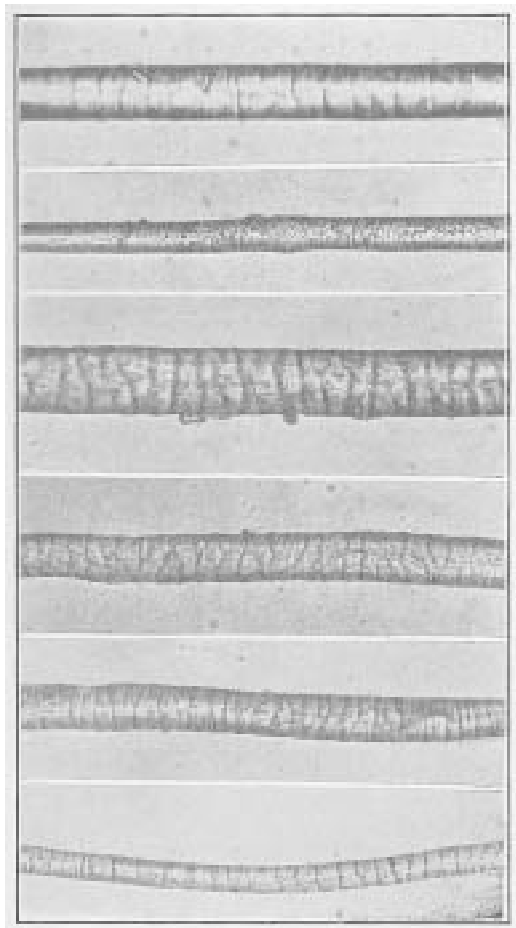


FIG. 6.—Micrographs of Wool Fibres: (*a*) Merino (Australian), (*b*) Southdown (English), (*c*) Cross-bred (New Zealand), (*d*) Lincoln (English), (*e*) Alpaca (South American), (*f*) Mohair (Turkish).

wools prior to dyeing. It is open to doubt as to whether the action of dyeing is entirely a chemical or partly a physical action. In the case of indigo dyeing, for example, there seem marked indications that the action is purely physical.

On the other hand, this cannot be said with the same certainty of most other dyes. Physically, the most remarkable thing about wool is its exterior scale structure (clearly shown in Fig. 6), to which it partially owes its felting property, and to which in part wool cloths owe their strength. Various qualities of wools have this exterior scale structure developed in different degrees, and as a rule those with the scales most marked "felt" the most easily, although there are exceptions to this rule, curliness and probably internal structure playing some part. Hairs only show more or less faint indications of the scale structure, and consequently do not felt so readily. Upon the other hand, they are usually more lustrous, their uncorrugated and unbroken surface reflecting the light intact. In fineness wool fibres vary from $\frac{1}{500}$ to $\frac{1}{3000}$ of an inch in diameter, but there is no well-defined relationship between fineness and length, although the Bradford quality numbers—now practically universal—such as 30's, 40's, 50's, 60's, 70's, etc., no doubt suppose some general coincidence between length and fineness of fibre. A year's growth in length may equal anything from 1 or 2 inches to 12 or 16 inches, a fair average being 7 to 8 inches. Wool, however, if left unclipped, will grow sometimes to 40 inches in length, and fleeces are on record weighing 57 lbs. The length of the wool fibre, as will be demonstrated later, largely determines the method of preparing and spinning it into yarn.

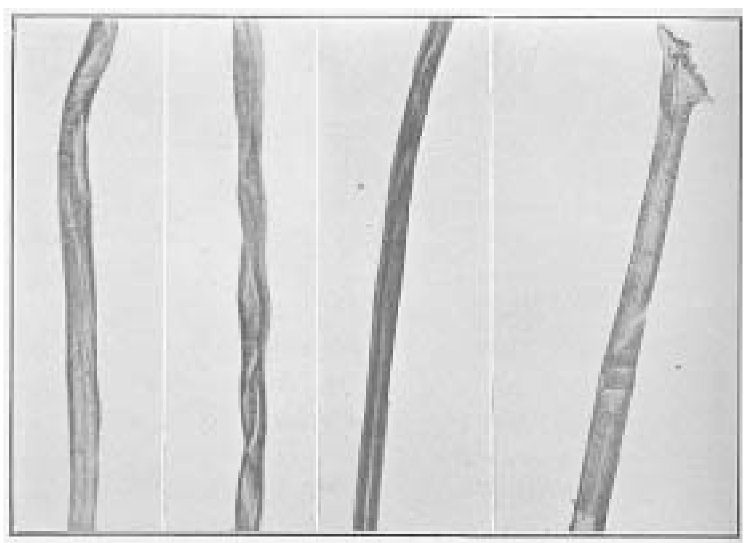
Of the second class, cotton is the most representative of the "seed-hairs." It is nearly pure cellulose, the formula for which is $C_6 H_{10} O_5$. Flax and the other "stem-fibres," while largely composed of cellulose, are much less pure in composition, and in many cases by their very impurities may be distinguished from one another (see List VI.).

Physically, cotton appears to take the form of a flattened, collapsed, twisted tube; in fact its form is best suggested by a thin indiarubber tube out of which the air has been drawn. If unripe, the characteristic feature of twist is absent, and the cotton neither dyes well nor does it spin to advantage. In length the cotton fibre varies from $\frac{7}{8}$ of an inch to $1\frac{3}{4}$ inches and in diameter averages about $\frac{1}{1344}$ of an inch. Fig. 7 illustrates some interesting features respecting the structure of the cotton fibre.

The chief characteristic of flax as viewed under the microscope is the appearance of nodes, these, no doubt, being limitations of growths. Flax may readily be recognized by the property it possesses of developing curious cross striations when treated with nitric acid and then sulphuric acid and iodine. Most of the vegetable fibres may be recognized by some special chemical reaction. Thus jute, for example, may be distinguished from flax, etc., by the action of an acidulated alcoholic solution of phloroglucine, flax being unchanged, while jute is stained an intense red.

Of the third class silk is the representative fibre. In most of its chemical reactions silk is akin to wool, but there are differences which enable the dyer to cross-dye silk and wool goods—*i.e.*, to dye the silk one colour and the wool another colour, although there are obvious limitations in this respect. The silk fibre consists of two distinct parts, a central portion and a coating of substances readily removable by hot water, termed the "silk gum." The central portion or "fibroin" has approximately the composition: $C_{15}\ H_{23}\ N_5\ O_6$. The silk gum, which often forms as much as 20 to 30 per cent. of the natural silk fibre, is usually boiled off, and only too often weighting added, which has a deleterious action on the wearing

a *b* *c* *d*



FIGS. 7 and 8.—Micrographs of Cotton Fibres: (*a*) unripe fibre, (*b*) ripe fibre, (*c*) mercerized fibre. Micrograph of Silk Fibre: (*d*) illustrates the twofold character of the silk fibre and the splitting and expansion of the fibrils which occur in some Tussah Silks.

qualities of the silk. Why silk should so readily weight-up does not entirely admit of a satisfactory explanation. It is, of course, a most expensive fibre, and as weighting agents cost 1*s*. per lb. and as silk sell at 12*s*., weighting naturally pays well. Physically, silk may be defined as a long fibre (cocoons contain from 400 to 1,500 yards) of a twofold character, this being due to the silk fluid issuing from a gland on each side of the silkworm, the ducts from these uniting in the head of the worm. Under the microscope the fibre appears more as a glassy rod of fairly round form (Fig. 8), but from time to time the two-fold character is perceptible in following along the fibre. In fineness it is from $\frac{1}{500}$ to $\frac{1}{1600}$ of an inch, the finer being the cultivated silks and the coarser the wild silks. A peculiar feature of the wild tussah silks is that upon the fibre being cut it breaks up into a number of fibrils, forming a bush-like end. This makes the fibre specially suitable for the production of plushes.

The mineral fibres are principally glass, tinsel, and asbestos. As they are of very limited application, their chemical composition and physical qualities need not be fully discussed here. Glass naturally partakes of the qualities of ordinary glass, but is much more flexible than would be naturally supposed. Tinsel is made from copper, aluminium, and other metals drawn out, and partakes naturally of the qualities of the metals from which it is made. Asbestos possesses characteristics which cannot be well defined on paper. As woven into cloth it is irregular, lumpy, soft, and plastic. It is naturally mostly employed next to heated surfaces, for firemen's jackets, etc.

The remanufactured fibres can only claim distinctive treatment from the physical point of view. They mostly consist of animal fibres which have been broken up in length and the scale structure of which has been partially damaged. The important quality of elasticity has also been seriously interfered with.

The artificial fibres are of such importance that it has been deemed advisable to devote a special chapter to them.

Notes on the Effects of Chemical Re-agents on the Textile Fibres.—The effects of even simple re-agents are so marked and so diverse that it is very necessary to have an accurate and extensive knowledge of such under all the varying conditions obtaining in practice. For instance, boiling water will disintegrate and weaken wool while it strengthens cotton. Again, sulphuric acid and caustic soda have very different actions on the cotton and wool fibres. Sulphuric acid with heat may be employed to disintegrate the cotton out of a cotton and wool fabric, while caustic soda may equally well be employed to dissolve the wool from the cotton. Cold strong caustic soda, however, may be employed to mercerize the cotton in wool and cotton goods without detriment to the wool. It is thus evident that absolute knowledge based upon incontrovertible experience is necessary if mistakes are to be avoided and the best results obtained.

CHAPTER III

THE MERCERIZED AND ARTIFICIAL FIBRES EMPLOYED IN THE TEXTILE INDUSTRIES

MERCERIZED COTTON.

THE term mercerization is now applied to a process by means of which cotton yarn or cloth is rendered lustrous and silky in appearance, and the importance of the process has made enormously rapid development since its introduction in 1895. The production of lustre is accompanied by considerable modifications in the structural appearance, chemical character, and dyeing properties of the fibre, and these latter effects of mercerization were first noticed and investigated by John Mercer in 1844.

Mercerization without lustre is carried out by steeping the dry cotton in a cold concentrated solution of caustic soda ($NaOH$ 50° to 60° Tw.) for a few moments, and then well washing to remove the alkali. This changes the microscopic appearance of the individual cotton fibres from that of flattened spiral tubes with thin walls and a relatively large central cavity to that of more or less cylindrical non-spiral tubes with thick walls. The effect in mass of this modification of the fibre is that the threads contract in length, become somewhat thicker, and much stronger; the dyeing properties being also much modified. Chemically the process results in the formation of a definite chemical compound of cellulose and caustic soda ($C_6H_{10}O_5 \cdot NaOH$) in a state of hydration. On washing, this is decomposed, the alkali being removed and the cellulose regenerated as a hydrate ($C_6H_{10}O_5 \cdot H_2O$) which permanently retains the altered appearance and properties above noted.

The natural shrinkage thus brought about is made use of in the production of *crepon* effects on mixed cotton and wool fabrics.

Lustreing by mercerization is obtained by a very slight modification of Mercer's original process; the shrinkage of the yarn or cloth which would naturally take place being prevented by mechanical means.

"Mercerization" may also be brought about by the use of substances other than caustic soda, *e.g.*, sulphuric, nitric, or phosphoric acid or zinc chloride; the use of these being mentioned in Mercer's original patent. Sodium sulphide has also been proposed, but none of these bodies are of any practical importance in this connection.

The Process.—The essentials of the process are very simple, but for economical and efficient working the following points require attention:—(1) The caustic soda solution should be used at a strength of about 55° Tw. and as cold as possible without artificial cooling; (2) the material must be thoroughly and uniformly impregnated; (3) the material must be kept in a state of uniform tension until the washing has decomposed the alkali cellulose; (4) as much of the caustic soda as possible must be recovered; (5) the cotton must be of long staple and the threads must not be too tightly twisted.

Many different mercerizing machines have been introduced, and their relative success depends upon the degree to which they satisfy conditions Nos. 2, 3, and 4 specified above, and are economical as regards output and labour required. The soda recovery apparatus is another important feature of a modern mercerizing plant. In this the wash waters are evaporated to mercerizing strength, and the recovered soda is treated with lime to recausticize the portion which has been converted into carbonate during the various operations.

Bleaching and Mercerizing.—If cotton is bleached after mercerization the process of bleaching does not destroy the lustre of the mercerized fibre; but this sequence of operations offers no advantage, and the maximum lustre is always obtained when the material is subjected to as little treatment as possible after mercerization. Treatment with bleaching powder after mercerizing is also liable to rot the fibre by oxidation.

The Dyeing of Mercerized Cotton.—It has already been mentioned that mercerized cotton has a much greater affinity for many mordants and dyes than the untreated fibre. The effect is greatest in the case of cotton mercerized without tension, and diminishes somewhat as the tension is increased, being least marked in fully lustred cotton. The difference in the chemical properties of mercerized and unmercerized cotton is the main cause of their different behaviour in dyeing, but structural or physical change has also a considerable effect.

Irregular mercerization is a frequent cause of irregular dyeing, and special precautions must be taken when the cotton is subsequently to be dyed in pale shades. Some further information regarding the dyeing properties of mercerized cotton will be found in the next chapter, p. 80.

Crimp effects on Cotton are obtained by mercerizing cotton cloth in stripes or other patterns by a printing process, the natural shrinkage of the mercerized portion producing the crimp. If printed and mercerized under tension, lustre patterns may be obtained on cotton cloth.

Crepon effects on Union Cloth.—Wool fibre is practically unaffected by caustic soda of mercerizing strength, and if suitably woven with cotton and the fabric mercerized, the shrinkage of the cotton throws up the wool into loops or knots. Silk-cotton unions may be similarly treated, but require great care in manipulation.

The Schreiner Finish.—This process of increasing the lustre of cotton is so closely connected with mercerizing lustre from the practical standpoint that mention should here be made of it. It consists in subjecting cotton cloth to the action of an engraved steel roller under great pressure. The engraving consists of very fine serrations, numbering 400 to 700 per inch, and these produce optically reflecting surfaces upon the threads which very greatly enhance the lustre of the material. Cotton lustred by mercerization and subsequently treated with the Schreiner calender rivals silk in appearance.

The Production of Mercerized Cotton is by far the most important recent development in the textile trade, having practically enriched it with a new fibre almost as lustrous as silk, and of course much less costly. One of the main defects of mercerized cotton is that its lack of elasticity renders fabrics made from it very liable to crease.

Test for Mercerized Cotton.—A solution of iodine in saturated potassium iodide solution colours both ordinary and mercerized cotton a deep brown. On washing with water, mercerized cotton changes to a blue black, which fades very slowly on long washing, whereas ordinary cotton rapidly becomes white on washing.

Artificial Silk.

The silk fibre, consisting of the solidified fluid of the silk glands of the worm, is devoid of cellular structure. Wool and cotton, on the other hand, are highly organized fibres from the structural standpoint, being composed of a vast number of individual cells built up in a definite and orderly manner. It is thus impossible to conceive of the mechanical production of a fibre resembling wool or cotton in character; but in its broadest outline the problem of the production of a fibre similar to silk is not a difficult one.

The problem involves two main features—first, the production of a viscous liquid analogous to that naturally existing in the silkworm glands, and, secondly, the mechanical conversion of this into thin fibres.

The second part of the problem offers no insuperable difficulties; in fact artificial silk fibres are now produced which are much finer than those of natural silk (Thiele silk).

The composition of the viscous liquid may be chemically similar to natural silk or may be of an entirely different character. The first artificial filament which resembled silk in appearance was spun glass, from which fabrics of brilliant lustre and considerable softness may be produced. These are, however, of little value, since the fabric rapidly disintegrates on account of the brittle nature of the fibre.

Vanduara Silk is obtained by using gelatine as a basis, the threads, after spinning, being treated with formaldehyde to render them insoluble in water. It is a beautifully lustrous fibre, and fairly strong and elastic in the dry condition, but if wetted it becomes extremely tender. It is now little, if at all, used.

Gelatine may also be rendered insoluble by the combined action of chromic acid and light, and this has formed the basis of an artificial silk process; but no practical success has been achieved on these lines.

Cellulose Silk.—All the commercially produced artificial silks are obtained by using some form of cellulose as a basis, and amongst these may be mentioned the *De Chardonnet*, *Pauly*, *Lehner*, *Vivier*, *Thiele*, *Stearn* and *Bronnert* silks, which are also known under such names as "*Collodion silks*," "*Glauzstoff*," "*Lustro-cellulose*," and "*Viscose silk*."

Cellulose, the chemical basis of cotton, linen, wood, and the structural portion of vegetable growth generally, is chemically a very inert substance, and only two or three ways of dissolving it are known.

(1) When converted into nitro-cellulose by treatment with nitric acid it becomes soluble in alcohol-ether. The various "collodion" silks are thus produced.

(2) Cellulose is soluble in a concentrated solution of zinc chloride, or

(3) In an ammoniacal solution of oxide of copper.

(4) If cotton is mercerized with caustic soda and treated with carbon disulphide while still saturated with the alkali, it forms a new chemical compound (cellulose thiocarbonate) which is soluble in water and is known as "viscose."

(5) Acetates of cellulose may be produced which are soluble in various solvents.

Each of the first four methods of dissolving cellulose forms the basis of a commercial process for manufacturing artificial silk.

(1) *Collodion Silk.*—This was the original artificial silk, and was first patented by De Chardonnet in 1886. After surmounting many difficulties, due chiefly to the inflammability and lack of strength of the fibre, the process is now a great commercial success, and it is estimated that the output of the various factories totals about 1,000 tons per annum. The chief names connected with this product are those of De Chardonnet, Lehner, and Vivier.

(2) *Bronnert Silk* is made from a zinc chloride solution of cellulose, but this process has not made such rapid development as

(3) The *Cuprammonium process*, which yields the *Pauly*, *Linkmayer*, and *Thiele* silks, which latter is, as regards appearance and handle, almost indistinguishable from natural silk.

(4) The *Viscose Silk* of Cross & Bevan and Stearn is also of much interest.

Properties of Artificial Silk.—The characteristic properties of natural silk which render it so much esteemed as a textile material are its beautiful lustre, softness, elasticity, strength, and covering power, and the ease with which it can be dyed. With regard to lustre the artificial silks exceed the natural fibre, some having almost an undesirable metallic lustre. In softness and general handle most varieties of artificial silk are somewhat deficient, but this defect has recently been entirely overcome by building up the thread of a large number of fine filaments, so that a thread of 40 denier may contain 40 to 80 of such filaments.

Such a product is now on the market (Thiele silk), and its softness and covering power equal that of natural silk. All the artificial silks are, however, somewhat difficult to manipulate in winding and in the loom.

In *elasticity and strength* artificial silks are somewhat deficient even when dry, and when wetted the defect is greatly accentuated. This renders careful treatment in dyeing very necessary.

Dyeing Properties.—The various artificial silks differ considerably in dyeing properties. Collodion silks dye for the most part similarly to natural silk, while Pauly, Linkmayer, and Thiele silks and Viscose silk behave much more like cotton (see Chapter IV.).

The importance of artificial silk as a textile fibre is now recognized, but it is not widely known that the production already amounts to eight or nine tons a day and is rapidly increasing. The price is from one-third to one-half of that of mulberry silk, but will undoubtedly decrease. Fabrics entirely composed of artificial silk have only recently been successfully produced, but it has for some time been largely used as weft yarn, and still more largely in the production of plushes and trimmings.

CHAPTER IV

THE DYEING OF TEXTILE MATERIALS

DYEING processes vary in character according to the textile material operated upon and the nature and properties of the colour desired. Thus, *e.g.*, the production of scarlet shades on wool and on cotton requires entirely different processes, and the method used in producing a blue on wool with indigo is quite distinct in character from that required for dyeing logwood black.

Many (but by no means all) of the processes used in cotton dyeing are carried out without heat. Silk is usually dyed in lukewarm baths, while wool dyeing processes are usually conducted in boiling baths. Silk is almost invariably dyed in the hank or warp ; cotton in the form of hank, cop (or bobbins), warp, or cloth; while wool is dyed at all stages of manufacture, viz., as loose wool, sliver, hank, warp (occasionally), and in piece.

In all cases the materials are applied to the fibre in aqueous solution, from which they are withdrawn either partially or completely by simple absorption or by some chemical action of the fibre. So-called " dry dyeing " is a special process used by garment dyers in which benzine or other similar organic solvent is employed instead of water. The object of the process is to avoid the removal of the stiffening materials in the fabrics.

The number of distinct dyes now on the market is very large (upwards of 1,000), and with a few notable exceptions they are all chemically derived from coal tar products. Of the natural dyes still commercially used, indigo and logwood are much the most important; but a few others, such as cochineal, fustic, and orchil, find a more limited application.

In addition to the dyestuff itself, various chemical bodies are required in dyeing operations, some being essential constituents of the ultimate dyed colour (mordants), and others merely aiding the solution or fixation of the dye (assistants). In this short summary of dyeing operations no exhaustive treatment either of dyestuffs, mordants, or assistants is possible; but many examples of each will be incidentally mentioned.

Mordants.—This term is applied to substances which serve a double purpose, viz., they unite both with the fibre and with the colouring matter, and thus fix the latter on the fibre, and at the same time the new chemical compound formed by mordant and dyestuff has frequently an entirely different colour to that of the dyestuff itself, being in fact the real dye. The mordant is usually applied in a separate process before dyeing; but with an increasing number of dyes the mordanting comes last, and in some cases the mordant and dye are used together. The chemical nature of the mordant must depend upon that of the dyestuff. In wool dyeing certain metallic salts are largely used (bichromate of potash, alum, sulphates of copper and iron), whereas in cotton dyeing tannin matters are largely used as mordants for the basic dyes. In dyeing silk, dyestuffs which do not require mordants are chiefly employed.

Assistants.—A large variety of acids, alkalies, and salts are used for various purposes in dyeing. The acids chiefly employed are sulphuric (vitriol), acetic, and formic, all of which are used with acid dyes. Carbonate of soda (soda ash), caustic soda, and ammonia are the chief alkalies used, and sodium chloride (common salt), sodium sulphate (Glauber's salt), and many other salts are employed in various cases as additions to the dye-bath. The *rôle* of assistants is very varied and cannot be shortly summarized.

Dyestuffs.—In view of the enormous number of dyestuffs it is impossible to deal with them without adopting some method of classification, and grouping them according to method of application, the following may be distinguished :—Group (1) *Mordant dyes ;* (2) *Acid-mordant dyes ;* (3) *Acid dyes ;* (4) *Direct cotton dyes ;* (5) *Basic dyes ;* (6) *Dyes applied by special processes.*

(1) *Mordant dyes.*—With some important exceptions this group includes the "fast" dyes. Many of them are extremely resistant to the action of the light and to such processes as washing and milling (fulling). They must be used in conjunction with some metallic mordant, such as bichromate of potash or alum, and can be applied to all fibres, though they are chiefly used in wool dyeing.

Example.—Boil the wool for one to two hours in a solution of 3 per cent. bichromate of potash (calculated on the weight of the wool); wash and boil in a separate bath with the dyestuff.

Dyes of this group are not, as a rule, capable of producing bright colours, being chiefly used for blacks, navies, browns, olives, etc. The group includes the alizarin, anthracene, chrome and diamond dyes, logwood, madder, and many others.

(2) *Acid-mordant dyes.* — These dyestuffs have very similar properties to the last group, but are applicable only to wool. They are of increasing importance and include the acid-alizarin and acid-anthracene dyes, the cloth reds, etc. They are applied in an acid bath and subsequently treated with a metallic mordant.

(3) *Acid dyes* are largely used both in wool and silk dyeing, but are not applicable to cotton. They are not used in conjunction with mordants, but are dyed direct with the addition of 2 to 4 per cent. (sulphuric or formic) acid to the dye-bath. They vary considerably in regard to fastness to light, some being very fast and others comparatively fugitive; but as a class they are not so fast as groups (1) and (2). They are also more readily affected by washing and milling (fulling).

This group is a very numerous one and comprises a complete range of shades from the brightest primary colours to black.

(4) *The Direct Cotton dyes.*—These, as their name implies, have the special property of dyeing cotton without the aid of any mordant. Many of them are also used on wool, on which fibre they produce shades which are fast to milling. They are little used on silk. The method of application to any fibre is very simple, the only addition required being salt or Glauber's salt, with or without a little soda ash. By certain methods of after-treatment ("saddening" and "developing") some of these dyes are rendered much faster than when dyed in the direct manner. Practically the same complete range of shades is obtainable with the direct cotton colours as with the acid colours. As examples of this group may be

mentioned the benzo, diamine, mikado, titan, and hessian dyes.

(5) *The Basic Colours.*—This group is numerically smaller, and in range of colour less extensive, than the groups of mordant, acid, or direct cotton dyes. It includes, however, the most brilliant dyes known, rhodamine pink, auramine yellow, malachite green, methylene blue, magenta, and methyl violet being well-known examples. The basic dyes (with few exceptions) are not used on wool, since they are apt to rub (smear). On silk they are dyed direct, with the addition of a little soap, but cotton requires to be previously mordanted with tannic acid or some form of tannin matter. The most serious defect of this group of dyes, as a class, is that they are fugitive to light.

(6) *Dyes applied by special processes.*—**Indigo.**—This is the most important of all dyestuffs, still retaining its pre-eminence in spite of the large number of competitors and substitutes which have been introduced. It is used very largely both on wool and on cotton materials, but only rarely on silk. Being quite insoluble in water, a special method of application is necessary, and this is the same in principle whether used for wool or cotton. The process is based upon the fact that when indigo is acted upon by what are chemically known as reducing agents, the blue insoluble substance is converted into a colourless body which is soluble in alkalies. The necessary ingredients in an indigo vat are thus the indigo, some alkali (usually lime), and some reducing agent; and the various kinds of vats in use differ chiefly in the nature of the latter. In the "woad vat," which is largely used in the dyeing of wool materials, the reduction is due to a specific bacterium which

is introduced by the woad; certain other substances, such as bran, madder, molasses, etc., being also necessary to supply foodstuff for the bacteria. This vat is used warm, and when once "set" may remain in use for several months, being systematically replenished with indigo, etc. The "hydrosulphite vat" contains indigo, lime, and hydrosulphite of soda, and may be used warm (for wool) or cold (for cotton). The "copperas vat" is made up with indigo, lime, and copperas (ferrous sulphate) and is used for cotton.

The process of dyeing in the indigo vat consists in saturating the material with the vat liquor and, after squeezing out the excess, exposing the material to the air, when the colourless reduced indigo becomes rapidly re-oxidized on the fibre into the original blue indigo.

Synthetic or "artificial" indigo, being chemically identical with natural indigo, is applied in the same manner. There are now several distinct but closely associated synthetical dyestuffs in addition to the true "artificial indigo." They are all dyed in similar manner, but yield a variety of blue, purple, and red shades.

In dyeing dark indigo blues on wool materials it is usual to "bottom" the wool with some other (cheaper) colouring matter before dyeing in the vat. Frequently also the indigo is "filled up" or "topped" after vatting, either with the same object or in order to impart a "bloom" to the colour. Heavy shades of pure vat blue are rarely met with.

Well-dyed indigo vat blue produces extremely fast shades on wool. It retains its fine bloom and brilliancy almost indefinitely, and washing does not affect it in the least. It also withstands sea air, but of course, if "bottomed" or "topped," the associated dyestuffs may be affected. The one defect of vat blue is that the colour "rubs off." This cannot be entirely prevented, but the more skilfully the dyeing process is carried out the less noticeable is the defect. Indigo blue is less fast to light on cotton than on wool.

Aniline black is another dye which requires a special method of application, being of such an insoluble and chemically resistant nature that the only practicable method of using it is to actually produce it on the fibre by suitable chemical reactions. It is the most brilliant, dense, and permanent black which can be produced on cotton, and is dyed, chiefly on cotton yarn, in large amount. It is little used on wool or silk. Aniline black is obtained by the oxidation of aniline, a basic substance ($C_6H_5 \cdot NH_2$) produced from the coal tar hydrocarbon benzene (C_6H_6). A bath is prepared containing aniline oil, hydrochloric (or other) acid, and some suitable oxidizing agent. The cotton is saturated with this liquor and then "aged" (hung in a warm, moist atmosphere) or otherwise subjected to oxidizing conditions.

As in the case of indigo, aniline black is apt to "rub off" if badly dyed. Another defect which can be avoided by skilful dyeing (but only in this manner) is tendering of the fibre. This may be due either to undue acidity of the bath or to oxidation of the fibre.

Aniline black is a very "fast" colour. It withstands "cross-dyeing" perfectly and is also fast to light, washing, milling, etc. If dyed in a special manner it is unaffected by the very severe processes involved in cotton bleaching

("bleaching black"). It is most readily attacked by reducing agents, such as sulphurous acid, which turn it green, and long exposure to the atmosphere of a room where gas is burnt may thus cause "greening."

The Sulphide dyes have only within the last few years attained to the great importance which they can now claim. The group includes many blacks, blues, dark greens, browns, and yellows, but at present a good red of this series has not been put on the market. With the exception of aniline black, they are now the chief dyes used to produce fast colours on cotton. They are most conveniently dyed on warps, but are also used on pieces and hanks. The general method of application is to dissolve the dyes (which are insoluble in water) in a solution of sodium sulphide, some sodium carbonate and Glauber's salt being also frequently used in the dye-bath. The baths are used warm, and dyeing must take place below the surface of the liquor.

A very serious defect of the sulphide dyes is that cotton dyed with them is liable to become tender (rotten) on storing. This is due to the slow development of sulphuric acid by oxidation of the sulphur associated with the dyestuff. The defect is most liable to occur in stoved union goods. The tendering may be prevented by any treatment which leaves the goods in a permanently alkaline condition.

The sulphide dyes are fast to "cross-dyeing" and to alkalies and milling. Vidal black was the first important dye of this series, and as further examples may be mentioned the "immedial," "katigen," "kryogen," "cross-dye," "sulphur," "pyrogene," "thiogene," "thionol," "thional," and "pyrol" blacks and colours.

The Ingrain dyes.—The term "ingrain" as applied to dyes is a very old one. It is now used to designate a certain series of cotton dyes—chiefly reds—which are produced on the fibre.

Para (or paranitraniline) red is produced on yarn, warps or pieces, by first impregnating the cotton with a colourless solution of naphthol, drying and "developing" by passing through a solution of paranitraniline treated with nitrous acid. The red is produced instantaneously. It is a very brilliant and fairly fast colour and is largely used as a substitute for Turkey red.

Primuline red is a somewhat similar dye, but is produced in the reverse way. The cotton in this case is dyed with primuline (a direct yellow dye), then treated with nitrous acid, and the yellow colour "developed" into a red by treatment with naphthol.

There are also black, blue, purple, brown, and yellow dyes belonging to this series, but they are not much used.

Turkey red has somewhat of the same pre-eminence as a red on cotton as indigo vat blue has on wool. Its production is a special branch of dyeing, carried on in special works in a few districts (Manchester and Glasgow). It really belongs to the class of mordant dyes, but is produced in such a special manner that it may more fittingly be mentioned in the section of "special dyes." The cotton, in yarn or piece goods form, is first treated with olive or castor oil, then mordanted with alumina, and finally dyed with alizarin. Many subsidiary processes are necessary in order to thoroughly fix the colour and develop its full brilliancy. Well dyed Turkey red is a bright scarlet colour and is very fast to all influences.

Water used in Dyeing.

In no industry is a plentiful supply of pure soft water of more importance than in dyeing, the use of unsuitable water resulting not only in considerable waste of material, but also in bad work. Perfectly pure water is, however, never available in sufficient quantity, since it is not found in natural sources, and thus the difference in the quality of various water supplies is largely one of degree. The chief impurities naturally present in water are the carbonates, sulphates, and chlorides of lime and magnesium, which impart to the water the property of forming a curdy scum with soap, usually termed "hardness." A "soft" water is most suitable for dyeing, but "permanent hardness," which is due to sulphates and chlorides, is much less harmful in dyeing than the "temporary hardness" caused by carbonates. In wool scouring or any other process in which soap is used, both kinds of hardness are equally injurious, and the lime-soap curd which is produced adheres to the fibre and causes much subsequent trouble and damage in dyeing and finishing operations. The wastefulness of hard water is well illustrated by the fact that 1,000 gallons of water of only 10° hardness will destroy and render not only useless, but dangerous, 15 to 20 lbs. of ordinary soap.

Iron is a not infrequent impurity in water supplies, particularly such as are obtained from coal measures, and water containing iron is totally unfit for use in a dye-house, since iron has a dulling and darkening effect on many dyes.

Water of less than 5° of hardness may be considered as a good quality for dyeing, particularly if the hardness is mainly "permanent." If the only available supply exceeds 8° or 10° in hardness it should be "softened" by chemical treatment before use. This can usually be done at a cost not exceeding 2*d.* to 3*d.* per 1,000 gallons.

The organic impurities in water have usually little effect on dyeing processes, unless the water is contaminated with the refuse from other works.

Reference may also be made to the desirability of using soft water for steam-raising in order to prevent the production of "boiler scale."

Interdependence of Processes.

In order to produce the best possible result it is not only necessary that the raw material of which a textile fabric is composed should be of good quality, but that all the various operations involved in its manufacture should be carried out with proper skill and care and with a due regard to each other. Thus the carder or comber, the spinner, the manufacturer, the dyer, and the finisher should each work with a sufficient knowledge of the bearing of his particular operation on the other processes of manufacture.

The high degree of specialization in the textile trade in some districts renders co-operation between the various branches specially necessary and at the same time specially difficult. This frequently causes great trouble to the dyer who may be merely instructed to match a given shade without being given information as to the processes which the material will afterwards undergo. This lack of information makes it impossible for him to select the most suitable method of dyeing to fit the conditions, and an element of risk is introduced which is entirely unnecessary and could be eliminated.

Processes Preliminary to Dyeing.

In order that bright, clear, and fast colours may be produced in dyeing it is necessary that the textile material, whatever its character, should be thoroughly cleansed from all grease, dirt, and other impurities before the dyeing process is carried out. The treatment requisite for this varies. In the case of wool the cleansing process is known as "scouring," while the "bleaching" operation has a very similar object in the case of cotton, and silk is "boiled-off."

Wool Scouring.—Raw wool is naturally covered with a preservative greasy matter, termed "yolk," to which also adheres a considerable quantity of sand, dirt, and other foreign matter; the amount of pure wool varying from 30 to 80 per cent. of the weight of raw wool. The "scouring" or "washing" of raw wool has the object of removing these impurities, and the process is carried out by treating the wool with warm (not hot) solutions of soap with the addition of ammonia or carbonate of soda. This emulsifies the yolk, the sand, etc., being then readily washed away. Scoured wool is usually oiled before carding or combing, and this oil, together with dirt, etc., contracted during the various stages of manufacture, must be removed by a second scouring operation before yarn or piece dyeing.

Efficient scouring has a great influence on the dyer's work and on the final appearance and quality of the pieces. If wool is not properly scoured the colour is apt to be dull and to "rub off," or may be uneven or show dark or light spots. On the other hand, if the scouring is too severe the fibre has a diminished lustre, a yellowish colour, and a harsh feel.

"Boiling-off" Silk.—This operation consists in treating the raw silk in (at least) two successive soap baths; the first one at a medium temperature, and the second being used boiling. It has the object of developing the lustre and soft feel of the silk by removing the "silk gum" with which the fibre is naturally encrusted. Silk may, however, be dyed "in the gum" or only partially boiled-off.

Cotton Bleaching.—The amount of impurity naturally present in raw cotton is small, but the raw fibre is not in a suitable state to be dyed, as the "cotton wax" present renders the fibre very non-absorbent. "Bleaching for white" is carried out by treating the raw cotton successively with boiling lime-water, boiling caustic soda, and cold dilute bleaching powder solution, with intermediate treatments with cold dilute acid and many washings. Goods which are to be dyed need not be treated with bleaching powder, excepting in the case of pale and delicate shades, but the earlier operations are always necessary.

Wool Dyeing Processes.

When a fabric entirely composed of wool is dyed in the piece it is obvious that a plain colour only can be obtained. If the design of the cloth includes differently coloured threads, the wool must be dyed before weaving, *e.g.*, as yarn; while certain effects (mixtures, etc.) can only be obtained by spinning together differently coloured *fibres* into the same yarn.

This last-mentioned case necessitates the dyeing of the wool in the form of sliver or of loose wool.

The form in which the wool is dyed (whether as loose wool, sliver, yarn, or cloth) greatly influences the choice of dyes to be used. Some dyes produce good, fast shades, but tend to dye unevenly; and such may be used for loose wool where any irregularity disappears in carding, spinning, etc., but are inadmissible in piece dyeing where absolute evenness of shade is essential. On the other hand, the cloth is not scoured after piece dyeing, and, therefore, dyes may be used which would be injured by the scouring process. Loose wool, however, must be dyed with dyes which will withstand scouring.

Dyeing of Loose Wool.—Loose wool may be dyed in square wood or stone vats heated by steam pipes, or in circular iron vats heated externally by fire. The wool must be stirred occasionally with poles to equalize the action of the dye liquor, but since this tends to felt it, discretion is necessary. Loose wool may also be dyed by packing it into perforated receptacles which are either moved about in the hot liquor or through which the liquor is circulated by means of a pump. These newer mechanical processes are now largely used, as they leave the fibre in a free and open condition.

Slubbing (Sliver).—After carding or combing, the thin film of wool fibre is "condensed" into a ribbon of sliver, and may be dyed in this condition either in the form of hanks or wound into balls (tops). At this stage of yarn production the fibres have little coherence, and the hanks or tops require careful treatment. Tops are dyed in an apparatus in which mechanical circulation of the liquor is provided for, but hanks of slubbing may be treated in the same way as yarn.

Yarn Dyeing.—Yarn may be dyed by hand or by machine. In the hand method the hanks are hung on sticks which rest across oblong vats containing the dye liquor. The hanks are systematically moved about in the liquor and pulled over the sticks. Dyeing machines are also largely employed, the hanks being mechanically moved about in the liquor, or the liquor mechanically circulated through the hanks.

Piece Dyeing.—In this case revolving rollers cause the pieces to travel through or move about in the dye liquors. The pieces run either at full breadth (dyeing in open width) or gathered together as a thick strand (dyeing in rope form), according to the nature of the material.

" **Woaded Colours.**"—This term implies that the wool has been dyed in the indigo vat. A woaded blue should be dyed with indigo alone, but in the case of woaded blacks, greens, and browns the indigo is necessarily combined with other dyes. The term has lost most of its significance since the introduction of the alizarin and other fast dyes.

Blacks on Wool.—*Logwood blacks* are very usual. The wool is mordanted with bichromate of potash and dyed with logwood in a separate bath, a small amount of yellow dye being used to neutralize the blue of the logwood. Beautiful blacks are thus produced, but they have the great defect of turning greenish during long wear of the material. *Alizarin blacks* are obtained by dyeing with a mixture of alizarin dyes or chrome mordant. They do not "green" in wear. Both logwood and alizarin blacks are fast to milling and scouring. *Acid-mordant blacks* (anthracene acid black, diamond black, etc.) are dyed with the addition of acid and are afterwards chromed. They are fast to all influences. *Acid blacks,* such as naphthylamine and Victoria black, are dyed with the addition of sulphuric acid. They are fairly fast to light, but are not suitable for goods which are to be heavily milled.

Dark Blues, Greens, and Browns on Wool.—These may be obtained by using dyes of any of the various groups mentioned under blacks.

Bright Blues, Greens, Reds, Yellows, and Fancy Colours are chiefly dyed with acid dyes.

Cotton Dyeing Processes.

Cotton is mainly dyed in the form of hanks of yarn and warps, less usually as piece goods. The dyeing of cotton on spools or cops is now rapidly extending, two types of machines being in use. In one type the cops are placed on perforated or grooved skewers and the dye liquor forced through by a pump (skewer dyeing). In the other type the cops are closely packed in a tank, compressed, and the liquor forced completely through the whole mass (pack dyeing). In warp dyeing a number of warps pass side by side continuously through a series of vats containing the necessary mordanting or dyeing liquors.

Occasionally weft yarn is dyed in lengths, as in the case of warps the yarn being subsequently rewound on to weft bobbins. This cannot be recommended, as it is not unusual for warps to be somewhat darker in colour at one end than at the other, and when rewound this may produce a stripy effect in the piece. Cotton in the form of piece goods is dyed in the open width or rope form, usually the former.

The dyeing properties of cotton are quite different from those of wool, and therefore the processes and materials used in the two cases are to a large extent different. Cotton has little affinity for metallic mordants or for dyes belonging to the mordant, acid, or basic groups. It has, however, a definite affinity for tannic acid and for colouring matters belonging to the class known as "direct cotton dyes." Cotton is dyed largely with this group, but the dyed colours, though bright and in some cases fast to light, are not fast to washing with soap. Many of these direct dyes are also affected by acids. A considerable number (but not all) of the direct dyes may be rendered satisfactorily fast by an after-treatment with metallic salts or by "diazotizing and developing," this applying principally to dark browns, blues, and blacks.

Fast Blacks on Cotton.—There are two ways of producing exceedingly fast blacks on cotton, viz., by dyeing it an "aniline black" or with a "sulphide black." Both are largely used, the latter chiefly for the warps of pieces which are afterwards "cross-dyed" (see Union Dyeing). Aniline black is somewhat more costly than a black produced by sulphide dyes, but is considered superior in body, tone, and brilliancy.

Fast Colours on Cotton.—Dark blues, browns, and greens, and a variety of greys, buffs, and pale fancy shades, are also obtained by means of sulphide dyes, but there is as yet no bright red belonging to this group. The fastest bright red on cotton is Turkey red, which is obtained by oiling the cotton, then mordanting with alum and dyeing with alizarin. Para red (paranitraniline red) is also very bright and fairly fast. It is produced by saturating the cotton with an alkaline solution of beta-naphthol, then drying and passing into a diazotized solution of paranitraniline. In this case, as in aniline black, the dye is actually formed on the fibre.

Cotton is also largely dyed with indigo in a similar manner to wool, but the vat is used cold and a chemical reducing agent is used (ferrous sulphate or sodium hydrosulphite).

Fast browns, drabs, etc., are largely dyed with catechu.

Basic Colours on Cotton.—These dyes are fixed on cotton by mordanting the fibre in a solution of some tannin matter (sumach or myrabolans), then "fixing" in a solution of some suitable metallic salt (tartar emetic or stannic chloride), and finally dyeing. The basic colours comprise a series of extremely bright reds, yellows, blues, greens, and violets, as well as many duller colours. As a class they are fugitive to light, but there are exceptions to this.

Dyeing of Mercerized Cotton.—The general dyeing properties of mercerized cotton are similar to those of ordinary cotton, but the affinity of mercerized cotton for the direct dyes, the sulphide dyes, indigo, and para red is much increased, and the shades obtained by using a certain strength of dye solution are much deeper and richer. On the other hand, mercerized cotton dyes less easily than ordinary cotton with basic colours. If the cotton has not been evenly mercerized it is impossible to produce level shades in dyeing.

Union Dyeing Processes.

Union goods composed of cotton and wool require special methods of dyeing. A common process is to dye the cotton in the warp, the dyed cotton being then woven with undyed wool weft. The pieces are then "cross-dyed" with acid dyes which colour the wool only. The cotton warp must, of course, be dyed with colouring matters (such as the sulphide dyes) which are unaffected by boiling dilute acid. Another process largely made use of in low-class unions is to first dye the wool in the piece with acid dyes, and then to "fill up" the cotton by mordanting with tannin and dyeing with a basic colour, the whole of the cotton treatment being conducted in the cold in order to avoid staining the wool. When a uniform shade is required on both fibres the union material may be dyed with direct cotton dyes which colour both wool and cotton.

Silk Dyeing Processes.

Silk is always dyed in hank form; and closely associated with the dyeing is the so-called weighting process. Silk has the peculiar property of absorbing certain metallic salts and other bodies (tannin, glucose, etc.) to an enormous extent without injury to its lustre, and by suitable treatment it can in this manner be weighted to such a degree that 1 lb. of raw silk produces 2 to 3 lbs. of dyed and weighted silk. This weighting process is very general, 25 to 50 per cent. of added weight being usual. The practice is, however, greatly to be deprecated, as it injures the wearing properties of the fibre. Pure silk has excellent lasting properties, while weighted silk will gradually become rotten merely by storage.

Wild Silk (Tussur Silk) is very difficult to dye, and a good black on tussur can only be produced by a few dyers. It dyes readily with basic dyes and fairly well with acid dyes.

Reeled Silk (Mulberry Silk) has, generally speaking, similar dyeing properties to wool. It is chiefly dyed with acid or basic dyes without mordant, and there is no difficulty in obtaining a variety of brilliant colours on this fibre. In boiling baths wool dyes deeper colours than silk, but at low temperatures the relative affinity is reversed, and an intermediate temperature may therefore be usually found (varying with each dye) at which the two fibres dye equally.

Silk is rarely dyed with indigo or with mordant dyes, excepting in the case of blacks.

The dyeing of black silk constitutes a special branch of the dyeing trade and needs considerable experience.

The Dyeing of Artificial Silk.

The artificial silks, being essentially constituted of cellulose, have dyeing properties similar to those of cotton, but the various kinds of artificial silk differ considerably in this respect. On account of the low tensile strength of many artificial silks when wetted, great care is required in dyeing these fibres. They are best dyed at a comparatively low temperature with basic dyes (without mordant) or with direct cotton dyes.

Colour Matching.

In dyeing any material to match a given shade great care is required to ensure that the two will match under all conditions. If the "matching off" is done by gaslight the two may be quite dissimilar when viewed by daylight. This well-known fact is due to the different optical properties of the various dyes. Two blue dyes, for example, may appear identical in hue, but when each is mixed with the same amount of the same yellow dye the resulting greens may differ considerably. If examined spectroscopically the two blue dyes will be found to have different absorption spectra, and this is the fundamental cause of their different behaviour in mixtures or when viewed in different lights. The special optical properties of the various dyestuffs are thus of great importance in "matching off" or dyeing to shade. Equally important is the character of the light by which the colours are viewed, and the light reflected from a white cloud into a window with a north aspect is considered the most suitable. The near presence of a red brick wall or any other coloured surface is quite sufficient to disturb an accurate match; direct sunlight or a deep blue sky being also fatal in matching certain greys, drabs, etc. The use of a perfectly uniform light of the same character as a north daylight thus greatly simplifies the accurate matching of colours.[1] The difficulties caused by the different absorption spectra of dyes can only be eliminated by a spectroscopical examination of each, or by using in bulk dyeing the same dyestuffs as were employed in dyeing the pattern which is being matched.

Fastness Properties of Dyes.

That some colours are "fast" and others are "fugitive" to light is a matter of as common knowledge as that some will withstand washing much better than others. These

[1] Such a light is to be found in the "Dalite" lamp of Dufton & Gardner.

differences are inherent to the nature of the dyes and are not (usually) due to defects in the methods of application. Thus the proper selection of dyes is of the greatest importance to the production of satisfactory results. It is obvious, for example, that material which is to be used for stuff curtains should be dyed with dyestuffs which have good fastness to light, fastness to washing being a secondary consideration; on the other hand, yarn which is to be used for making socks or underwear must be dyed with washing-fast colours, the effect of exposure to light being here less important. Again, in the case of woollen goods which are heavily fulled (milled), if yarn dyed the colours must be able to withstand that somewhat severe operation, and cotton warps which are made up with wool weft and then "piece dyed" must be dyed with colours which will not be affected by boiling dilute acid. Each case must thus be specially considered from this point of view as well as regards the question of producing the desired colour.

Tables have been drawn up showing the fastness properties of the various dyestuffs as regards light, milling, scouring, cross-dyeing, rubbing, washing, steaming, hot-pressing, etc., but it is impossible to usefully summarize such lists, and on this point manuals of dyeing must be consulted.

CHAPTER V

THE PRINCIPLES OF SPINNING

It may seem somewhat out of order not to give priority to preparing and combing. But the end must justify the means.

Just as weaving naturally developed before spinning, so did spinning naturally develop before the many interesting and ingenious processes which to-day precede the spinning operation, rendering this operation much easier of accomplishment and vastly more perfect in its results than was the case in the olden days. In dealing with spinning prior to dealing with the preparatory processes, then, we are but following the natural evolution of the processes; and in so doing we have the great gain of knowing exactly what is required—what are the necessary conditions for a "good spin"—and can therefore more perfectly realize the *raison d'être* of the various processes to be subsequently dealt with and described. It might be contended that, following out this principle, weaving should be first dealt with. There is, however, a natural limit beyond which we may not pass without loss rather than gain.

Spinning may be defined as the art of throwing a number of more or less short fibres together in such a way that, being drawn out to form a comparatively fine filament, they grip one another by reason of the twist inserted, and thus form a comparatively firm, strong thread. Thus spinning primarily consists of the two operations of drawing-out, or "drafting," and twisting. It should at once be noted that this operation is entirely distinct from silk "throwing," which simply consists of reeling the continuous thread of from 400 to 1,600 yards forming the silkworm's cocoon, and throwing or twisting it with one or more threads of similar character to form a firm, stronger thread.

Long Fibre Spinning.—Very brief study of the art of spinning will demonstrate the comparative ease with which long fibres, such as flax, hemp, long wool, etc., may be spun into yarn. Given length and all else is simple. The early recognition of this fact would naturally lead to the preparation of flax, hemp, wool, etc., bundles or slivers so arranged that a continuous band of more or less parallel fibres might be passed into the spinning machine to be given the necessary twist and so be converted into thread. Thus the simplest and consequently earliest form of spinning would consist of some arrangement whereby, after having deftly formed a small band or sliver of fibres by the hand, twist might be expeditiously inserted. Such was "distaff spinning," the process being exactly that just described, with very few conveniences for facilitating speed of production. How long the art of spinning rested in this very inefficient state we do not know, but probably for hundreds of years. Amid the ingenuity with which we of the twentieth century are surrounded from the cradle we cannot well gauge the mental effort necessary to evolve the idea of a continuous spinning process in place of the slow intermittent process. But it came at last, and the flax wheel was evolved. In this the deftly extended sliver of right thickness and regularity was fed continuously by hand into a flyer revolved by means of a foot-treadle, which, in conjunction with the bobbin upon which the yarn was to be

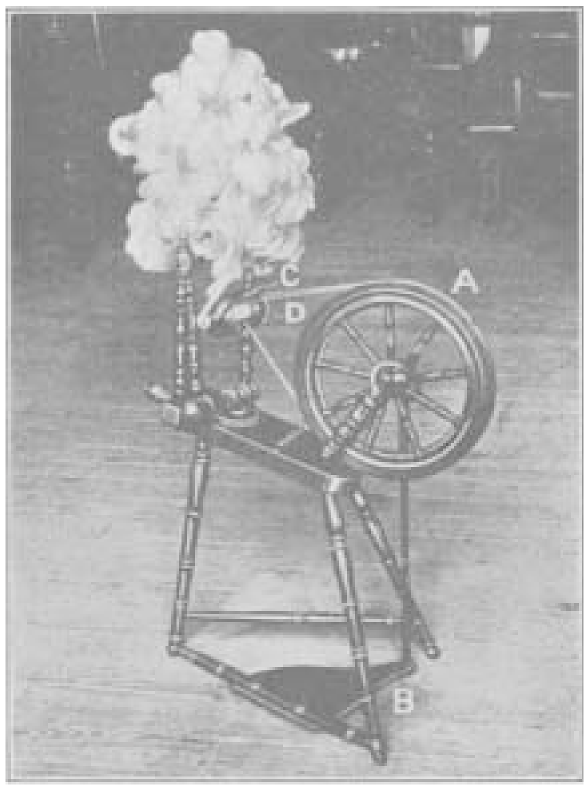


FIG. 9.—Double-grooved Wheel A; Pedal B; Flyer C; Bobbin D.

wound, both twisted it and wound it neatly upon this bobbin. No doubt the difficulty in evolving this arrangement was due to the fact that it is impossible to effect the continuous feeding in and twisting of a sliver without some means *of winding on to the twisting spindle* the thread so formed, or, on the other hand, of winding the yarn continuously on to a bobbin without some arrangement for the continuous twisting of the same. The bobbin and flyer — practically the fundamental principle of all continuous spinning frames — is really a most ingenious arrangement, and it would not be surprising to find that short fibre spinning on the ordinary simple-spindle hand wheel really preceded this invention. The principle of long fibre spinning is infinitely simpler than the principle of short fibre spinning, but the necessary hand machine for continuous long fibre spinning is much more subtle and complicated than that required for short fibre spinning.

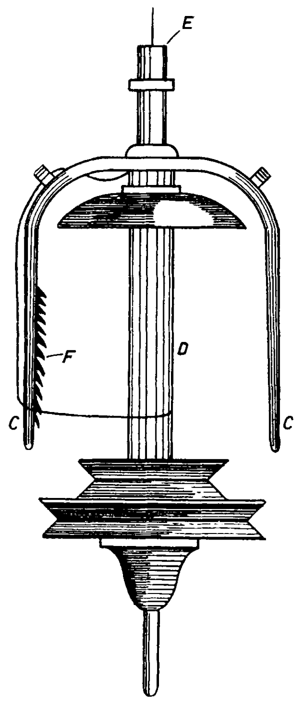
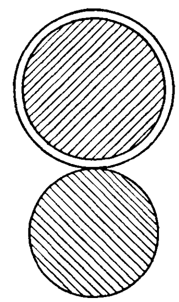


FIG. 9A.—Diagram of Flyer and Bobbin arrangement on the ordinary Flax Wheel.

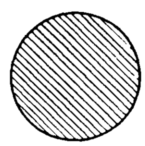
The "flax wheel" (Figs. 9 and 9a) consists of a double-grooved wheel (*A*, *A*) worked by a foot-pedal (*B*) round which two bands pass, one to the grooved flange on the spindle and flyer (*C*), and the other to the grooved flange of the bobbin (*D*), so that as the wheel is revolved by the foot-pedal it in turn revolves both flyer and bobbin. As the bobbin has a smaller grooved flange than the grooved flange or driving wheel of the spindle, it therefore goes somewhat quicker than the spindle and flyer. The bundle of flax or wool is conveniently placed above the flyer and bobbin, and a convenient or correct thickness of sliver is made up from it and passed through the eye (*E*) of the flyer, round the wing and over a notch or wire (*F*) which directs the thread on to the bobbin. Upon the wheel being revolved, twist is put into the sliver in proportion to the length of sliver delivered to a given number of revolutions of the flyer; and the yarn is wound up in proportion as the bobbin gains upon the flyer. *If no sliver were delivered and the wheel revolved, twist only would be put into the sliver. If all the sliver required were delivered, the bobbin held fast, and the flyer rotated, yarn would simply be wound upon the bobbin. The actual spinning operation comes in between these two extremes.*

The idea of increased production by a continuous employment of both hands and feet would naturally lead to further attempts at increasing production. It would at once be realized that two main developments were necessary, viz., a more speedy means of preparing the slivers to be spun and a greater number of spindles to be worked by hand. This latter idea probably germinated first, as we have fairly early records of a double-spindle flax wheel. Few people, however, would be skilful enough to work this with the condition of feeding the spindles with unprepared slivers; hence little advance was made. The development of drafting rollers by Lewis Paul eventually entirely removed this limitation. How crude the ideas of the eighteenth century were we can only realize by again reverting to the fact that it was supposed that, as with metals, one pair of

Double Rollers.



Single Roller.



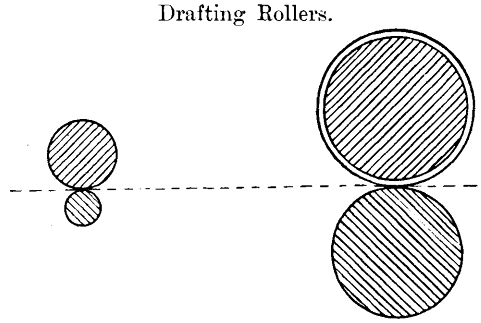
Points for Consideration.

(1) Size.
(2) Material (foundation and covering).
(3) Fluting.

Points for Consideration.

(1) Sizes and Relative Sizes.
(2) Material (foundations and coverings).
(3) Fluting.
(4) Method of Weighting.
(5) Method of Driving.

Drafting Rollers.



Points for Consideration.

(1) Relative Sizes of Back and Front Rollers.
(2) Materials (foundations and coverings).
(3) Flutings.
(4) Method of Weighting and Influence on Power Consumed.
(5) Distance apart.
(6) Method of Driving.
(7) Relative Speeds of the two pairs of Rollers.
(8) Inclination of Rollers.
(9) Supports (carriers) between the two pairs of Rollers.

FIG. 10.

rollers would be sufficient to effect the necessary drafting. The development, however, was made, and its utility gradually realized to the full. We can well imagine the interest that Lewis Paul, Arkwright, and others would have in experimenting with rollers and noting the conditions under which they might best be employed for drafting, and it is something to their credit to be able to say that these early workers practically developed in their machines principles and methods which we have not been able to improve upon in principle to any great extent.

A few words on roller-draft will demonstrate the principles employed. Some of the factors of roller-draft are illustrated in Fig. 10. These factors seem comparatively simple, but they are not really so. Take for example the first factor—size of rollers. At least three varying factors are here involved, viz., length of fibre to be drawn, size of roller to give the best conditions of wearing surface, and exact condition of gripping of the fibre desired. Thus in the spinning of short fibres such as cotton the diameter of the rollers should be approximately the length of the fibre (Fig. 11), while in long wool fibres (Fig. 12) there is little relationship of the diameters of the rollers to the length of the fibres, but on the other hand these diameters are decided with reference to grip on the fibre and surface wearing quality. For a 1½-inch staple cotton a 1⅝-inch diameter pair of rollers is usually employed, while for an 8-inch wool yarn a 1¼-inch diameter bottom back roller and a 5-inch top front roller bearing upon a 4-inch diameter bottom roller are usually employed. Here again it will be noted there is an interesting question of "grip." With small rollers the gripping surface will be

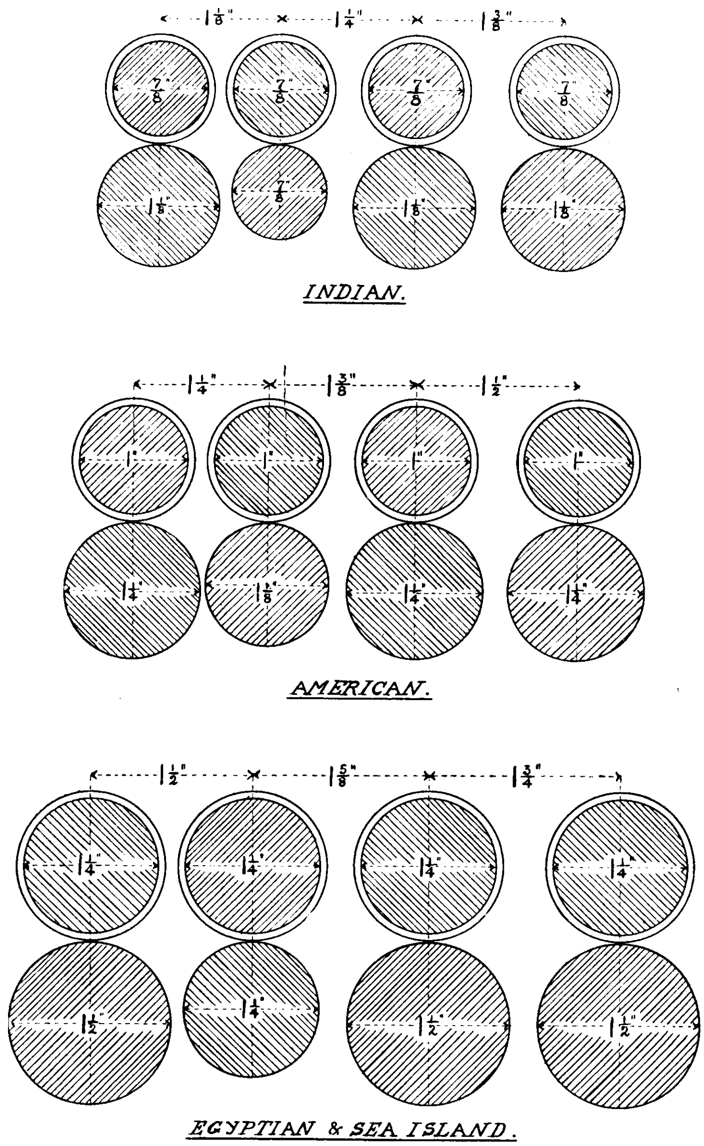


FIG. 11.—Drafting Rollers for Various Lengths of Staples of Cotton.

small, and consequently there is a tendency to "cut." With larger rollers the gripping surface will be much larger, and consequently a firmer grip obtained with less fear of cutting. It will further be evident that it may be very desirable to leave some rollers bare and to clothe other rollers with leather,

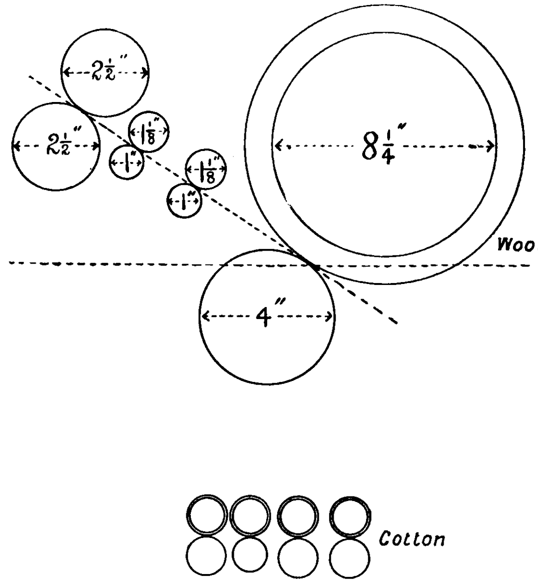


FIG. 12.—Illustrating the Relative Sizes of Wool and Cotton Drafting Rollers.

etc. Now steel rollers may be clothed with leather in two ways, first by running a continuous leather apron between them, or by actually clothing one of the rollers with leather upon a felt or other foundation. Corresponding fluting necessitating rollers of equal size renders the leather apron idea more economical, and in fact necessary, in certain wool boxes, while in other boxes and frames a large 6-inch roller, leather clothed, fulfils the requirements of the case both from the efficiency and wearing surface or cost points of view.

Again the questions of double metal nip, metal and leather or cloth nip, or double leather or cloth nip are worthy of the most careful consideration. The rollers in a wash-bowl are clothed with wool and wool works wool. But in the case of cotton, leather against metal is applied. Here is a most interesting problem.

Then with reference to the distance apart of the two pairs of drafting rollers most interesting points are to be studied. Take, for instance, an 8-inch wool fibre. If this is passed through rollers 6 inches apart—the front rollers revolving faster than the back rollers—it will probably be broken. If the rollers are exactly 8 inches apart the back pair will give it up just as the front pair take it; while if the rollers are, say, 10 inches apart the fibre must freely ride upon its neighbours for 2 inches after leaving the back rollers before the front rollers take it. The middle condition is the correct one, all cotton drawing rollers being very accurately set to control the fibre as positively as possible without breaking it. But in a well-prepared wool combed sliver or "top" the fibres may vary from 4 inches to 10 inches or 12 inches, while there is also the question of twist in the sliver to be taken into account, twist enabling the drawer, as it were, to work the fibre with the fibre. If it were not for the twist factor and the natural cohesion of wool—save when affected with electricity—wool "top" drawing would be a much more difficult process than it actually is; in fact it would be necessary to work to the shortest fibre, breaking all the longer fibres, thus consuming power and destroying the quality of length so often required in worsted yarns.

An economical question is involved in the speed at which

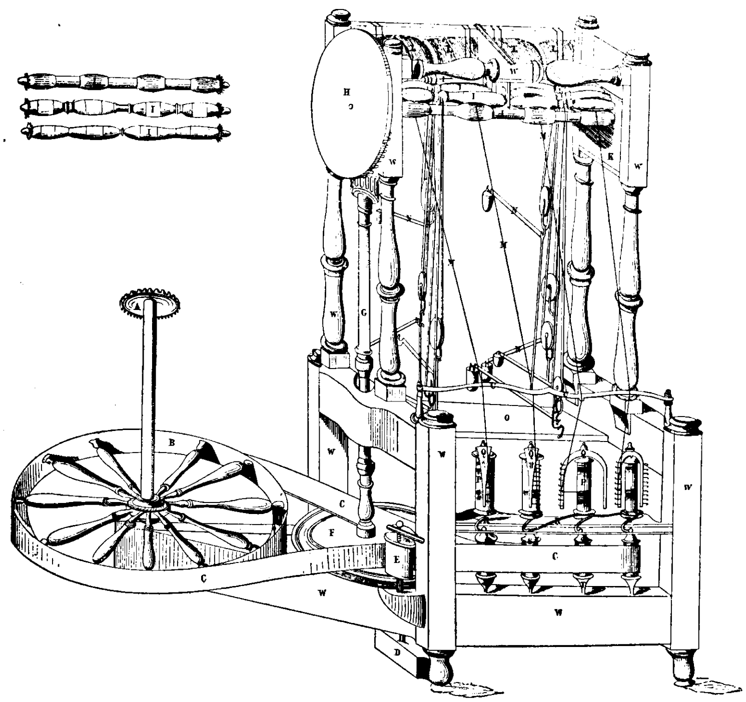


FIG. 13.—Arkwright's Water-frame.

drafting rollers can be run. Alone, *i.e.*, without any spindle attachment to twist and wind up the sliver drafted, the limit would depend in part on the nature of the fibre. Cotton, for example, can be drafted quickly when the fibres are once started sliding upon one another, *but not* *before;* and again, air blasts and air friction so affect cotton that they must be very carefully taken into account. There is also a mechanical problem of wear and tear involved, so that altogether this also is really a most interesting, if involved, question.

It will now be realized that given drawing rollers, the flyer and bobbin mechanism, and a reasonably steady driving power, the factors for a successful automatic machine are present. Richard Arkwright was the first to recognize this, and his water-frame was the first machine of any moment effecting the spinning of yarns automatically.

The illustration of Arkwright's "water-frame" (Fig. 13) will explain the general arrangement. The only new problem involved is the relationship of front rollers and spindle. The possible positions of spindle to front rollers are illustrated in Fig. 14, but it should be further remarked that the solution of this problem will in part depend upon the inclination of the drawing rollers. It should further be remarked that probably "gravity" cannot be entirely ignored. So far as relative position goes the relationships shown at *A* and *E* are identical, but it will be realized at once that the force of gravity may make a material difference in the "spin," especially if the sliver is heavy and has not marked adhesive qualities. The main point to note, however, is that of limitation of the twist. Anything touching the yarn between the top of spindle and the nip of the front rollers will limit the twist to below this point. Thus in some cases it may be desirable to have such a relative position of spindles and front rollers that the twist runs right up to the nip of the rollers; in other cases it may be desirable to lay the sliver on the bottom front roller; and in other cases it may actually be neces-

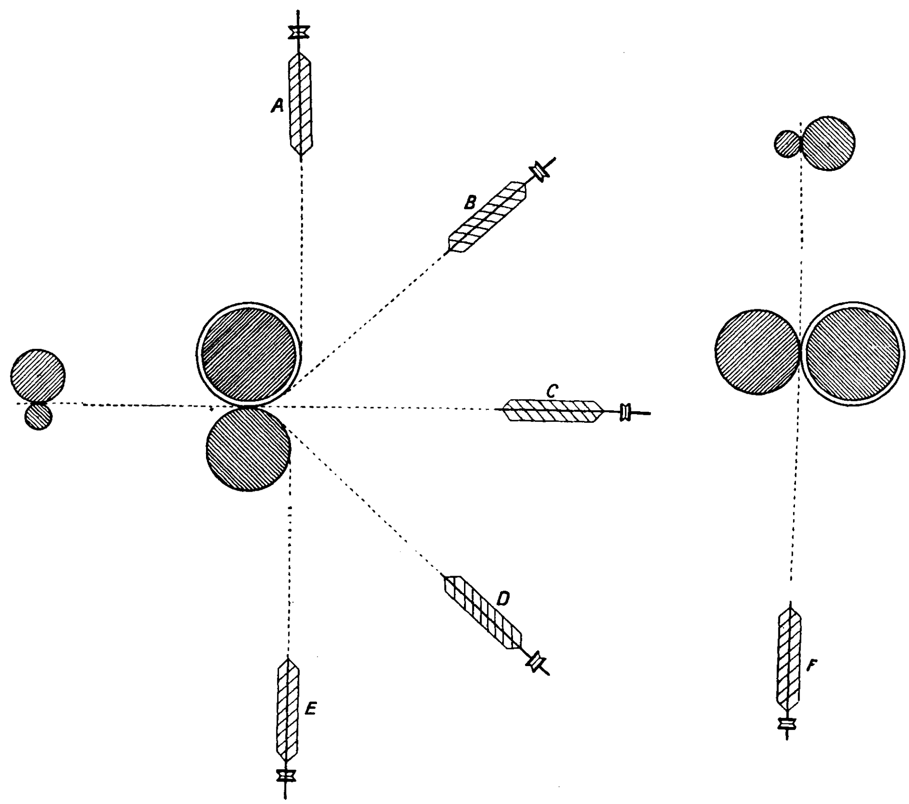


FIG. 14.—Possible position of Spindle in relationship to Drafting Rollers.

sary to introduce what is known as a trap-board with the threefold object of carrying the yarn straight from the nip of the rollers, of centring the yarn above the spindle—as in the cap frame—and of holding the twist in the yarn

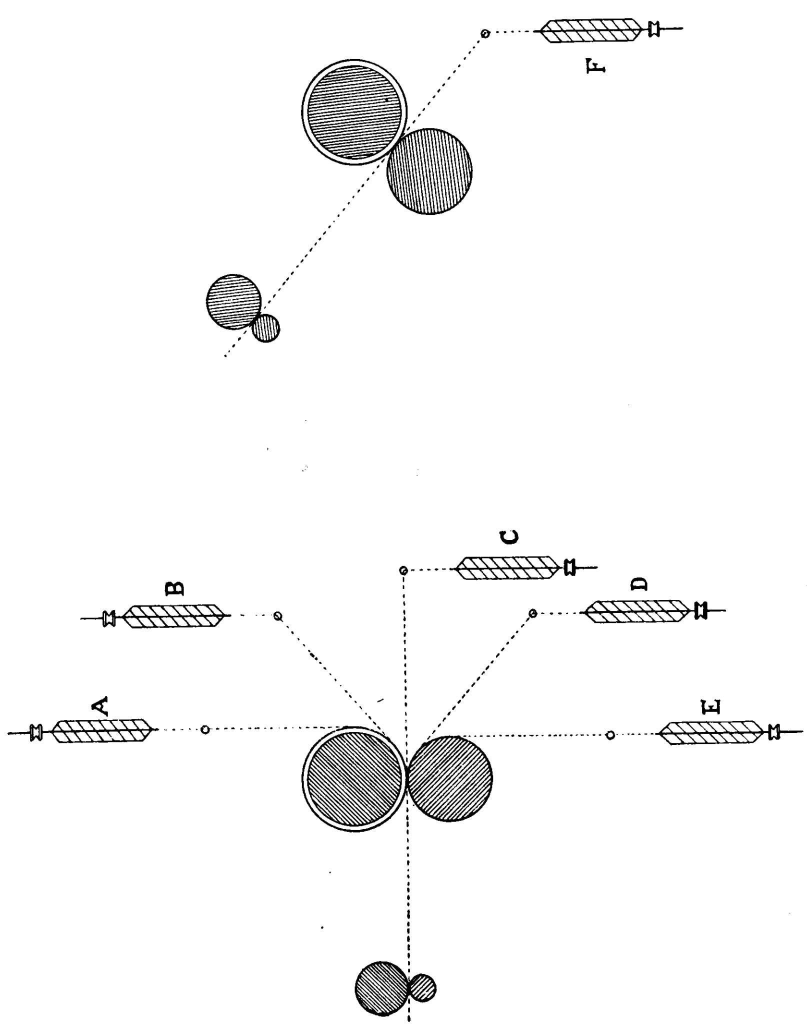


FIG. 14A.—Possible position of Spindle with Guide Eye in relationship to Drafting Rollers.

near to the spindle or cop. This latter point is worthy of very careful consideration, as the holding apart of two threads to be twisted together just above the twisting spindle has a marked effect on the regularity of the twist. The inclination of the spindle also, as will be noted directly, is most important in the woollen mule, and in general hardly receives the attention it merits.

A glance may now be taken at the modifications of the continuous bobbin and flyer principle of spinning introduced since the time of Arkwright.

When it was realized that the bobbin or spindle was the spinning mechanism and the flyer the winder-on, an endeavour was naturally made to simplify this latter, thereby saving expense in construction, effecting a reduction in the consumption of power, easier doffing and quicker running. The labour difficulties in America further forwarded this movement and so the ring frame came into being.

In the modern ring frame the spindle—but in this case without a flyer—is the chief motive factor. The drafted sliver is delivered from exactly above the centre of the spindle, so that upon the spindle being revolved twist is put into the sliver. But how is winding-on effected? Surrounding the spindle is the ring—or, conversely, the spindle passes exactly through the centre of the ring, and upon this ring, suitably controlled by the ring-flange, is a "traveller." The sliver, instead of passing directly to the apex of the spindle, first passes through the traveller and then on to the spindle or bobbin placed on the spindle. The traveller thus acts as a retarder, enabling the spindle to wind up the yarn delivered to it by the front rollers. The

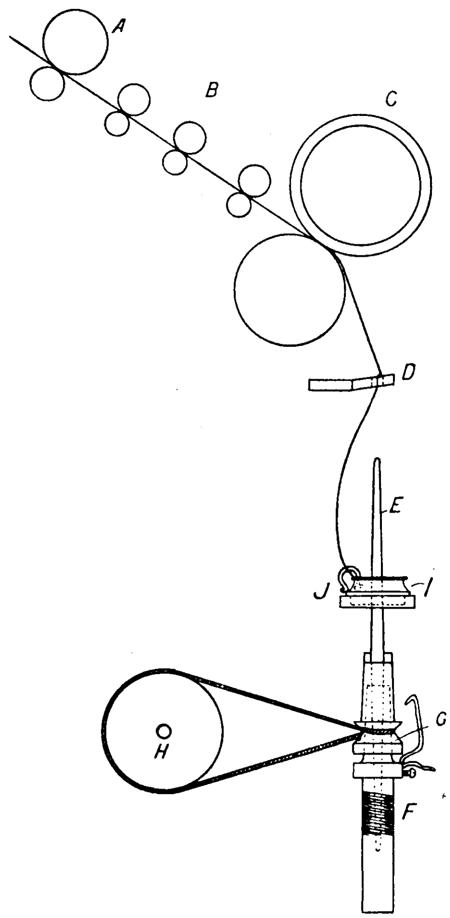


FIG. 15.—Ring Spring Frame.—*A*, back rollers; *B*, carriers; *C*, front rollers; *D*, eyelet board; *E*, spindle; *F*, spindle support; *G*, spindle wharl; *H*, tin drum round which spindle band passes; *I*, ring; *J*, traveller.

yarn is distributed on to the bobbin by the slow movement up and down of the ring-rail, the spindles naturally being fixtures. To ensure high speeds on this machine—say 7,000 to 12,000 revolutions—many spindles of special construction have been designed, some self-balancing, some running in oil, etc. (see Fig. 15).

The development of the ring frame would naturally lead inventors still further afield, and eventually the cap frame was evolved.

The cap frame is very similar to the ring frame, save that the edge of the cap develops, or helps to develop, the friction whereby the bobbin may wind yarn on to itself. As the caps are too heavy to move, the bobbin-rail moves to effect the distribution of the yarn on the bobbin (see Fig. 16). When the cap frame was first tried in Bradford the cops produced were so soft that the yarn could be jerked off the bobbin. This was owing to the fact that the frame was run at 2,800 revolutions per minute "to give it a chance." It was only when the frame was speeded up to 5,000 revolutions per minute that its great possibilities were realized. The cap frame came into the wool district from the cotton district. Why it should be so successful for pure Botany wool and so useless for cotton is again a most interesting question which we have not space to investigate here.

In two important points the supposed automatic spinning frames are not automatic. They neither feed themselves automatically nor do they "doff" themselves automatically. The comparatively large bobbins placed in the creel behind the back rollers of a spinning frame contain so much sliver to be spun that little manual labour is necessary

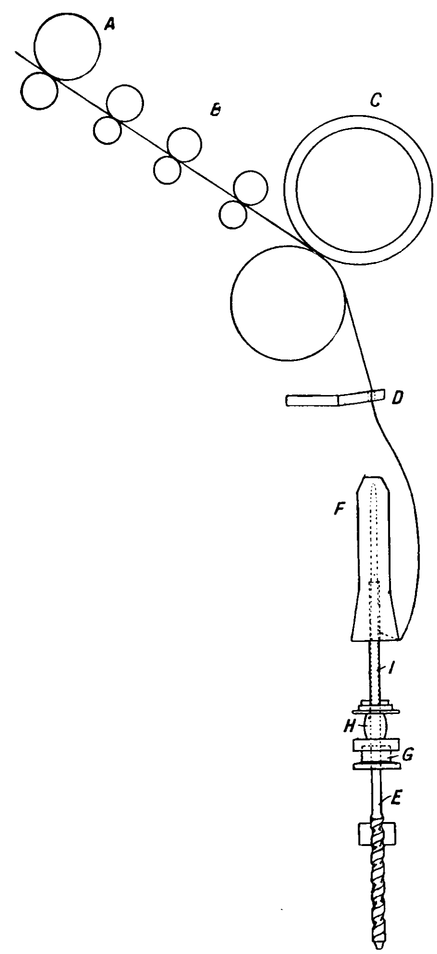


Fig. 16.—Cap Spinning Frame.—*A*, back rollers; *B*, carriers; *C*, front rollers; *D*, eyelet board; *E*, spindle fixed in framework; *F*, cap supported by spindle; *G*, bearing for tube *I*; *H*, wharl round which driving tape passes; *I*, tube upon which bobbin or spool is fixed and carried round.

to keep the frame supplied with slivers or roving to be spun into yarn. Very different is it, however, with the doffing of the comparatively small spools or bobbins upon which the spun yarn is delivered. On an average a flyer frame running on $\frac{1}{40}$'s with 10 turns per inch, will be doffed six times per day of $10\frac{1}{2}$ hours, and a cap frame running on $\frac{1}{48}$'s with 16 turns per inch seven times per day of $10\frac{1}{2}$ hours. With the scarcity in half-time labour the invention of an automatic doffing motion has become imperatively necessary. Messrs. Clough & Co., of Keighley, have successfully employed such a motion on their flyer spinning frames during the past five years, while Mr. W. H. Arnold-Forster, of Burley-in-Wharfedale, has also recently patented such a motion of somewhat novel construction. At first it was thought that given half-time labour such a motion was not required from the economical point of view. From experiments recently made, however, it would appear that it is more than probable that the doffing motion will ultimately supplant half-time labour, being actually considerably more efficient with regard to output. This, however, refers more particularly to flyer frames—the conditions of doffing cap and ring frames being somewhat more complicated. Considering the mechanical problem in a broad way it would seem as though the mechanical problems of doffing are greater than the problems involved in spinning, and that therefore the spinning machine should be made to the doffer and not, as at present, the doffer applied to a machine designed without regard to any such attachment. Of course, to change a machine which, although apparently simple, has been evolved by generations of workers and probably contains more than we have the least idea of, is a dangerous thing. Still, the result may justify the attempt.

Short Fibre Spinning.—The art of short-fibre spinning would possibly develop some time after long-fibre spinning, being somewhat more involved and of such a nature that it would not so readily be "thought of," but would probably be accidentally "discovered." Briefly, the art of short-fibre spinning consists in supporting the thread or sliver during elongation with twist instead of with rollers. Did spinning simply consist of *twisting* fibres together, then it would be impossible to differentiate between long-fibre spinning and short-fibre spinning. Any difference would then probably lie in the preparation of the respective fibres for the spinning. But the drafting or drawing out of the sliver being necessarily implied, at once emphasizes the difference between long- and short-fibre spinning. For in long-fibre spinning the fibres are of such a length and are arranged so parallel in the sliver that when the spinning twist is inserted it is inserted into a sliver or thread already formed, and of which the thickness is already decided. Whereas in short-fibre spinning the commencement of the final twisting is really a putting in of drafting-twist, *i.e.*, as the twist is inserted the sliver is elongated. But for this drafting-twist the short-fibred slivers to be spun would break. This drafting-twist running into the thinnest sections of the slivers strengthens them, and these becoming the strongest in turn serve as a means to draft the sections which are now relatively weaker. Upon the drafting being completed the elongated sliver is then converted into a true thread by receiving its final complement of twist. So potent is the drafting-twist that it must be exactly adjusted to the length of fibre being spun, the shorter the fibre and the more drafting-twist, and conversely, the longer the fibre the less drafting-twist, until for long fibres no twist at all is possible, as they bind the sliver too much, under which circumstance roller control must be resorted to. The

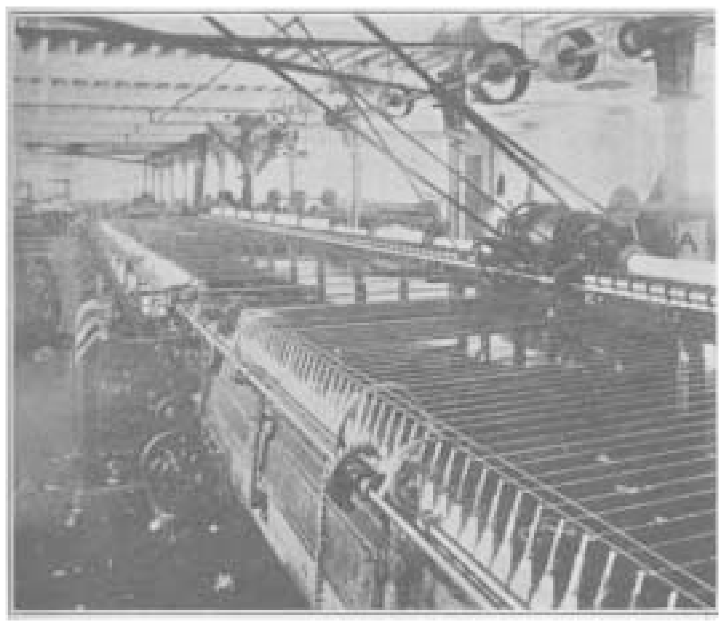
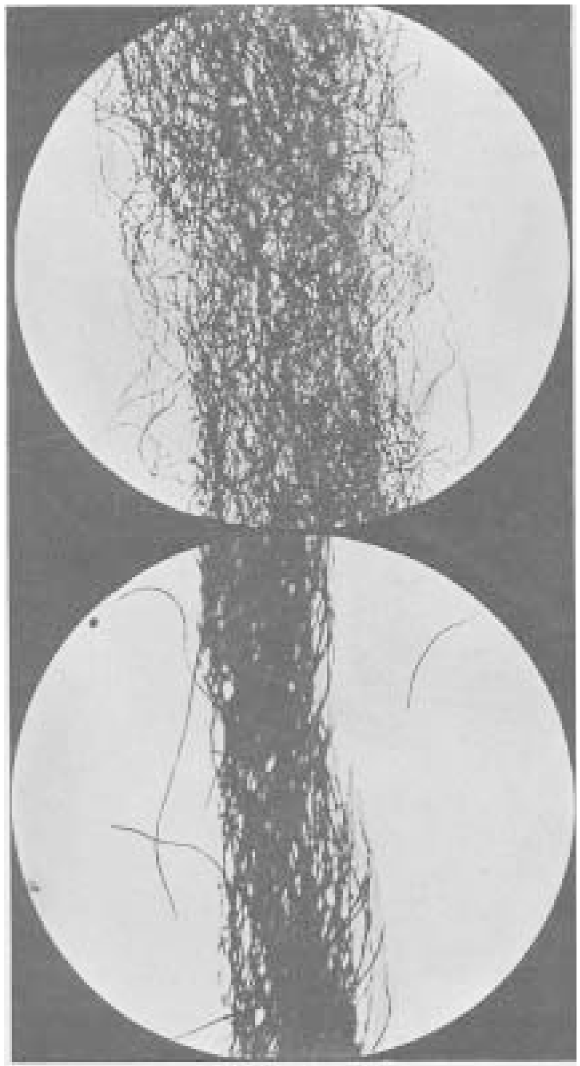


FIG. 17.—General View of Woollen Mule.

principle of spindle-draft is the distinguishing feature of mule spinning, especially woollen mule spinning, producing yarns of marked characteristics which in turn have a marked influence in both the weaving and finishing operations. Again, the method of inserting twist into the slivers on a mule must have some influence upon



(*A*)

(*B*)

FIG. 17A.—(*A*) Condensed woollen sliver, prior to spinning; (*B*) condensed worsted sliver prior to spinuing.

the resultant yarn, though what it exactly is we cannot yet say.

The woollen mule is the perfect short-fibre spinner. In brief, a woollen mule consists of three main parts, viz., the prepared or condensed sliver holder and deliverer, the carriage with its spindles, and the headstock which controls the action of the other two. The condensed sliver (A, Figs. 17 and 17A), brought up from the carding machine on lightly-flanged long condenser bobbins, rests on a delivery roller, and being turned by surface contact is always completely under control. The slivers from these condenser bobbins are passed through a pair of stationary rollers the revolution of which is in accord with the turning of the condensed sliver roller, and both are under perfect control from the headstock, intermittent delivery being varied at will according to the requirements presently to be described. The carriage—carrying from 300 to 700 spindles of any suitable pitch, thickness and inclination, according to the work to be done—is perfectly controlled from the headstock by means of drawing-out and running-in scrolls. The speed of the spindles is also under perfect control so far as drafting-twist and final twist are concerned, and something more than under perfect control when the building up of the cop is in process, as will be explained immediately. One complete spin, starting with the carriage run-in to the delivery rollers, and consequently with the spindle points close to the grip of the rollers, from which the condensed sliver passes direct to the spindle points, takes a few turns round the spindle, and in the shape of spun yarn forms the cop on the spindle, may be described as follows: As the delivery rollers deliver condensed sliver the carriage with its spindles slowly retreats until it reaches about half the distance of its complete traverse, when the delivery rollers suddenly stop. The carriage, however, goes on towards its full traverse slower and slower, in the meantime the spindles putting in just the requisite drafting or supporting twist which, owing to the nearly upright position and thickness of the spindles, vibrates right along the slivers and ensures distribution in fair proportion to the diameter of the yarn, so that as thin places are strengthened and become strong the thick places are drafted out, and so an equalizing action goes on right throughout the drafting operation. Upon the carriage reaching the extent of its traverse—when drafting is completed—the spindles are turned on to double speed to effect the necessary twisting of the two yards of yarn per spindle, just twisting as quickly as possible. The insertion of so much twist naturally causes a contraction of the thread, and to allow for this a slight return of the carriage towards the delivery rollers is arranged for. Upon the completion of the twisting the spindles are reversed for a few turns—this is termed "backing-off"—to enable the faller guide wire to commence building up the cop from where it left off at the last run-in, and a counter-faller wire, suitably weighted, rises, as a perfectly even tension must be maintained on the yarn, otherwise it "snarls" and forms kinks. The carriage is now freed and commences its run-in under the control of scrolls which, working in conjunction with a quadrant which controls the turning of the spindles, and a "copping-plate" which controls the traversing of the faller-wire, result in a firm, sound cop being built up. Upon reaching the delivering rollers the faller-wire rises; the counter-faller wire falls and the spindles are free to repeat the cycle of evolutions. Of course a greater or less amount of condensed sliver may be delivered, according to the draft required, more or less drafting-twist may be inserted in accordance with the binding qualities of the material being treated,

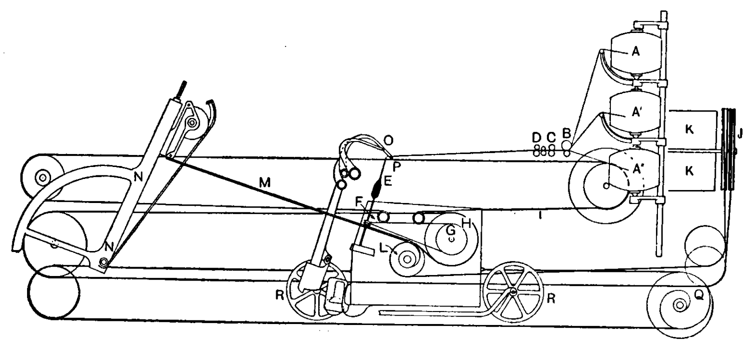


FIG. 17B.—Worsted Mule Section.—*A*, A_1, A_2, French drawn rovings ready for spinning; *B*, jack drafting rollers; *C*, carriers; *D*, front drafting rollers; *E*, spindle carrying spun yarn; *F*, wharl on spindle from which band passes to tin drum *G*; *H*, drum which conveys motion through the cord *I*, from the twist pulley *J*, in the headstock *K*, to tin drum *G*; *L*, a catch scroll which receiving a variable motion from the quadrant *NN*, through the chain *M*, gives the spindles the correct rotation to wind up the yarn for building a firm cop during the running in of the carriage at the same time that the faller wire *O* and counter-faller wire *P* direct and tension the winding up of the yarn, this being further controlled by the action of the "copping plate," which controls the up and down movement of the faller wires.

the exact turns per inch required may be inserted at double speed, and by a change of "copping-plate" the yarn may be spun on bobbins instead of on paper tubes.

From this description the two main features of mule-spinning, viz., the spindle-draft (properly spoken of as twisting-draft), and the twisting of unsupported threads will be fully realized. It should be noted, however, that as previously remarked the machine just described should not be called a mule, for Crompton's "mule" received its name from being a hybrid combination of roller and spindle-drafting, while in the Woollen mule there never has been any roller-draft; it is simply an automatic jenny in the "billy" form.[1] The cotton and worsted mules, however, are genuine mules, as roller-draft in these plays almost a leading part. If, as very often happens, little or no spindle-draft is inserted by these mules the only possible advantage would appear to be in the method of inserting the twist. Against this presumable advantage there is the intermittent character of the cycle of spinning operations and the additional floor space occupied to be placed. That there must be an advantage is evident from the fact that mule spinning in the cotton trade at least holds its own, while in the case of the worsted it is rapidly making headway. In both these cases it may be that it is the peculiar method of sliver preparation, which it makes possible, which is the real advantage. This will claim attention in the next chapter.

It will have been noticed that although cotton is short fibred, nevertheless it is frequently spun on the roller-draft or long-fibre spinning method. This is accounted for by the nature of the cotton fibre, which is much more docile than wool and does not require length to control it, but may readily be controlled by the small drafting-rollers. In this connection it is interesting to note that prior to the mechanical era cotton yarns were probably spun very

[1] It is an interesting problem in economy of power to decide whether the spun yarn should be run backwards or forwards and the condensed sliver left stationary or *vice versâ*. Both forms are still in use to-day.

largely, if not entirely, upon the short-fibre spinning system. This is borne out by a knowledge of the cotton industry in India, in which the flax wheel plays no part, all the spinning being done on the simple spindle wheel. This rendered cotton spinning a relatively difficult process as compared with either linen or long wool spinning; hence the comparatively small number of people engaged in the industry prior to the mechanical era. But the introduction of the various automatic drawing and spinning machines rendered possible the drawing and spinning of cotton on the long-fibre principle; in fact it is practically true to say that the cotton industry is a machine-created industry. It would probably always have remained small but for the introduction of mechanical methods. It would also be interesting to investigate to what extent the short or Botany wool industry is a machine-created industry. It is true that woollen yarns were spun from short wools prior to the mechanical era, but the short wool worsted yarn is evidently a creation of the mechanical era; and consequently to this mechanical development must the large demand for Botany wools be attributed. That this is so is proved by the fact that the largest increases in the production of these yarns have taken place since the perfecting of the necessary preparatory machinery and the machine wool comb specially adapted for short wool combing, *i.e.*, between 1840 and 1880, although short Botany wools were previously largely employed in the clothing and woollen trade.

During the past twenty-five or thirty years many endeavours have been made to produce a frame yielding yarn possessing the same characteristics as yarn spun upon the mule. If such a frame could be produced a great saving in space and a markedly increased output would be effected, since such a frame would be a continuous spinner, whereas the mule is an intermittent spinner. The difficulties to be faced are principally these:—Firstly, the continuous drafting of the sliver along with the insertion of the necessary drafting-twist; secondly, the insertion of the true thread twist; thirdly, the construction of a frame as easy to follow—to piecen up broken ends on—as the mule; and fourthly, a frame as inexpensive in both initial cost and in following as the mule. One of the first attempts was that made by Celestin Martin, of Verviers, in which a "twizzler" to insert false drafting-twist is placed between two pairs of drafting rollers, and a ring-frame arrangement placed to receive, twist and form a cop of the drafted but twistless yarn as delivered by the second pair of rollers. This machine, although employed to a considerable extent on the Continent, cannot be considered entirely satisfactory. The drafting being effected or supported by false twist is very different in character from that obtaining on the mule. Again, the vibration which runs along the thread in mule spinning owing to the thickness and inclination of the spindles is not attempted here. Again, the final twisting conditions obtaining on the mule do not in the least obtain here; and finally, the difficulties of piecening up are greater.

In Fig. 18 the latest style of mule-frame is shown. In this it will be noted that the "twizzle" (*B*) is placed practically upright and has two projections upon it. This is to give the "vibration" or short pulls to the thread which no doubt plays such an important part in spindle-drafting on the mule. This form of twizzle, however, obviously

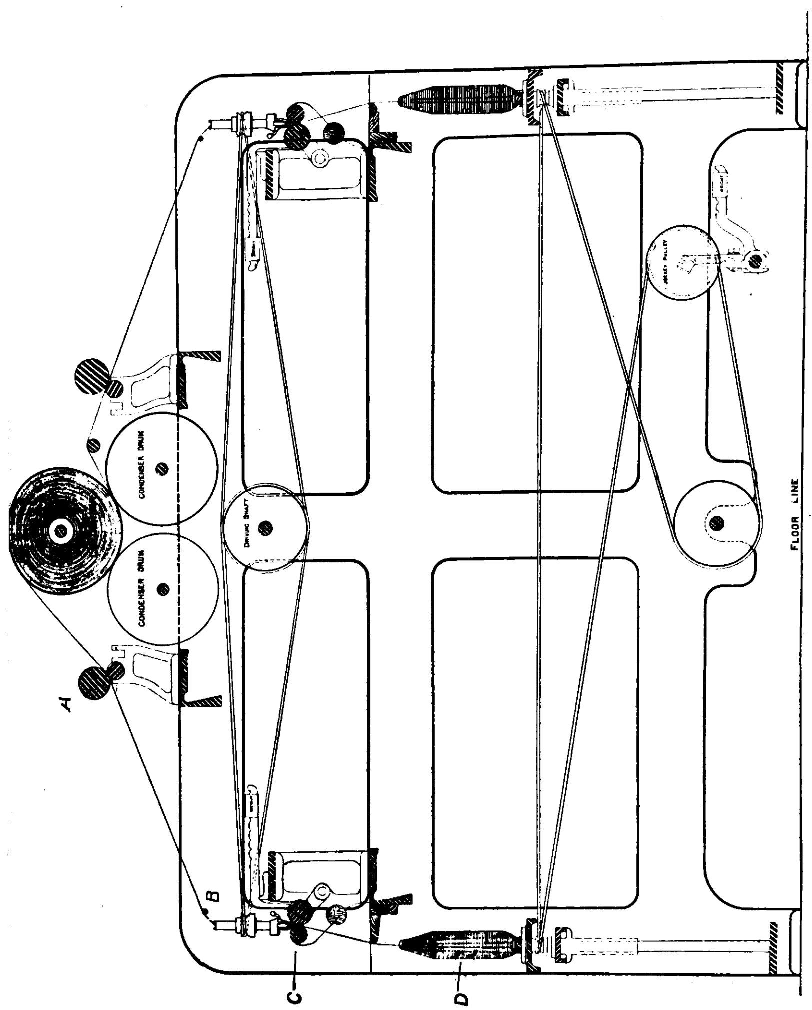


FIG. 18.—Platt's Mule-frame Sectional View. *A*, first drafting rollers; *B*, lugged twister; *C*, second drafting rollers; *D*, ring spinning frame.

increases the difficulties of piecening up. Arrangements are also made in this machine to make the drafting intermittent, but the twisting and winding on to the bobbin are continuous. As the main point in production lies in the twisting, this appears to be a move in the right direction. The conditions of final twisting, however, are the same as in the Celestin Martin's frame, and will probably result in a different yarn being produced as compared with the genuine mule-spun yarn. Considering the economic effect in the space occupied and the possibly greater production owing to the continuous action of the frame, it seems probable that this frame may be wisely and economically employed for the spinning of certain classes of woollen yarns, although its initial cost per spindle will probably be much greater than the mule.

In another frame of a similar style bars are inserted between the back and front rollers, near to the back rollers, with the idea of limiting the "run-up" of the twist in the thread, so that drafting may be more readily effected. This, however, shows a total want of perception as to the fundamental principles of spindle-draft.

Again the difficulty was supposed to be solved by the addition of an apparatus to the condenser, which took the slivers directly from the ring doffer—thus obtaining a "free-end"—and twisted them into what were called threads. As there was no draft at all in this case the resultant strands were simply twisted slivers and not spun threads.

From these attempts it would appear that for the spinning of characteristic woollen yarns—especially fine yarns with much twist—the woollen mule is not at all likely to be superseded.

CHAPTER VI

PROCESSES PREPARATORY TO SPINNING

In the foregoing chapter the various principles of spinning have been fully considered on the supposition that both long and short fibres of various classes were available for spinning. No account, however, was taken of the fact that in no case, with the partial exception of silk, are either the long or short fibres of commerce found naturally in a condition suitable for being spun into yarn. In fact, the variation in length in most materials necessitates a combing operation to classify the fibres which may be satisfactorily spun together, long spinning well with long, and short with short, but not long with short. Again, all contain either impurities natural to their growth or accidental impurities which get into the mass of fibres and must be removed before spinning can be attempted. In the first class the cortical substance in flax, the gums in China-grass, the yolk in wool, the gum in silk and the seeds in cotton, may be cited. In the second class water, beyond a certain amount, in flax, wool, and cotton; and burrs, seeds, straw, and sand in wool may be cited. Whatever the impurity be, it is usually necessary to remove it with the least possible damage to the fibre and to leave the fibre in a condition for being spun into a good useful yarn as already defined.

The processes preparatory to spinning are very varied, naturally being suited to each particular fibre. The principles involved, however, are all comprised in the following machines,[1] the action of which will be described after the natural requirements of the various fibres have been considered.

Machine.	Materials for which Employed.
The Gin	For cotton.
The Washing or Scouring Machine	Wools and hairs.
The Dryer	Wools, hairs, etc.
The Scutcher	(*a*) For cotton. (*b*) For flax.
The Backwasher	Worsted slivers and tops.
The Gill-box	Long wools and silk (modified form).
The Carder	Medium and short wools and cotton.
The Dresser	Waste silk and China-grass.
The Comb	Wool, cotton, and sometimes silk and China-grass.
The Drawing-Box	Wool, cotton, and silk.
The Cone Drawing-Box	Wool and cotton
The French Gill or Drawing-Box	Short wools.

The important points to study about these machines are, firstly, the principle underlying their construction; secondly, the way the material should be prepared for presentation to these machines; and, thirdly, the way in

[1] Net Silk Machining is treated separately in Chapter XV.

which these machines should deliver the material ready for the ensuing process or processes. Before dealing with these points, however, the natural requirements of each fibre should be considered, as it must always be the fibre which decides the type of preparing machine—even iron and steel must conform to soft cotton and wool, lustrous silk and harsh China-grass. Thus in the preparation of cotton and wool for spinning on the short-fibre principle good carding is so important that the resultant spin may absolutely be said to depend upon it. In the preparation of flax and certain other vegetable fibres for spinning on the long-fibre principle satisfactory retting, scutching and dressing are equally important. In the preparation of long animal fibres such as English wool, mohair, and alpaca, as also in the case of the "combed" cottons, an averaging of the fibres by means of the operation of combing—which in turn has its preparatory processes in the form of carding or preparing—is necessary to ensure a satisfactory spin. It is obviously impossible to say that any one process is the most important in the sequence; each operation must be worked to the best advantage if good results are to be finally attained.

Four Methods of Preparing Vegetable Fibres for Spinning.—To ensure satisfactory results in the spinning it has been found necessary to employ at least four distinct methods of preparation for the various types of vegetable fibres, each of these methods having been naturally evolved through experience with the respective fibres to which each is best suited. These four methods are as follows:—

1. *Air-blast Preparation.*[1]—This is chiefly employed for

[1] See p. 128 for description of ginning machine, the first machine employed in cotton.

cottons, being the main principle of the openers, scutchers, and perhaps not altogether inactive in the carders. The initial stages of the preparation are usually followed by carding, sometimes combing (as explained in the chapter on the Cotton Industry), and then drawing as directly preparatory to spinning.

2. *Retting Preparation.*—This is chiefly employed for flax and a few analogous fibres, in which the fermentation due to steeping in peaty water, or perhaps "dew retting," is sufficient to destroy the cortical substance in the flax stems and thus render fairly free the fibrous portion. Scutching to further loosen any cortical particles still adhering, and dressing, complete the cleaning preparation of the fibres, which are then got into sliver form, as in the case of long wools, etc., and finally drawn and spun on the long-fibre principle as already explained.

3. *Scraping Preparation.*—This method is employed for such fibres as Ramie and China-grass, in which no form of retting is altogether satisfactory, probably owing to the gums which act as firm binding or integrating agents. Not only is a good scraping in running water usually necessary, but "degumming" by means of caustic soda or other reagents is also necessary later. Once the "filasse" is in a really fibrous and clean state it may be treated somewhat on the flax principle, or, better still, on what is known as the "spun silk principle," in which an averaging up of the fibres is effected by a process known as "dressing" (see p. 126) followed by sliver forming arrangements similar to those employed for long wool, and spinning on the long fibre principle.

The Noble comb is sometimes employed in place of the dressing frame, but is not nearly so effective.

4. *Artificial Preparation.*—As artificial silk spinning is here in question and as most artificial silks are formed from vegetable matter, such processes should claim consideration here. The spinning referred to is not really spinning, it is rather a drawing-out of a prepared wood or cotton pulp into a fine filament which, hardening on exposure to the air or by special treatment, thus becomes a fine strand and is later twisted or "thrown" with other strands to form in turn a true thread. As the later principles involved are those of silk throwing no further description is here called for. It is interesting to note, however, that artificial flax is now being placed on the market, and no doubt other varieties of such fibres or filaments will follow.

Four Methods of Preparing Animal Fibres for Spinning.—As animal fibres are usually delivered into the hands of the spinner in a fibrous state, their preparation is different from that of flax, etc.; on the one hand by reason of the absence of the necessity for mechanical treatment, and on the other hand in that certain adhering impurities must be removed by certain chemical or chemico-physical operations, the washing or scouring of the wool, etc., being the chief of these. This operation of scouring, however—take what care one will—frequently so mats the wool or hair that special machines must be employed to disentangle it and constitute it into a sliver suitable for spinning from on the short-fibre principle or a sliver suitable for spinning from on the long-fibre principle.

The four methods of preparation employed for wool and hairs are as follows :—

1. *The Woollen Method.*—In this case willowing, teasing, scribbling, and carding result in the wool being delivered as a broad continuous film—with fibres perfectly dis-

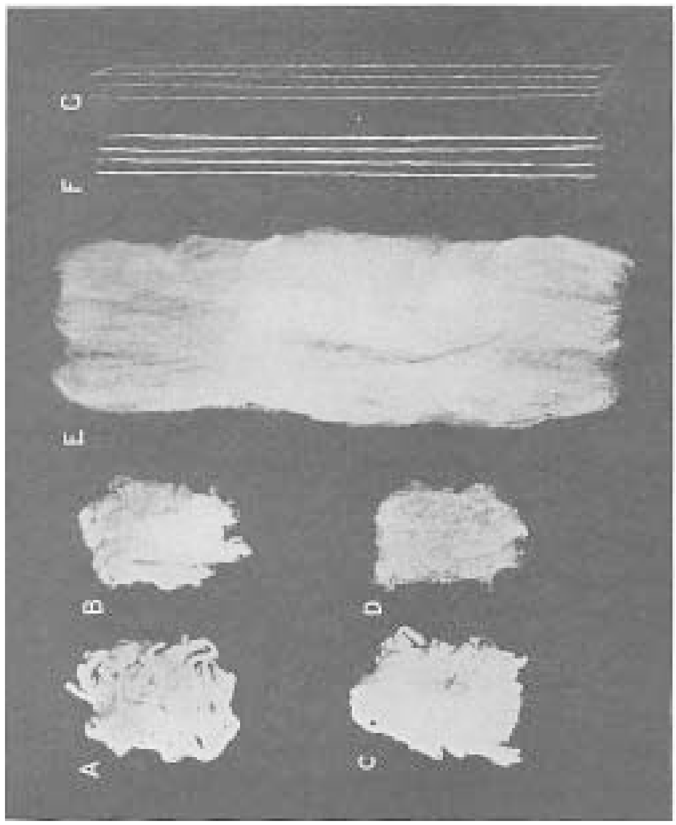
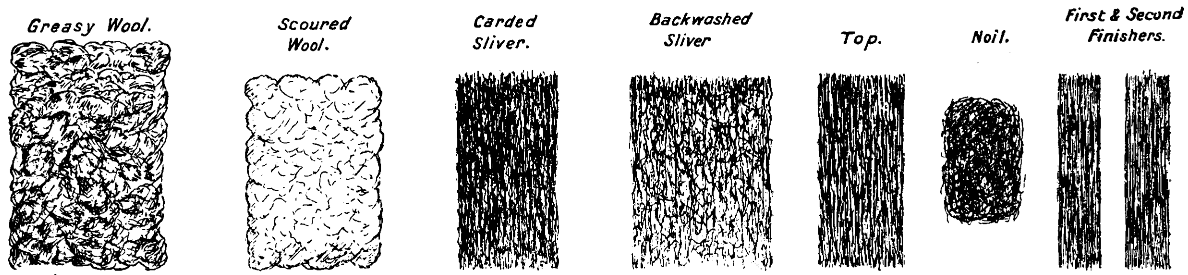


FIG. 19.—Stages in Woollen Yarn Spinning. *A*, wool to be blended with cotton *B*; *C*, blend of oiled wool from Fernaught; *D*, blend from scribbler; *E*, blend in rope form from intermediate card; *F*, condensed slivers; *G*, mule-spun thread.

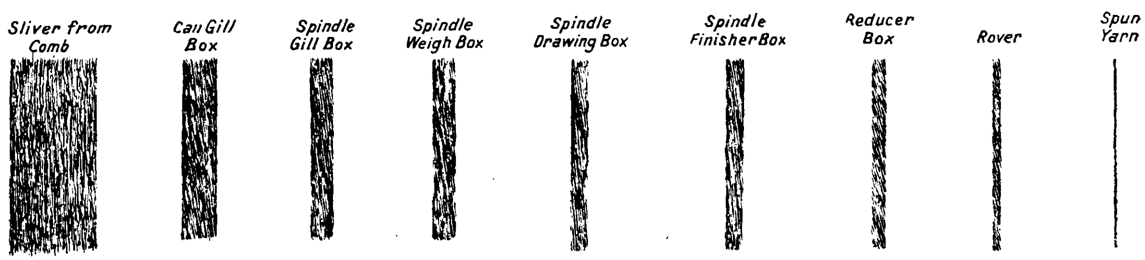
tributed—to the condenser which breaks the broad film of, say, 48 to 72 inches up into 60 to 120 pith-like filaments—not threads, as there is no twist in them—which are continuously wound on to the condenser bobbins, which in turn are transferred to the mule to be spun into threads by additional draft and twist. (See Fig. 19.)

2. *The Botany Worsted Method.*—Fine, fairly short wools which later may be spun on the long-fibre principle are carded to obtain an even distribution of the fibres in the sliver delivered from the card. But the carding operation no doubt tends in part to arrange the fibres longitudinally in the sliver, being aided in this by the way in which the sliver is drawn off the machine as compared with the delivery of the sliver from a woollen card. The combing operation now follows, being undertaken with the idea of taking away the short fibres, termed "noil," and thus leaving in the slivers to be spun only the fibres of a good average length. Gill-boxes and drawing-boxes then effect the "straightening" necessary before spinning can be satisfactorily undertaken, the two principles of "doublings" and "draft" being applied with the idea of obtaining a level sliver which will spin out to the required count. The excess of draft over doublings gives the reduction in thickness of sliver. The knowing when to double and when to draft to obtain level slivers is still only imperfectly understood. (See Figs. 20 and 20A.)

3. *The English Worsted Method.*—Long wools and hairs such as mohair, alpaca, etc., are treated on this system, although it is well to note that there is a marked tendency to prepare by carding much longer wools than was formerly the case. These long-fibred materials are gilled as a preparation for combing and combed on the Lister or Noble comb. Gill-boxes and drawing-boxes then effect the necessary "straightening" prior to spinning, doubling and



GRAPHIC ILLUSTRATIONS OF PROCESSES FROM WOOL TO TOP

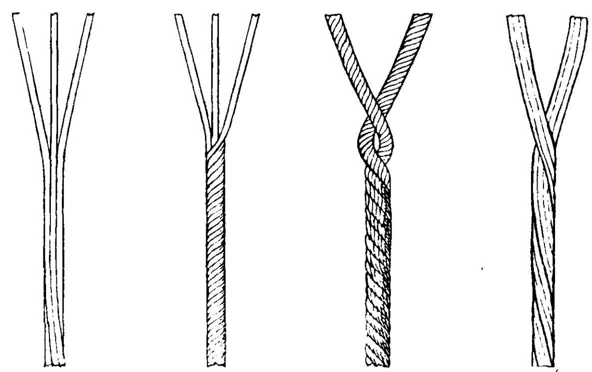


GRAPHIC ILLUSTRATIONS OF PROCESSES FROM TOP TO YARN

FIGS. 20 and 20A.—Stages in Wool Combing and Worsted Yarn Spinning.

drafting being applied very much as in the case of Botany wools, but as a rule there are fewer operations.

4. *The French Worsted Method.*—The shortest and finest Botany wools are prepared for spinning on this method, the principle being that the wool is treated in an open condition without twist by drafting rollers throughout, twist being unnecessary. Of course special support and



Single used for Tram. Single used for organzine. Organzine (2-single). Tram (2-single).

FIG. 21.—Graphic Illustration of Net Silk Yarns.

control of the wool during drafting and a special form of delivery are necessary. The worsted mule almost invariably forms the climax to this method, although there is a question as to whether spinning on the cap principle may not yield economical and useful results.

Two Methods of Silk Preparation.—The special characteristics of silk are its gumminess and its "slipperiness." These two factors play an important part in deciding the processes through which the fibre shall pass. The two great methods of preparation are designed for the "net" silks and the "waste" silks respectively, the "net" silks requiring a "continuous fibre process" and the waste silks simply a "long-fibre process."

1. *The Continuous Fibre Silk Process.*—In this case the

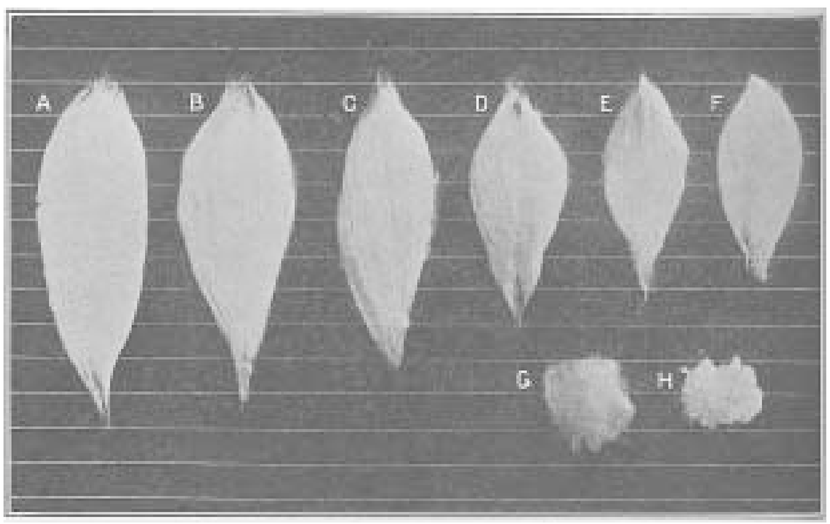


FIG. 22.—Spun Silk Drafts (the horizontal divisions = 1 inch). *A*, *B*, *C*, *D*, *E*, and *F* are 1st, 2nd, 3rd, 4th, 5th, and 6th drafts; *G*, the shorts, and *H* the noil.

fibre is simply reeled from the cocoon its full length, cleaned, softened, and "thrown" with other fibres, twist being inserted according to requirements, quantity and direction being important matters to attend to (see Fig. 21). In this case the preparation for the spinning or "throwing" is very similar to the actual throwing operation. Degumming is effected with soap and hot water, and may be carried out either after spinning or advantageously after weaving, as the silk gum strengthens the thread and results in better work right away through the processes. The

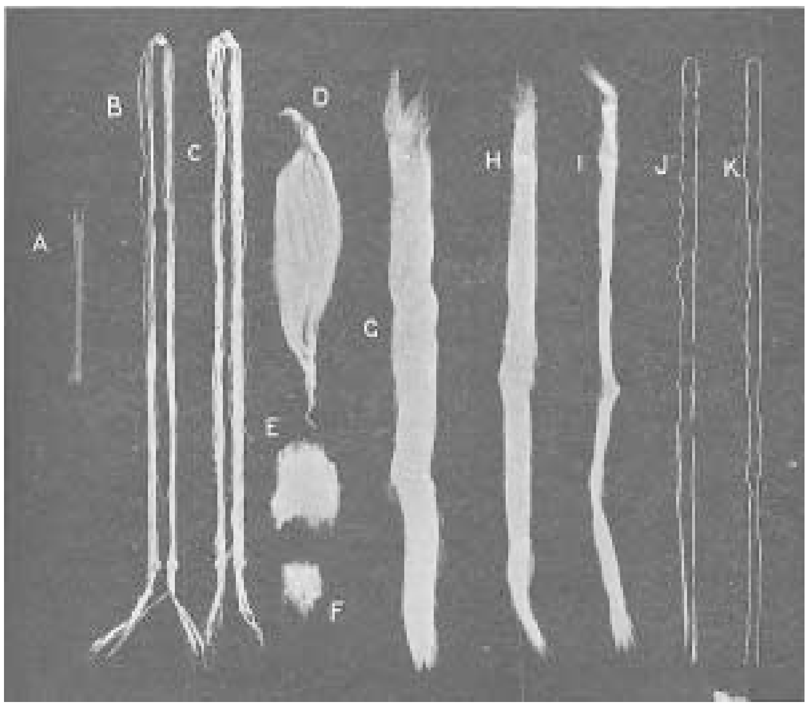


FIG. 22A.—Stages in China Grass Spinning. *A*, stem of Bœhmeria Tenacissima; *B*, decorticated fibrous mass; *C*, degummed and bleached filasse; *D*, dressed filasse; *E*, shorts; *F*, noil; *G*, sliver from spreader; *H* and *I*, slivers from intermediate boxes; *J*, the roving; and *K* the spun thread.

necessity for dyeing and the difficulty of degumming certain fabrics result in large quantities of silk being woven in the degummed form.

2. *The Long-Fibre Silk Process.*—In this case the fibres, although long—say 8 inches to 12 inches—are not continuous. They may be prepared and got into fairly satisfactory sliver form by rollers and gills (which are usually of the intersecting type to control them better), but to spin them satisfactorily the fibres must be averaged up on the dressing-frame—*i.e.*, separated, say, into seven lots or "drafts," as they are termed, according to the length of fibre, the first draft being, say, 12 inches, the second 10 inches, and so on (see Fig. 22). The slippery nature of the silk fibre necessitates its treatment on the "dressing-frame"; in fact, this fibre has given rise to the dressing-frame, which now is not only employed for silk, but also very largely for China-grass (see Fig. 22A).

The still shorter or real waste silk may be again carded up and prepared and spun upon the Botany worsted method.

Typical Example of the Method of Preparing and Spinning a Textile Material (China-grass or Ramie).

Ramie Manufacture: Order of Processes.

1a. Decorticating usually on plantation while stems are green.
1. Boiling with caustic soda, etc.
2. Bleaching—ordinary method.
3. Washing.
4. Hydro-extracting.
5. Heat drying—without confusion of "fibre-bundles."
6. Roller-softening. Through rollers—6 inches forward, 3 inches backward, etc.

7. Carding and fibre cutting process. 18 combs. Cuts at $7\frac{3}{4}$ inches.
8. Dressing between 32 corks on flat dressing-frame with stripping drums.
9. Spreading or gilling (intersecting gills). Lap-drum 3 feet in diameter. Ratch=11 inches to 12 inches. Fallers occupy space of 8 inches. Two passages.
10. Gilling (ordinary). Ratch 11 inches to 12 inches. Fallers occupy space of 8 inches.
11. Drawing on open-gill—4 heads. Ratch 11 inches to 12 inches. Fallers occupy space of 8 inches.
12. Roving on 40 spindle frame. 1 sliver up. Ratch 10 inches to 11 inches. Fallers occupy space of $7\frac{1}{4}$ inches.
13. Doubling on 60 spindle frame. 2 to 4 slivers up. Carriers in place of gills.
14. Hot water spinning on 300 spindle ring frame. Ratch of 10 inches.
15. Dry twisting on 272 spindle ring frame.
16. Gassing on gassing frame.
17. Reeling.
18. Bundling.

PREPARATORY MACHINES

Each of the machines previously mentioned must now be briefly described, when the reader will no doubt be able to adjust the requirements of any particular fibre to the mechanical principles of any required machine, or *vice versâ*.

The Cotton Gin.—This machine in its simplest form consists of a roller with a broad steel blade sprung against it. The roller draws the cotton round between itself and the blade, and the seeds, being large and hard, instead of following are freed from the cotton fibre and drop off into a receptacle arranged for them (Figs. 23 and 23A).

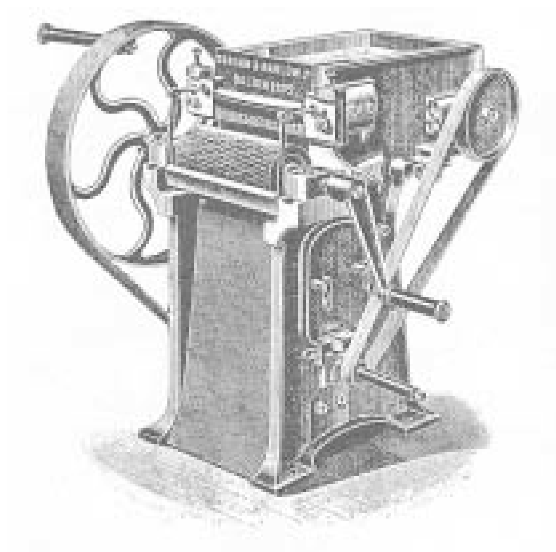


Fig. 23.—Cotton Gin.

The Washing or Scouring Machine.—This primarily consists of a bowl for holding the heated scouring liquor in which the wool is to be cleansed by immersion. This appears very simple, but a few moments' thought will show that some complexity is inevitable. The liquor must be maintained at a definite heat, hence steam must be laid on ; it will also be advisable to lay on water, soap liquor and possibly alkali, so that perfect control of the temperature, heat, and strength of the liquor is obtained.

The yolk, sand, dirt, etc., got out of the wool must be disposed of. Thus, satisfactory means of emptying the bowls must be adopted, drain pipes being suitably fixed to the bowl or bowls to deliver the liquor to the settling or waste product tanks.

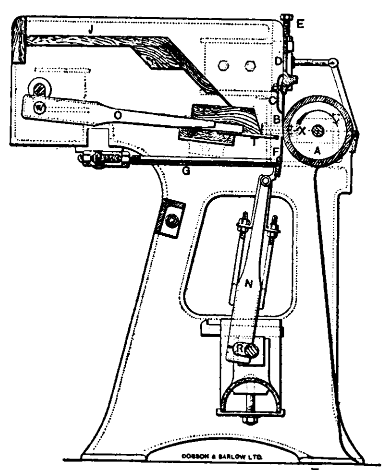


FIG. 23A.—Section of Single Macarthy Cotton Gin.

But, again, during the operation of scouring the dirt and grease, etc., should be got away from the wool entering the bowl, this being usually effected by the settling which takes place by floating the liquor out with the wool and arranging for a tank at the side for the grease, sand, dirt, etc., to settle into, but so constructed that it may be readily cleaned out.

The propelling of the wool from one end of the tank to the other and especially taking it out of the machine are also matters which require very careful thought and arrangement.

Scouring sets now frequently consist of four or five machines giving about 60 to 80 feet of bowl, in which the wool is immersed on an average for about eight minutes.

It may be interesting here to give a brief *résumé* of the evolution through which wool scouring has passed.

The first idea was to pass the wool rapidly through the scouring liquor; this matted the wool, prevented perfect scouring, and resulted in bad work throughout all subsequent processes.

Then the idea of forcing the scouring liquor through the wool was tried, with a very similar result.

Then it was realized that the natural tendency of wool to open out when placed in water—when the surface tension was removed—must be made the basis of wool scouring, and the wool was floated along with the scouring liquor.

Then the idea of a wet nip or "possers" was tried and found wanting, a wet nip apparently nipping dirt into the wool.

Finally it was realized that a combination of circumstances and conditions was necessary, that attention must be paid to all points, and the bearing of one point upon another fully taken account of. Thus were evolved the sets of modern wool-scouring machines in which the necessary agitation may be obtained, but which deliver the wool free, clean and wonderfully dry.

Modifications of wool-scouring machines to effect "wool steeping," and thereby reclaim the valuable potash salts, are also placed upon the market.

The Dryer.—There are several forms of drying machine,

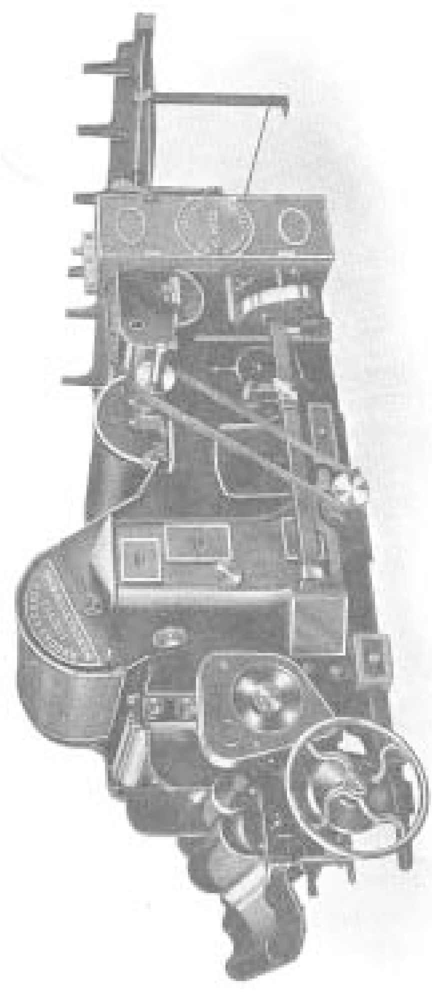


Fig. 24.—The Cotton Scutcher.

such being necessary in the case of English and cross-bred wools after scouring and also useful in such operations as carbonizing. The drying machine has followed an evolution similar to the scouring machine. The material to be dried has been held and air forced through it—as in the case of the table dryer; the material to be dried has been carried into the drying air, and last, and perhaps best of all, the mean between the two has been adopted as in the latest form of McNaught dryer.

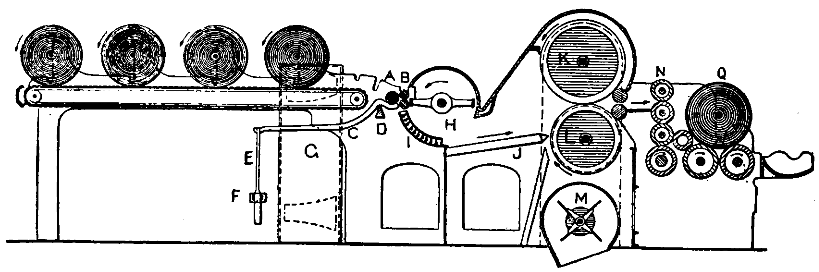


FIG. 24A.—Section of Single Cotton Scutcher.

The Cotton Scutcher.—This is a machine to thoroughly disintegrate and clean the cotton prior to carding. Briefly it consists of "cage" rollers upon which the cotton is blown, which pass it forward until eventually it is delivered as a lap. Suitably arranged "grids" allow sand and heavy foreign matters to drop out of the air currents; thus the cotton is fairly well cleaned and freed prior to carding (Figs. 24 and 24A).

The Flax Scutcher.—This is a machine to beat and break the flax straw after retting so that it is in a suitable state for the dressing frame. It is practically a "breaker" of the flax straw and also a partial cleanser (Fig. 25).

The Backwasher.—This machine usually consists of two small washing or scouring tanks, drying cylinders, and

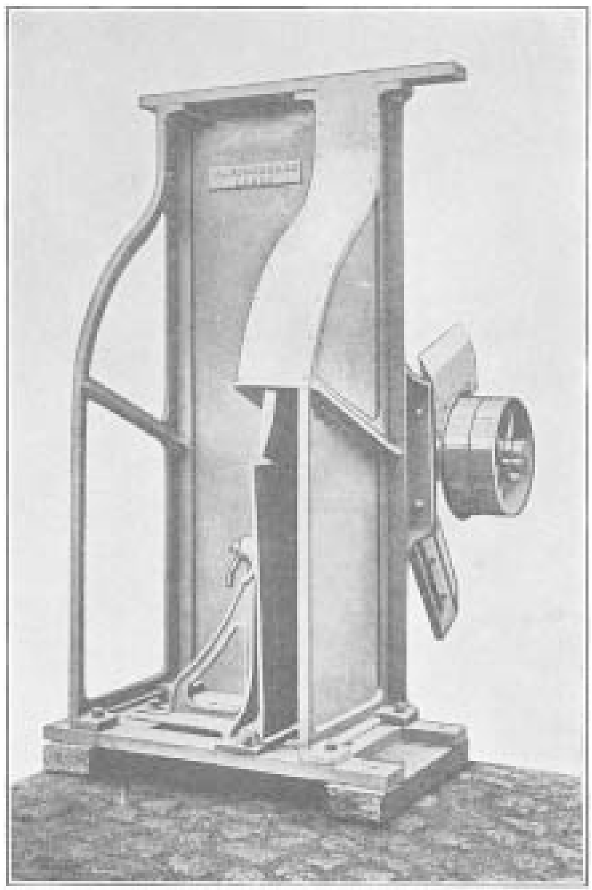


FIG. 25.—The Flax Scutcher.

a straightening gill-box. It is made in several forms, for each type certain constructional advantages or advantages

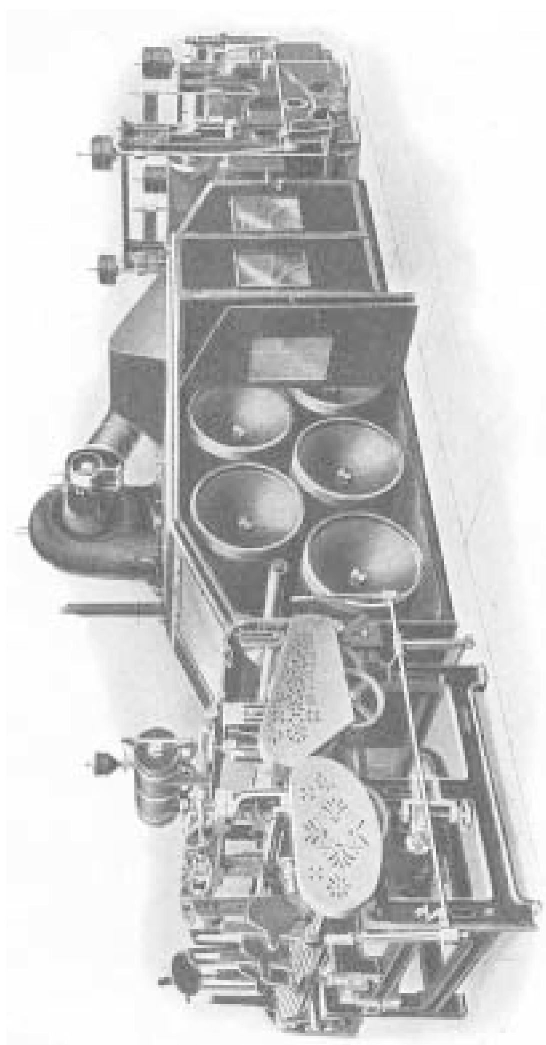


Fig. 26.—The Backwasher with Hot-air Drying.

for the material treated being claimed. It is employed either before (in England) or after (in France) combing to thoroughly clean worsted slivers or "tops," for not only does the wool become sullied in passing through the several preparing machines, but impurities which cannot be extracted in the scouring bowls have revealed themselves and may here be conveniently got rid of. The process of "blueing" to give a white appearance to the slivers or tops is frequently resorted to, and is usually effected on the backwasher. The latest innovation in this machine is the adoption of hot air drying in place of cylinder drying (see Fig. 26).

The Preparing Gill-box.—This consists of a pair of back rollers, gills or fallers riding on screws, and front rollers, with feed sheet and lap, balling-head or can delivery. The action on the wool may be either a combing action or principally a drawing action. For example, when wool is much matted the fallers, working quicker than the back rollers, comb out the fibres and deliver them to the front rollers, which should be set to the fallers. But when the material has been much worked and is fairly straight, the faller-pins simply slip through the fibres and consequently can only act as supports between back and front rollers; in other words, the operation becomes largely a drawing operation.

As pointed out with reference to cotton, the distance apart of drawing rollers, size of rollers, etc., must be very carefully considered. With wool the ratch or distance between back rollers and fallers or back rollers and front rollers is equally important, but as the wool fibre is so much larger than the cotton fibre the size of the rollers need only be taken into account from a wear and tear and possibly from the grip and weighting points of view.

The Preparing Gill-box may be best considered as an

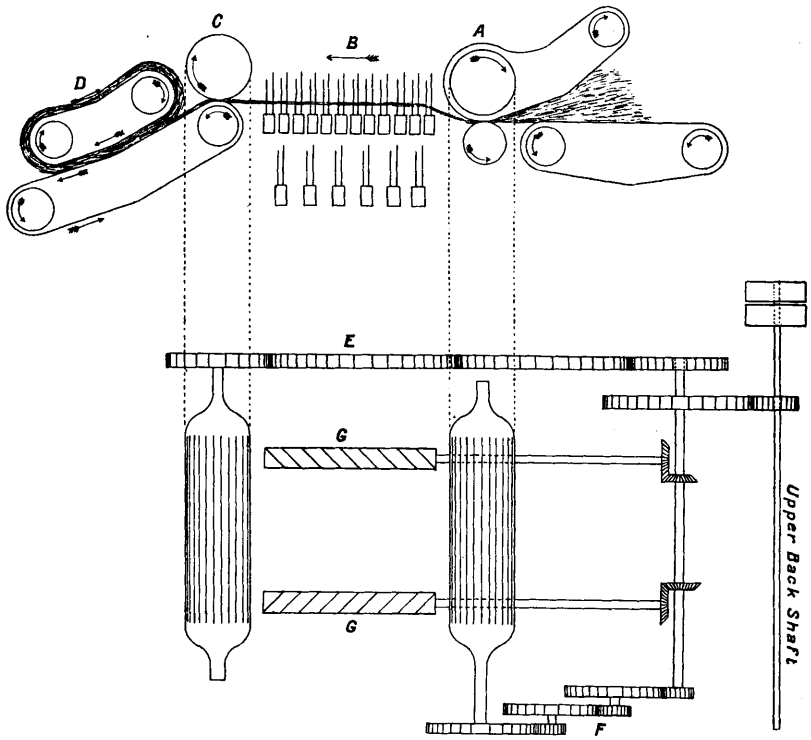


FIG. 27.—Plan and Elevation of Sheeter Gill-box. *A*, back rollers; *B*, fallers set with pins (gills); *C*, front rollers; *D*, sheeting leathers; *E*, train of wheels driving front rollers; *F*, train of wheels driving back rollers; *G*, screws driving the fallers or gills.

admirable straightener for wool and the various long animal fibres, and also as a mixer for fibres of varying qualities or colours (see Figs. 27 and 27A).

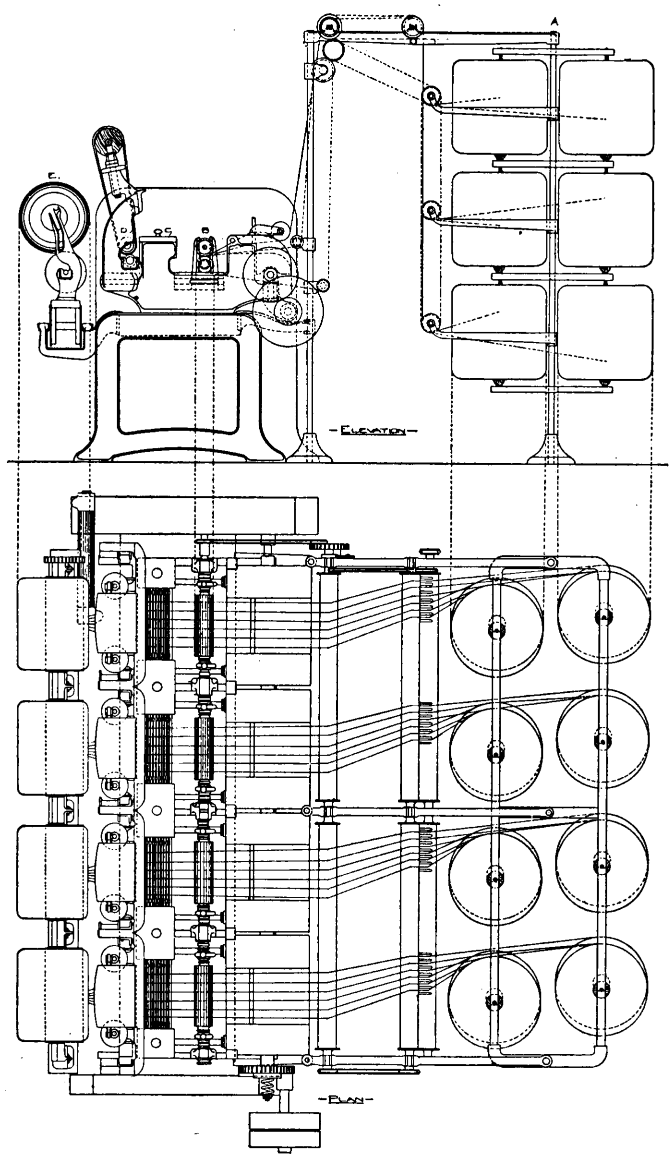


FIG. 27A.—Four-head French Gill-box in Plan and Elevation. *A*, creel; *B*, back drafting rollers; *C*, pinned fallers or gills; *D*, front drafting rollers; *E*, balling head.

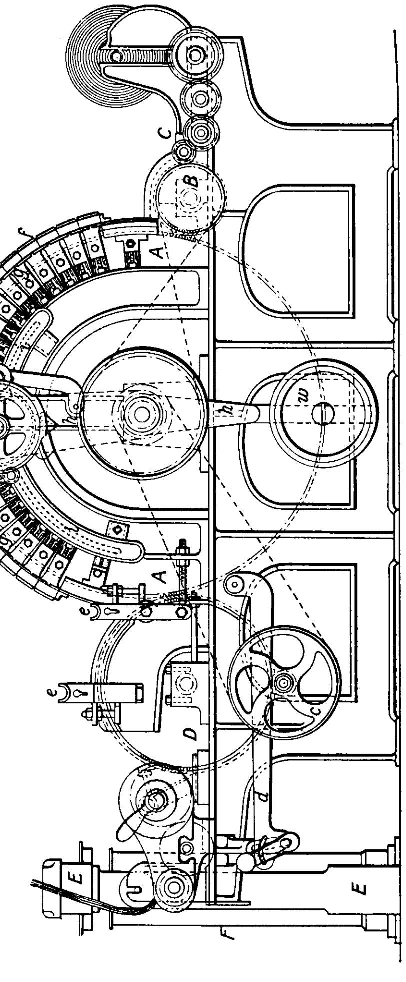


FIG. 28.—Self-cleaning Flat Cotton Carder, illustrating the Evolution from the Early Form of Card to the Revolving Flat Card.

The Carder.—This machine has been evolved from the hand-cards, such as are still used in the home industries of Scotland and Ireland. The first step towards an automatic card was made when a cylinder—which might be turned by hand—was clothed with card-clothing and the wool worked between this cylinder and a flat card held in the hand. This early form of card gave rise to the flat and the revolving flat cards still largely employed in the cotton trade. Finally the whole of the carding was effected by cards mounted upon cylinders, and after many trials, involving both successes and failures, the modern roller card was evolved. It is here interesting to note that, owing to the susceptibility of cotton to air blasts, the cotton roller card is invariably made narrow and enclosed more than is the wool card; while, as a matter of fact, probably due to this, and also to the fibre length, the flat card seems the favourite for cotton (see Fig. 28).

In working carding machinery there are two main points to be attended to, viz., the satisfactory carding of the material and the designing and arrangements of the various parts to work to the greatest advantage with the least possible wear and tear. The satisfactory carding of the material depends in the first place upon the principle upon which the card works. This in the case of the roller card is as follows:—The swift acts as the main carrying cylinder constantly endeavouring to pass the wool forward, but is opposed by the teeth of the workers, which, acting as a sort of sieve, do not allow material to pass them until it is finely divided up. Thus from beginning to end of a card the workers should be set closer and closer—the first worker a fair way off, the last close to the wires of the swift, but never touching.[1] Thus material is really worked

[1] This is not quite true, as in carding mungo, etc., the wires are set to run into one another.

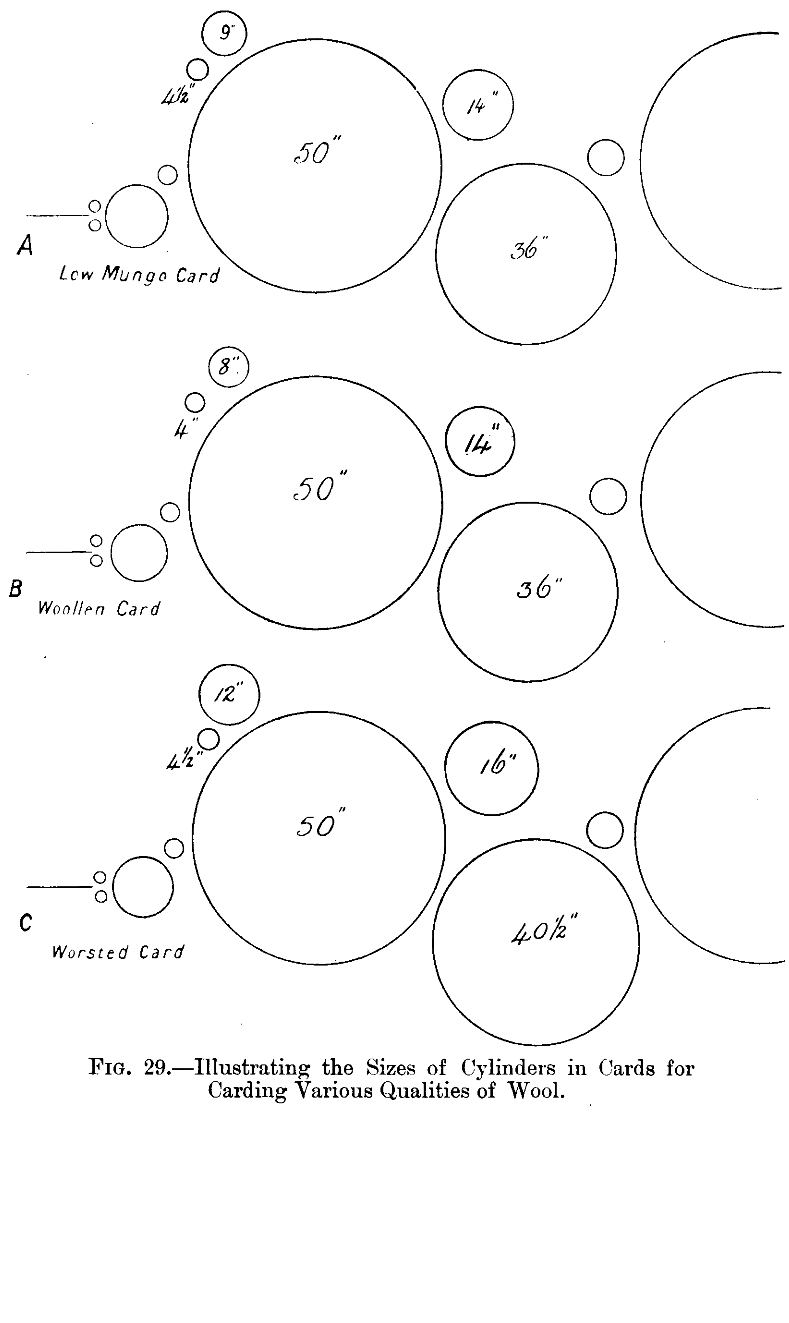


FIG. 29.—Illustrating the Sizes of Cylinders in Cards for Carding Various Qualities of Wool.

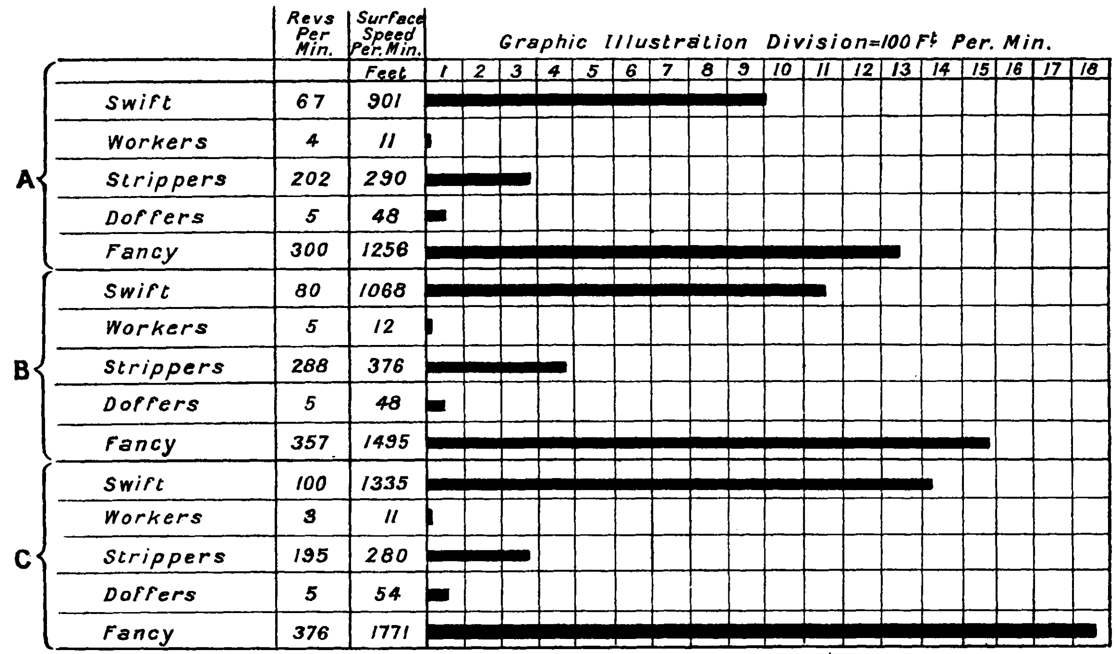


FIG. 30.—Graphic Illustration of the Surface of Speed of the Main Cylinders in *A*, low mungo card; *B*, woollen card; and *C*, worsted card.

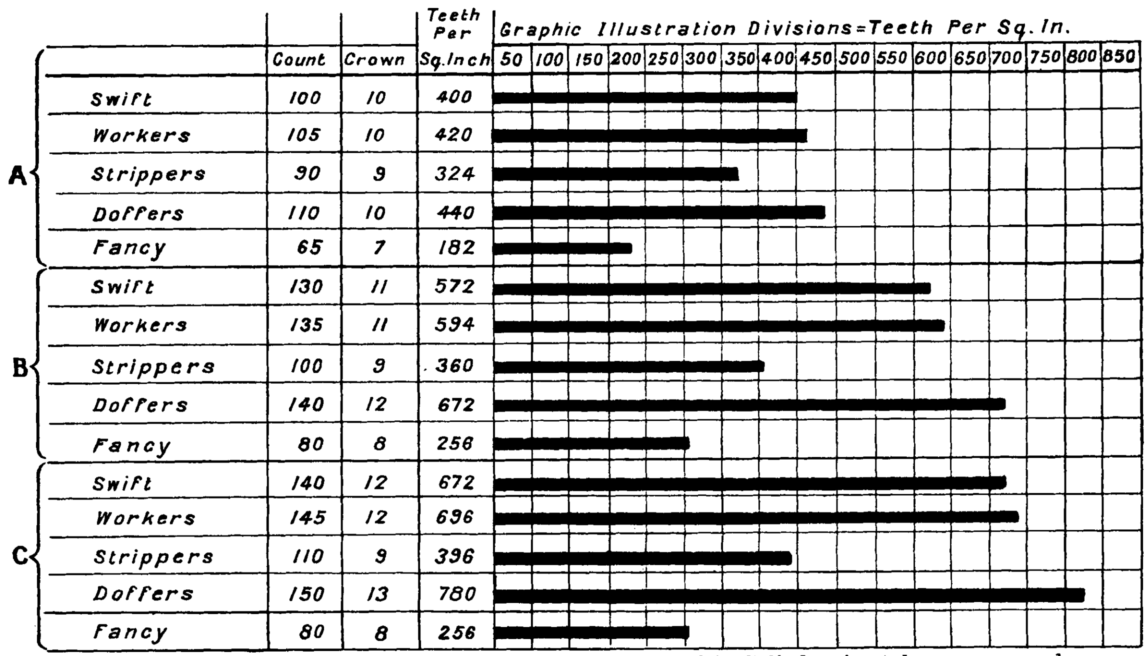


FIG. 31.—Graphic Illustration of the Wire Clothing of the Main Cylinders in *A*, low mungo card; *B*, woollen card; and *C*, worsted card.

by material. The material is condensed or "doubled" on the workers and then elongated or drafted by the strippers, and again by the swift stripping from the strippers. This is the carding operation; feed-rollers, licker-in, fancy and doffer being the means of conducting wool into and out of the machine. It will be noticed that the satisfactory accomplishment of the operation just described depends upon (a) the surface speeds of the rollers, which in part necessarily influence the size of these rollers; (b) the direction in which the rollers revolve; (c) the inclination or bend of the card teeth; and (d) upon the relative density of the card-teeth with which the various rollers are clothed. The wear and tear upon a card depend largely upon the size of the rollers, and of course upon the practical setting.

The material of which the cards are built is of course another important matter, but ordinary engineering principles here apply. Iron is more stable than wood but is readily broken, while wood is more convenient but does not long remain "true." The following diagrams and lists will illustrate the principles of carding and of satisfactorily clothing the card cylinders (see Figs. 29, 30, and 31).

The Dresser.—This machine takes the place of the comb when the material is (a) too rough, as in the case of flax, to be satisfactorily combed; or (b) too slippery, as in the case of silk and china-grass, to be satisfactorily combed.

Briefly, it consists of a series of boards, books or holders between which one end of the material to be dressed is firmly clamped and held; a framework upon which these boards may be fixed so as to be carried continuously into the machine or placed in the machine and withdrawn when necessary; and a series of cleansing combs with

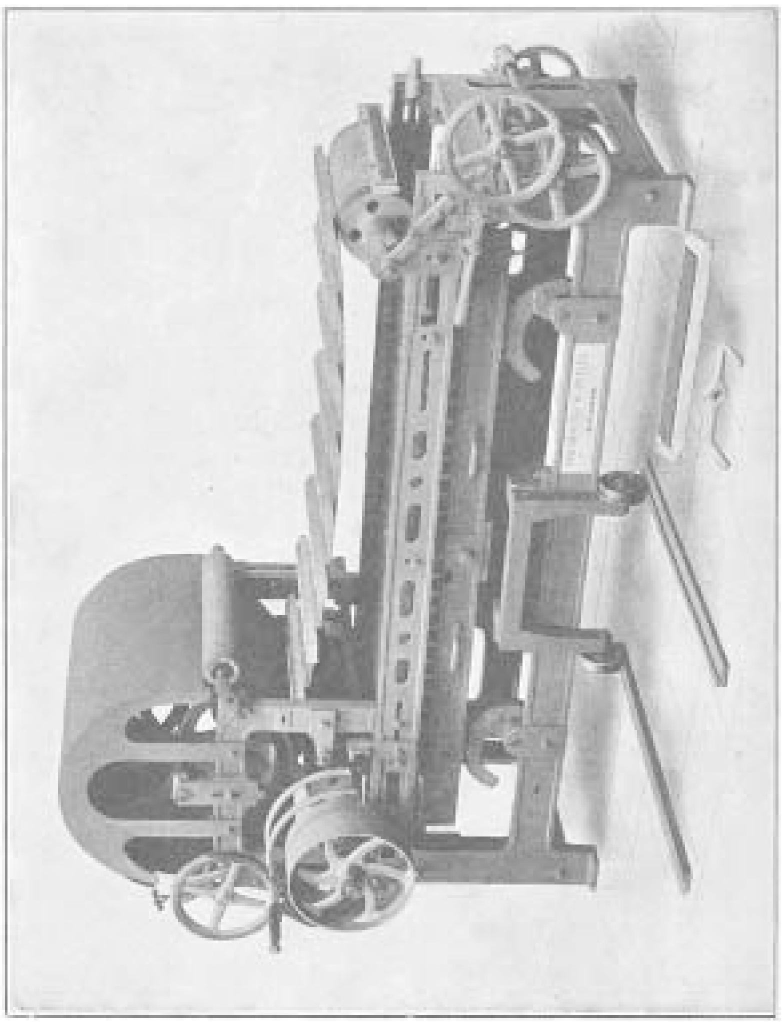


Fig. 32.—Silk Dressing Frame.

cleaning or noil arrangements so that they may work to the greatest advantage.

The material may be presented upwards to the combs as in the case of silk, or downwards as in the case of flax. In the case of silk-dressing the operation is undertaken more with the idea of averaging the fibres into the several different "drafts"; in the case of flax the operation partakes more of a cleansing character (see Fig. 32).

The Comb.—While combing may in part be said to be based upon the idea of averaging up the fibres, still more

FIG. 33.—Position of Large and Two Small Circles in the Noble Comb.

truly may it be said to consist in combing out all fibres under a certain length, leaving the long or top wool to form what is termed the "top" and the short to form "noil." Along with combing, as with dressing, must go a straightening operation; in fact, in the days of the hand comb, the second combing was termed "straightening."

There are two types of comb in use, the horizontal circular and the vertical circular. The Noble comb is the best representation of the horizontal circular (Figs. 33 and 33A). The combing operation here is based upon the drawing out of the long fibres between the diverging circles until the one having the shortest end as it were leaves go, leaving the

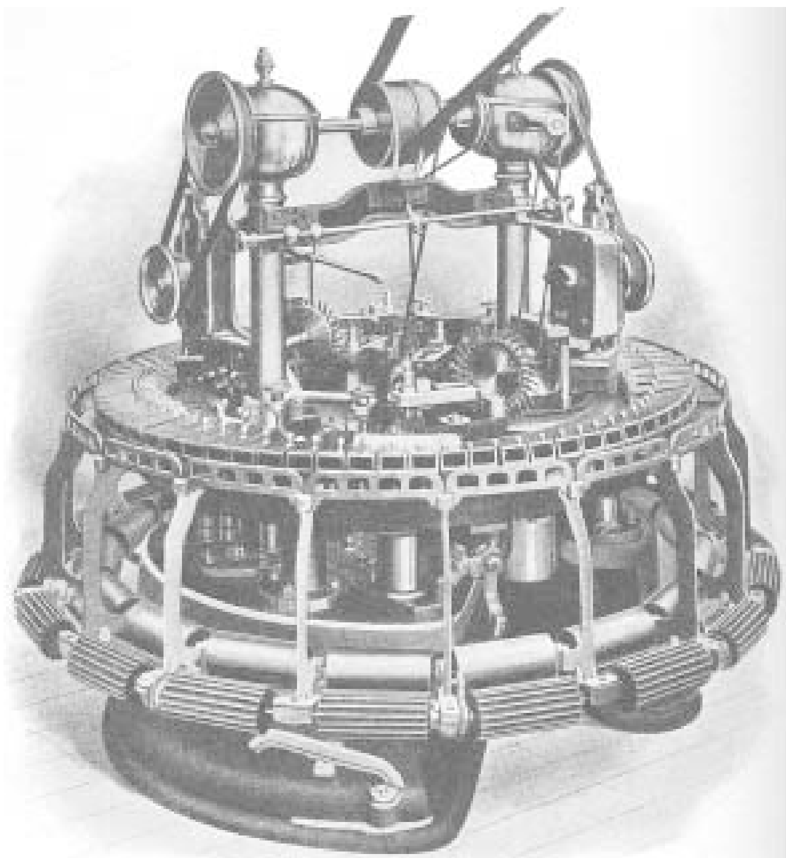


FIG. 33A.—Self-supporting Noble Comb, latest Form.

long fibres hanging on the outside of the small circle and the inside of the large circle, from which they are drawn off by suitably placed rollers. The noil in the meantime

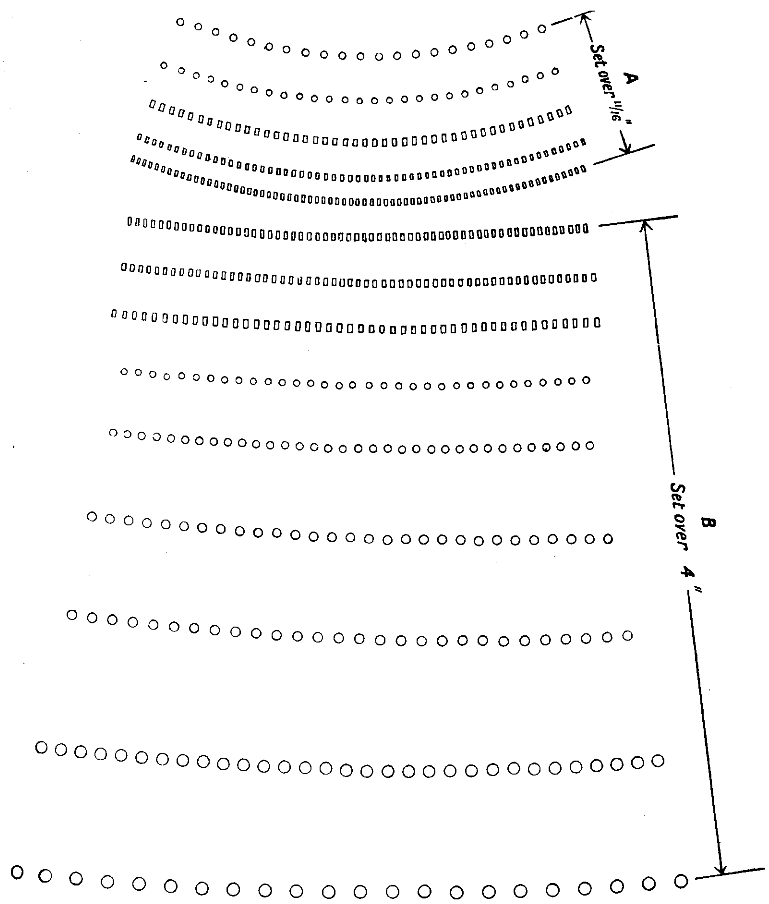


FIG. 34.—Pricking from a Long Wool Noble Comb Circle. *Note.*—For a Botany Comb the "set over" for *A* is $\frac{5}{8}''$, the "set over" for *B* is $1\frac{3}{4}''$.

has been held within the pins, and ultimately is taken off from between the pins of the small circles by what are known as noil knives. The pinning of Noble comb circles

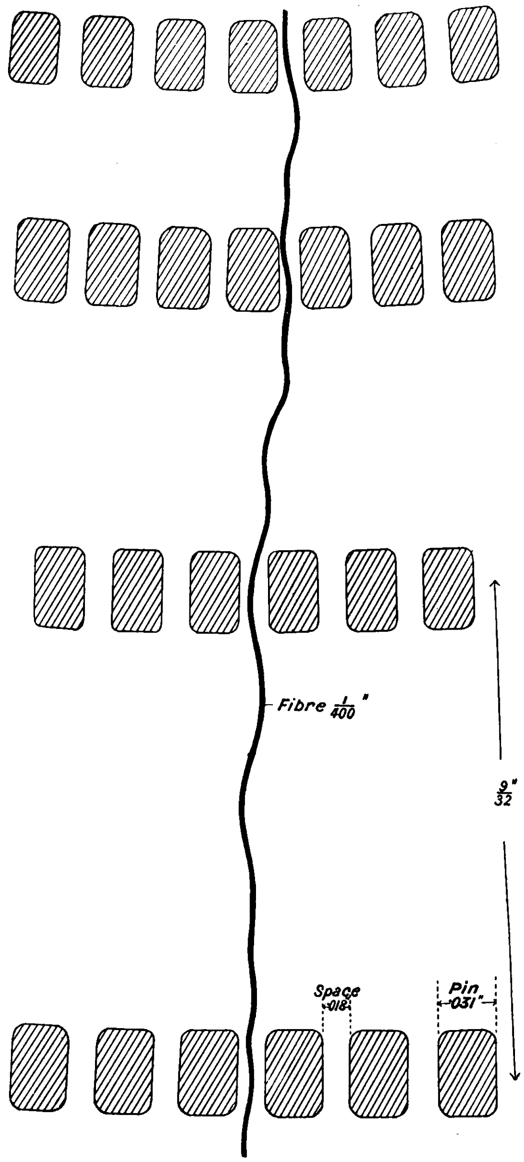


FIG. 34A.—View of Wool Fibre in the Pins of a Noble Comb. Drawn to scale.

should be definitely based upon the diameter of the pin and the space to leave in between for the fairly free running of the fibres—say, one-fourth pin to three-fourths space.

As the satisfactory holding of the fibres by the pins is the basis of the Noble comb, it will be realized that, not only must the distance apart and thickness of the pins be taken into account, but also the set-over or space over which the pins are set (see Figs. 34 and 34A).

The Heilman comb in its various forms is the best example of the vertical circular comb. Briefly, it consists of a pair of jaws to hold a tuft of fibres, a comb cylinder to comb one end of this tuft, a pair of rollers to take hold of the combed end, combs through which the uncombed end may be drawn and thus combed, and a continuous lap forming arrangement. As in most combs the operation of combing must be more or less gradual, the comb cylinder here employed has the first row of teeth fairly openly set, the next closer, and so on, the finest being set about 60 per inch for wool and about 80 for cotton. There is also a preparation of the sliver for combing prior to the jaws referred to coming into action.

The Drawing-box.—This is similar in many respects to the gill-box, but lacks the gills or fallers, their place being taken by carriers which support the wool between back and front rollers. The distance between back and front rollers is usually somewhat greater than the length of the longest fibre being treated, so that in part fibre may be said to be worked by fibre (see Fig. 35).

The Cone Drawing-box.—So far as the drawing action of this box is concerned the action is the same as in the ordinary box. As remarked, however, with reference to

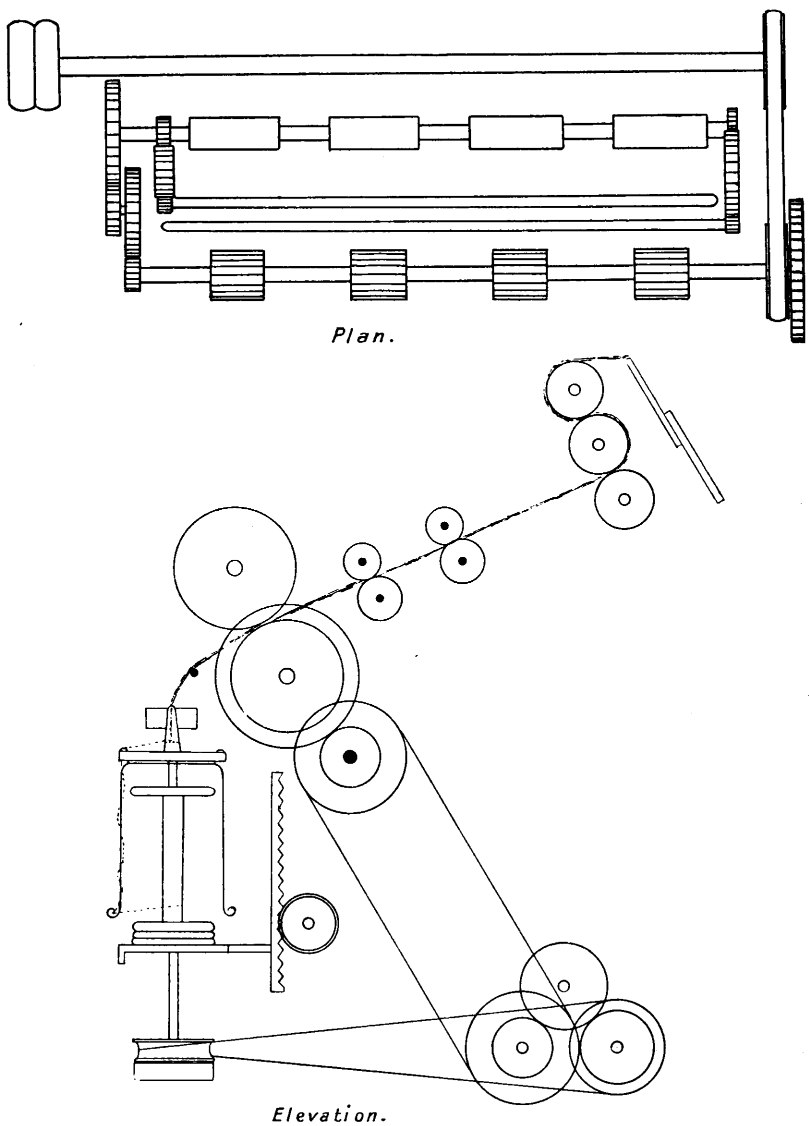


Fig. 35.—Plan and Elevation of a Drawing-box.

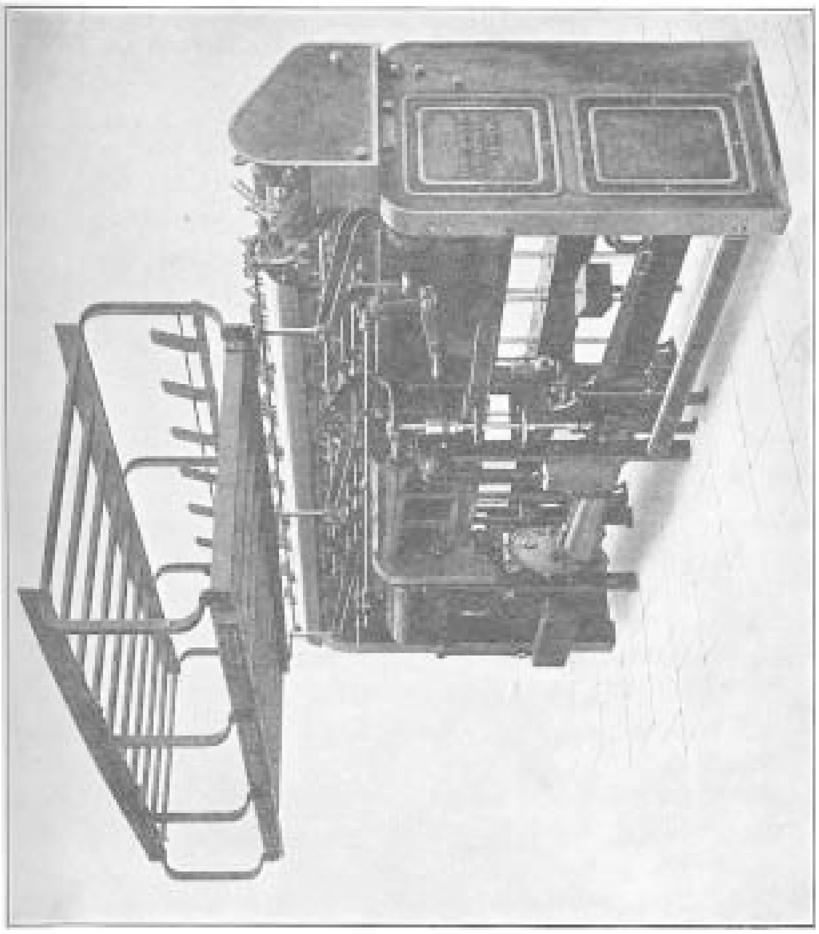


FIG. 36.—Cone Drawing-box.

the scouring machine, the getting of the material into the machine and out of the machine again may be no trifling matter; in fact it may be and in this case is more of a problem than the main operation itself. To put the matter briefly—in a cone-box the material is positively wound on to suitable sized bobbins with practically no strain upon it, while in the case of the ordinary drawing-box twist must

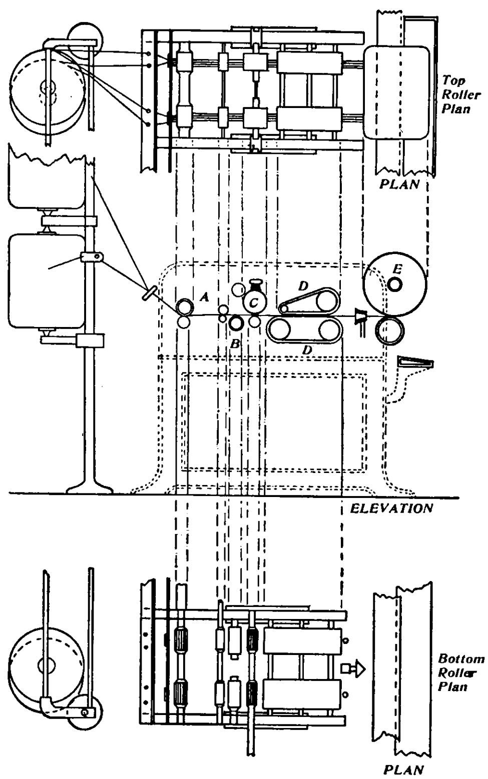


Fig. 37.—French Drawing Frame in Plan and Elevation.—*A*, back drafting rollers; *B*, porcupine; *C*, front drafting rollers; *D*, rubbing leathers; *E*, balling head.

be put into the sliver to give it sufficient strength to pull the bobbin round. It is thus evident that with a cone-regulated wind-on two great advantages accrue—firstly, the slivers may be drawn much softer and thus a better final spin obtained, and less consumption of power in the machine be required; and secondly, larger bobbins may be employed, resulting in more economical working, especially for large quantities. It is also interesting to note that as both flyer and bobbin are positively driven, bobbin may lead flyer instead of flyer leading the bobbin as ordinarily obtains. The relative advantages of these two methods are worthy of careful consideration.

It is interesting to note that with the cone frame the

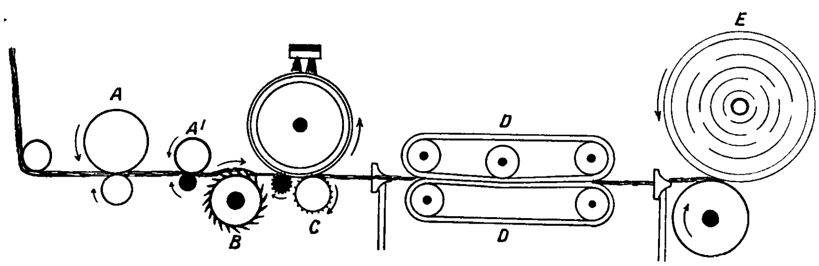


FIG. 37A.—Enlarged View of principal parts in a French Drawing-box.

limit of the strength of the sliver is not in the winding on to the bobbin, but in the pulling of the sliver or roving off the bobbin (see Fig. 36).

The French Drawing-box.—This consists of back-rollers (*A*), porcupine or circular gill or fibre controller (*B*), front rollers (*C*), rubbing leathers (*D*), and delivering head (*E*) (Figs. 37 and 37A). No twist is here inserted, so that a pith-like thread is produced. The arrangement enables doubling and drafting to be effected most readily, and practically does away with the necessity for gills working on screws. The value of this method of producing soft spin mixtures has probably not yet been fully realized in this country.

CHAPTER VII

THE PRINCIPLES OF WEAVING

As previously remarked, the art of weaving, or perhaps more correctly the art of "interlacing," preceded that of spinning. The "wattles" we read of in connection with early methods of building were no doubt willow or other pliant stems of trees or plants interlaced to form a firm foundation for plastering upon. Baskets were similarly made from twigs of suitable thickness, and many other interlacings no doubt preceded the actual art of weaving in the evolution of every race and every country. The idea of actuating in two series all the strands running in one direction, forming a "warp," would soon develop where strands or threads of any required length were forthcoming to form the warp from. The half-heald worked by hand would then appear, followed by the full-heald bringing the feet into play as an aid to the hands. The method of throwing the weft through successive sheds or openings of the warp-threads would similarly pass through many stages before arriving at the present day shuttle and picking apparatus; indeed the fly shuttle itself only appeared in 1738. At first the whole length of warp would be stretched out upon the ground and the weaver would advance as he interlaced the weft from one end of the piece to the other. The idea of beaming the warp on to a roller and of winding up the cloth as woven in order that the weaver might remain seated in one position and thus work to the greatest advantage is still in embryo in some semi-civilised districts. It is more than probable that long before the hand-loom was in any sense developed very elaborate textures were produced—very laboriously it is true—by hand, almost thread by thread and pick by pick. The art of gauze weaving, for example, was perfectly known to the Egyptians, as in mummy cloths we find some really elaborate styles of this order of interlacing. Pile weaving would also be practised in very narrow fabrics or ribbons. Thus it may be said that the art of weaving passed from the stage when very simple means were employed to effect interlacing, to the stage when very complex hand processes were employed in producing elaborate design; then through a stage in which endeavours were made to markedly increase the output by the hand method, finally culminating in the automatic production of fabrics on the power-loom. It may safely be said that so far as we can tell all the most intricate and pleasing methods of weaving by hand came to England from the Continent of Europe. On the other hand most of the mechanical methods of reproducing the somewhat complicated hand methods went from this country to the Continent. Of course there are exceptions to this, but such are exceedingly few and really trivial.

To-day it may be said that there are practically three kinds of weaving, viz.:—**Unit Weaving**, as illustrated in Axminster carpets; **Group Unit Weaving**, as illustrated in the ordinary loom; and **Average Weaving**, as illustrated in Lappet weaving and in the Electric Jacquard.

The Axminster carpet method of weaving is simply an imitation of the Oriental knot, as practised in the making of Turkey carpets and in certain Gobelins tapestries, both hand productions. The weaver—if such he may be termed—simply selects from his bundle of yarn the right colour for a small defined section of the carpet he is making, and knots this yarn into that section. As there is no limit to the colours employed and as the structure is firm and well knotted together, the result obtained is usually magnificent. The Axminster carpet loom follows this hand method as exactly as possible. As each individual thread (or perhaps pair of threads) is "latched" by another distinct thread, hence the term "unit" weaving.

The group-unit system results from arranging as many threads as possible in a warp to interlace in the same way, and then to fix these upon the same apparatus—usually a heald-shaft—which thus very simply works them all together exactly as required. Thus if there are 2,000 ends in a warp and plain cloth is to be produced, the odd ends to the number of 1,000 will be mounted on one heald-shaft, and the even ends to the number of 1,000 upon another heald-shaft. Thus each thread is a unit to itself, but there is a grouping of units to effect simplification in production. This system is by far the most frequently employed, and consequently will be dealt with at some length later.

The average weaving method is quite distinct from the other two methods, as no attempt is here made to work each thread with absolute accuracy as in the other two methods. In certain Electric Jacquards,[1] for example, a rough selection of the threads in accordance with the

[1] Carver's Electric Jacquard, at present being tried in the linen districts of Ireland, is an excellent example of this system.

requirements of the design is effected, while in the case of the Lappet frame, although an endeavour is made to work so accurately that each needle places its thread precisely in the cloth, still a rough averaging up only is attained. With more perfect mechanical appliances it is just possible that this system will be much more fully utilised in the future. The Szczepanik designing and card-cutting apparatus forms an interesting attempt in this direction.

Group-Unit Weaving.—In this method of weaving it is obviously necessary that all previous processes to the actual weaving should be perfectly carried out if really satisfactory weaving is to be the result. The first necessity is a yarn which will weave satisfactorily. To obtain this at a reasonable rate becomes year by year more difficult, as the tendency towards cheapness becomes more pronounced. As a rule a yarn with a minimum strength of 4 ounces is the very weakest which should be employed.

The warping operation consists in obtaining a given number of threads (say 2,000), of a given length (say 100 yards), in a given order (sometimes any order will do; sometimes a colour scheme, say four black, two grey, four white, two grey, must be maintained), and at an equal tension, in a convenient form for being wound on to the warp-beam of the loom. Hand-warping is only resorted to for pattern warps. The upright warping mill is still largely employed both for cotton and wool warps, but is frequently inefficient, as it tends to develop stripiness in the pieces—both a sectional stripiness and a distributed stripiness, owing to its failure to control the tension on individual threads unless very carefully set and geared.

The cheese system is still largely employed, but again tends to show a defect in cheese widths, which while not noticeable in fancies, in plains may become very objectionable. The Scotch or horizontal warping mill is gaining in favour and for fancies is practically perfect, but for plains also tends to show a defect in section of the number of bobbins warped with. The warper's beam system, all things considered, seems the most perfect system, as all defects tend to become distributed and thus neutralise one another. This system is simplicity itself for plain warps, and for fancies, with a little arrangement, may also be used to advantage.

Sizing follows warping, the idea being to coat the thread and thus prevent its wearing fluffy in the gears of the loom; and further, if possible, to strengthen the thread. In the past the tendency has always been to put vegetable size on to vegetable fibres and animal size on to animal fibres. To-day, however, the tendency is to put vegetable sizes on to every kind of material, no doubt on account of cheapness. Of course care must be taken that the vegetable size is readily extracted from the fabrics during the finishing operation, otherwise clouded pieces, owing to this irregular sizing, may result. Certain combination warping and sizing machines are placed on the market, but the call for these has rather declined than increased.

After sizing follows dressing, which consists in winding the warp at a uniform tension—both across and lengthwise—on to the loom beam. English dressers prefer to compress the warp on the beam with the tension that the warp itself will naturally stand, but American dressers often attempt to compress the warp still further in order that the warp beam may be made to carry a greater length of warp, thus saving a certain number of tyings-in.

Drawing or twisting-in follows. If the warp is to be passed through a new set of gears it will have to be drawn by hand through these. A good drawer-in working with a reacher-in passes about 1,000 to 1,200 threads per hour. Should it only be necessary to twist or tye the new warp to the warp—or "thrum" as it is called—already in the gears this may readily be effected either in the loom or out of the loom at the rate of about 1,800 threads per hour. If the warp is plain and no precise order of coloured threads necessary, the recently introduced "Barber-Warp Tyer" will twist or rather tye-in a warp out of the loom at the rate of 250 knots or threads per minute.[1] This machine works on the "average" principle; thus, although almost perfect, it cannot be relied upon to maintain an absolute order of the colours in a fancy warp.

Reference may here be made to the various styles of healds put on the market. It is probable that not nearly sufficient attention is given to this section of the work, as good wearing, easily regulated, and convenient styles of healds are most necessary. Of late wire healds seem to have come much more into use, but there are good and very bad styles of wire healds, so that great care should be exercised in selecting these. Again, a shed full of wire healds means much more weight for the engine to lift.

After drawing-in, "sleying," or the passing of the threads singly or in groups of two, three, four, five or six through the reed is necessary. This is effected at the rate of about

[1] A mechanical "drawing-in" machine is now placed on the market.

2,000 threads per hour by means of two sleying knives worked alternately by hand. Reeds again should receive more attention than they at present claim. English reed makers can make a good ordinary article, but German and French reed makers are much ahead in the production of really fine reeds with properly feathered dents regularly soldered together.

After the warp has been passed through the gears and reed the warp-beam and gears must be lifted into the loom—the gates in the loom shed being sufficiently wide to ensure this without damage to either warp or gears, the gears hung in position, the reed placed in position, the warp attached to the cloth beam by means of a level wrapper, and then after the necessary gearing up the actual operation of weaving ensues.

The principal movements during weaving are as follows:

Shedding, or forming a passage for the shuttle through the warp threads, certain of the threads being definitely raised and the others depressed; threads lifted and depressed being varied for a succession of sheds.

Picking, or the throwing of the shuttle through the shed which has been formed, leaving the pick behind it in the shed.

Beating-up, *i.e.*, the reed beating the pick just inserted up to the cloth already formed to make a firm, even texture.

Letting-off, *i.e.*, unwrapping warp from the warp-beam to take the place of that used up in interlacing with the weft to form the cloth.

Taking-up, *i.e.*, winding up on to the cloth beam the cloth woven, this movement of necessity being worked in conjunction with the letting-off.

The following accessory mechanisms are practically necessary to ensure economical and satisfactory work:

The Boxing Mechanism, by means of which any required colour of yarn is presented, in its shuttle, on the picking plane and thus thrown into the cloth as required.

The Stop-Rod or the Loose-Reed-Mechanism, through which the loom is brought to a standstill should the shuttle fail to reach the box, serious breakage of warp threads thus being avoided. The first style is applied to plain or rising box looms, the latter to circular box looms.

The Weft-fork Mechanism, which only permits the loom to go on with its work while weft is presented to it. Should the weft be broken or absent the loom is immediately brought to a standstill. There are two forms, the side-weft fork for plain looms and looms with boxes at one end only, and the centre-weft fork for double box looms.

The Warp-Stop Mechanism, by means of which the loom is brought to a standstill should any warp-thread break.

The Spooling or Shuttling Mechanism, by means of which when the cop of yarn placed in the shuttle is finished or about to be finished either it or the whole shuttle is automatically ejected and a fresh spool or shuttle pushed in to take its place without stopping the loom or without the intervention of the attendant.

Before describing certain typical looms placed upon the market reference must be made to the various methods of effecting the primary weaving movements and also to certain points of importance with reference to the accessory mechanisms.

Shedding.—To the uninitiated this may seem a simple matter requiring little consideration. Perhaps this would be so were the yarns which it is necessary to weave always strong and were time no object. But yarns must sometimes be woven which will hardly stand dressing, and looms must run from 80 up to 300 picks a minute—although a high

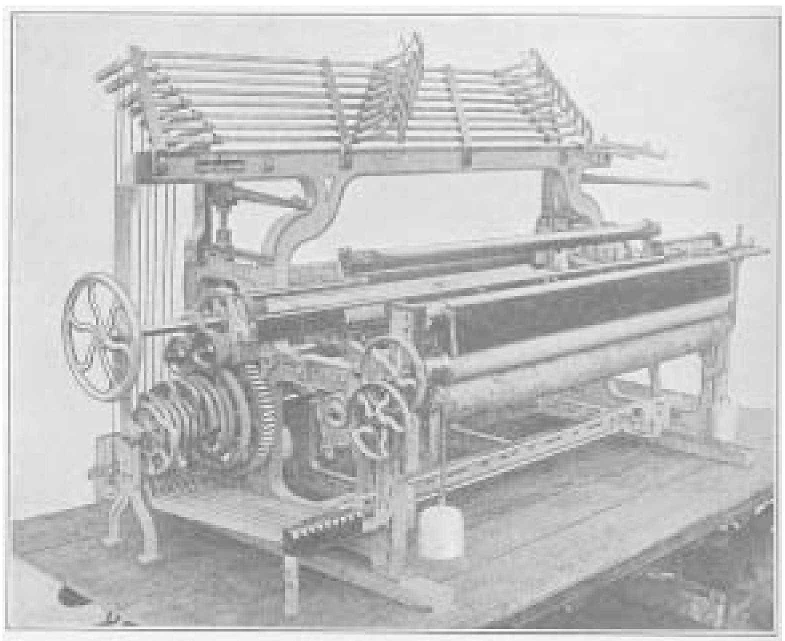


Fig. 38.—Tappet Loom with outside treading.

speed is by no means always economical—and thus it comes about that most careful and detailed consideration must be given to every point in the shedding mechanism. The chief points for consideration are—firstly, the method of selecting the healds to be raised and the healds to be lowered—absolute certainty must here be ensured; secondly, the movement of the healds to put as little strain as possible into the warp threads during the change of shed; and thirdly, the satisfactory holding of the threads up and the threads down during picking to ensure the safe passage of the shuttle. Of the varied mechanisms to effect this, the Tappet mechanism (either inside or outside tread, with

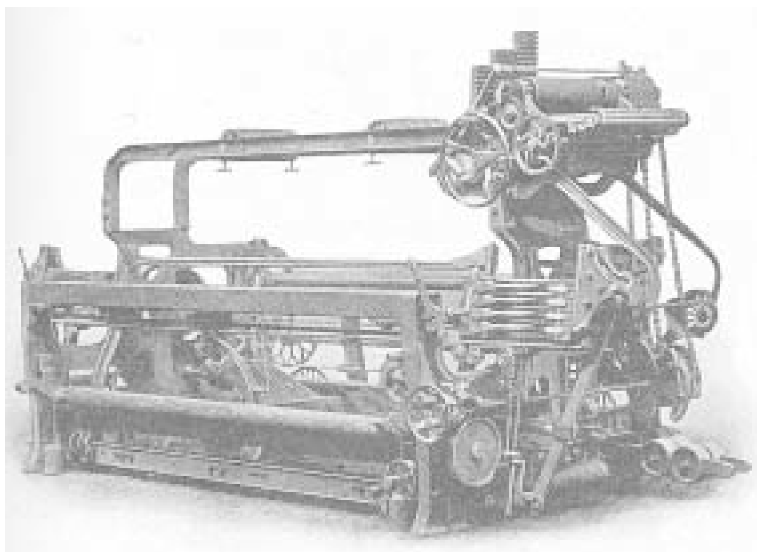


FIG. 39.—Heavy Coating Loom.

"top" or "under" motion) is the simplest and most satisfactory, as the curve for the "rise" and for the "fall" of the heald-shaft can be made to give a simple harmonic motion or any other desired motion, while the "dwell" of the heald-shaft may be regulated to a nicety. (Fig. 38.) Unfortunately, the interlacing or figuring capacity of the Tappet loom is not great, so that for anything above a

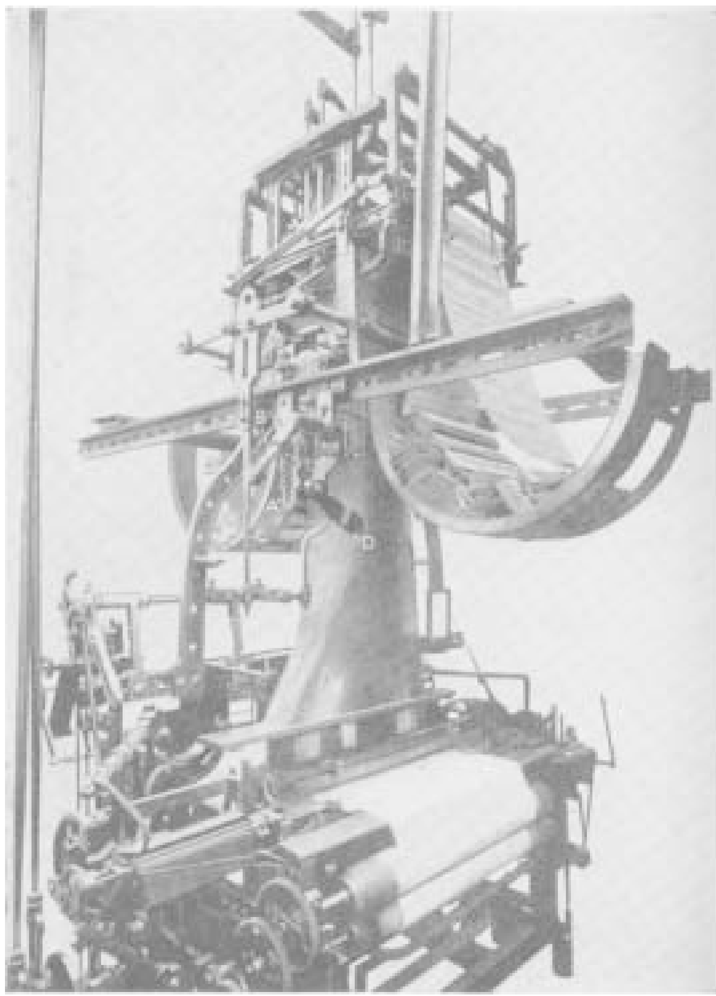


Fig. 40.

weave repeating on 12 to 16 shafts a Dobby must be employed, while for anything above, say, 36 shafts, a Jacquard is employed. The shedding arrangements of Dobby looms are usually in some sense an imitation of the Tappet action (see Fig. 39), but the following variations are to be met with: close shedding and open shedding Dobbies, single-lift and double-lift Dobbies, with combinations of the same. Each possesses certain advantages either for the fabric being produced or in quick and perfect running. The only difference in principle between the Dobby and the Jacquard is that in the Dobby each heald-shaft may usually be controlled positively whether lifted or depressed, while in the Jacquard the lifting only is positive, the depressing being effected by weights on the harness cords. The usual figuring capacities of Jacquards are—Bradford, 300 or 600; Huddersfield, 400; Belfast, 1,200 to 1,800; but there are naturally variations from these precise numbers in each district and for specific purposes. (See Fig. 40.)

Weaving wages largely depend upon the shaft or harness capacity of looms.

Picking.—The throwing of the shuttle through the shed—under the guiding influences of the shuttle-race and reed—is a most difficult and important matter. If thrown too strongly it is liable to break the weft yarn and to wear itself and the loom out quickly, and if thrown too weakly the loom knocks off. Again, the tendency of shuttles to fly out of the shed has necessitated the adoption of shuttle-guards to protect the weavers. There are two main types of picking motions, viz., over and under. The over-pick is the "sweeter" and safer, but unfortunately consumes a large quantity of picking-strap. The under-pick partakes less of the slinging character than does the over-pick, so that for the weaving of lightly-twisted weft yarns such as mohair and alpaca the over-pick system possesses marked advantages.

Beating-up.—Sufficient attention is not paid to this motion by many loom makers, as the satisfactory running of the loom may largely depend upon the satisfactory running of the going-part which carries the shuttles, etc., as well as the reed. The points to be carefully considered are—sweep of crank, length of connecting pin, method of attachment of connecting pin to sword-arms, and the relationship of sword-arm connections to crank centre.

Letting-off and Taking-up.—These two mechanisms are usually worked in conjunction, for what the cloth requires must be delivered to it by the warp-beam. Both these mechanisms may either be positive or negative, but usually the taking-up motion is positive (so that the wefting of the cloth is perfectly controlled) and the letting-off negative. The latest form of positive letting-off motion, however, in which the tension of the warp itself regulates the letting-off, has proved a marked practical success and is nearly always adopted for heavy wefting. For lighter work and even for some forms of heavy work the ordinary or special form of negative letting-off motion is adopted. The taking-up of the cloth woven is almost invariably effected by means of a friction or sand roller (which bears upon the cloth beam, and thus turns it by friction at a fixed rate, notwithstanding its increase in circumference) driven through a train of wheels, the last one of which receives its movement from a pawl on the sword of the going-part. One or more of these wheels may be changed to give the required number of picks in specific cloths. In the best train there is a direct relationship between the picks per inch and the teeth in the change wheel.

The Boxing Mechanism.—Boxes are made in two forms—rising and falling, and circular. In rising boxes there is no limit as to size or number, while in the case of circular boxes there is a distinct practical limit in size, and it is not as a rule convenient to have more than six boxes to the round. Thus, for heavy thick materials rising boxes of great size are employed; while for fine cotton, silk, etc., the smaller circular boxes are mostly used.

Looms are made in three forms with reference to their boxes, viz., without boxes, *i.e.*, plain looms; boxes at one end only; and boxes at both ends. In looms with boxes at one end only there are limits in colouring, as only double picks may be inserted without very special arrangement and loss of time, while in one most important type of circular box there is a further limit as to which colours may be presented on the picking plane.

The addition of boxes to a loom usually reduces its speed from 5 per cent. to 10 per cent. and necessitates the payment of a slightly higher wage to the weaver.

The Stop-rod and Loose-reed Mechanism.—Plain and rising box looms are fitted with the stop-rod mechanism, while circular box looms are fitted with the loose-reed mechanism. In the stop-rod mechanism the reed is prevented from coming within less than, say, 4 inches of the fell of the cloth, unless the shuttle is in the box, by means of a stop-rod which plays against a special casting, termed the "frog." As the shuttle normally enters the box, however, it lifts this stop-rod clear of the "frog" and so the loom proceeds with its task. Should the shuttle fail to reach the box and stop in the shed, the loom is knocked-off by means of the stop-rod coming against the special casting or "frog," which, in turn, acts upon the setting-on lever and loom brake. Few or no warp threads will be broken down, as the reed cannot get nearer than about 4 inches to the fell of the cloth—a distance which is just judged sufficient to save breakage of warp threads when the shuttle is left in the shed.

In the case of the loose reed mechanism the shuttle is allowed to knock the reed out to prevent the reed breaking the shuttle through the warp threads. To allow of this the reed is only lightly held until it is within, say, 2 inches of the cloth—when, if the shuttle were there, the reed would be forced out and the belt thrown on to the loose pulley—after which it is firmly locked for the beat-up. Owing to this locking and unlocking of the reed heavy wefting cannot be effected by this mechanism.

The Weft-fork Mechanism.—In plain looms this is at the side, close to the setting-on handle. It consists of a small three-pronged fork passing through a grid in the going-part, across which grid the weft has to pass. If the weft be present it does not allow the prongs of the fork to pass through the grid, but, instead, tilts the fork. At this moment a hammer head is drawn back by means of a projection on the low shaft of the loom (once every two picks), but nothing happens if the weft is there and has tilted the fork. If the weft is not there, however, the fork is not tilted and a catch upon its extremity is caught by the hammer head and the loom thus brought to a standstill. Mr. Pickle, of Burnley, has patented a markedly improved form of this fork which mechanically may be considered perfect, and this cannot be said of the ordinary form.

The centre weft-fork mechanism—which must be employed when there are boxes at both ends—acts through the weft supporting if present, or allowing to fall if absent, a lightly-weighted fork, which, by means of a slide, is connected with the setting-on lever.

The Warp-stop Mechanism.—While the weft-stop mechanism has always been considered as essential to the satisfactory running of a loom, the warp-stop mechanism has never been in favour, and obviously it can only be of economical value in the case of weaving tender warps (when possibly it helps to break down threads) or where one attendant looks after a large number of looms. With the comparatively recent introduction of the automatic loom, warp-stop methods have increased in favour, but their application in anything but very plain work is still comparatively rare.

There are two forms placed on the market—the mechanical and the electrical. The chief objection to them is the time taken in readjustment when drawing in a new warp, while, of course, it is conceivable that they may in all warps occasionally cause ends to break down. Possibly the greatest advantage lies in that a weaver cannot produce an imperfect piece as the loom will not run with ends down.

The Spooling or Shuttling Mechanism.—This is the mechanism of most recent introduction, although so called automatic looms were tried about forty years ago. If one weaver is to attend to sixteen or twenty-four looms, it is evident that there must be some self-shuttling arrangement, or there will always be some looms standing. On the other hand, the additional mechanism involved may necessitate additional attention on the part of the tuner or overlooker

—usually a high-wage man—and hence he will not be able to follow so many looms.

In the cotton trade the Northorpe loom—one form of the automatic loom—is being largely adopted, the spool ejecting mechanism being brought into play by the weft running off, so that each change of spool may be accompanied by a broken pick in the piece. This broken pick would be a serious defect in cloths other than cotton, so that some means to indicate for the ejection of the spool before all the weft has run off must be adopted. On the other hand, spools must not be ejected before the weft is practically run off, or the waste will be too great. The latest system of effecting this is by means of a special split bobbin held together by the weft. The pike of the shuttle is so designed that it gently bears upon the split bobbin, but only succeeds in opening it just as the last layers are taken off. The opening of the bobbin brings into action the spool ejection mechanism, the old spool or bobbin is ejected and a full one automatically taken from the reservoir and put in its place without interfering with the running of the loom.

The classification of looms is based chiefly upon the type of shedding mechanism, but sometimes upon the boxing capacity. Thus looms are usually classified as Tappet, Dobby, or Jacquard looms, but manufacturers of tweeds and coloured fancy goods naturally think more of the boxing capacity than of the figuring capacity, as they usually only require a four or six thread twill weave, depending upon colour as a means of beautifying their fabrics, although, of course, the colour is usually applied to a good sound structure.

The outside tread Tappet loom is most largely employed in Yorkshire for all classes of simple interlacings, including such light weight goods as Orleans, Italians, cashmeres, serges, etc. The inside tread Tappet loom is more largely employed in the Lancashire cotton trade for all styles of simple cotton fabrics, and in broad looms for heavy Yorkshire woollens.

The Dobby loom—of various types and makes—is employed in both Lancashire and Yorkshire for fancy styles, which are not floral, but rather fancy in the sense of being compounded of more or less intricate interlacings.

The Jacquard loom is employed when elaborate figuring is necessary, as in this loom from 100 to 1,800 threads may be controlled individually by means of cards with holes cut or uncut to produce the required pattern.

For special purposes combinations of the three types are frequently met with. In tapestries, for example, the Jacquard is frequently mounted in conjunction with a Tappet or a Dobby; for skirtings Tappets and a Dobby are frequently combined, while boxes may be employed in conjunction with any and every shedding combination, sometimes the relationships of Jacquard, Tappets, and boxes being very complex, but really most delightfully controlled; from which it will be gathered that the weaver who can perfectly control such a combination is no mean, unintellectual person, but rather must be regarded as a truly matured craftsman possessing at least some of the qualities of the methodical scientist.

CHAPTER VIII

THE PRINCIPLES OF DESIGNING AND COLOURING

As it is generally recognized that the perception of form precedes that of colour it is more than probable that the first attempts at woven decorations would take the form of diagonals, stripe and check effects, possibly produced by interlaced rushes or bands.[1] Just as the Norwegian peasant takes out his knife and carves the wooden wall by the side of his chair so would our ancestors amuse or profit themselves by schemes of interlacings with such materials as were to hand. Thus we can well imagine the various natural shades of wool such as are indirectly referred to in early Biblical history for example, affording opportunities for the development of design in form long before artificial colours made their appearance. For the sake of variety various kinds of materials would next be tried, and so a second factor of interest would be introduced. Finally, the appreciation of colour would be developed and attempts made at colouring the raw materials by such herbs, etc., as were available, or rather of which the colouring properties were known. For it must have been a grievous thing to the ancients to discover that red poppies would not yield their colour, that Tyrian purple must be sought

[1] The Scotch plaid was originally a plait or possibly a number of interlaced plaits.

for in a mollusc and not in the gorgeous garb of nature. As has been already pointed out, the inborn love of man for artistic productions was developed long before the present-day economic spirit; hence artistic weaving was developed at a very early date and was followed much later by attempts, firstly, at quicker production of artistic patterns, and, secondly, by attempts to produce goods more economically and by simpler means. A relic of this evolution is in evidence to-day in the fact that so far as the art of designing and weaving is concerned England is absolutely indebted to the Continent, everything good coming to us from Italy, France, the Netherlands, or Germany. On the other hand, so far as economical production is concerned, the Continent is indebted to England, we leading the way in all power machinery. Curiously enough, America led the way during the last century in devising means for the quicker production of elaborate styles, as instanced in the plush wire loom and the Axminster carpet loom. This was, no doubt, due to the enormous wealth so rapidly developed resulting in a great call for what might be regarded as luxuries.

Present-day textile design may be very conveniently studied under its three factors—material, interlacing, and colour. Of course, there are many varied combinations of two or more of these factors, but brief study will prove that these factors are really the key to the thorough comprehension of all textile design, and that consequently each merits careful consideration.

Materials.—These briefly are animal, insect, vegetable, mineral, and artificially produced fibres or filaments. Among the animal class are specially to be noted all the varieties of wool, mohair, alpaca, vicuna, cashmere, camels' hair, horsehair, rabbit fur, etc.

A special class is made of the insect fibres, seeing that they are so valuable and useful, and further that from the point of view of chemical reaction they cannot quite be classed with the true animal fibres. Cultivated and wild silks are the chief representations, while certain "spider" silks and other varieties of cocoons are continually making their appearance.

The vegetable fibres may be divided into two very distinct classes—viz., the fluffy seed hair types of which cotton is the principal representative, but of which various "thistle-down" and other fibres keep putting in an appearance; and the stem fibres, such as flax, hemp, jute, china-grass, etc. Plants themselves, as notably the mosses, also are sometimes spun and woven.

The mineral fibres are principally metallic threads, and such special minerals as asbestos and silica, which are specially spun and woven into fabrics for fire-resisting and other purposes and in the form of glass for pure novelty.

The artificially produced fibres include artificial silk, artificial linen, paper, and, latest of all, some organic or crystalline forms of other substance somewhat of the same character as asbestos, which lately have been successfully produced in Germany.

It should be further noted in this connection that it is not sufficient to simply consider the raw material. The manner in which it has been prepared and spun may create differences as marked as the differences between some of these distinct classes. For example, there may be a greater difference between woollen and worsted yarns and net and spun silk yarns than there is between raw wool and cotton. The arrangement of the fibres in the threads of which a fabric is composed, while not directly affecting the interlacing, may nevertheless indirectly cause the designer to adopt specific styles of interlacing to develop a particular characteristic in the resultant cloth; so that it is customary to pay particular attention to this apparent detail, and especially to consider the conditions of twist in both single and twofold yarns. If, for example, three lots of two 40's black botany yarns are twisted 7 turns, 14 turns, and 28 turns per inch respectively, in the woven fabric they will show a marked difference. If the yarn be black and white twist not only will there be a difference in texture, but also in the speckled appearance of each lot of yarn as it appears in the piece. The direction of twist of warp and weft and also in relationship to twill interlacings is also very important.

Interlacing.—There are three recognized methods of producing fabrics—viz., by felting, by knitting, and by weaving. Felt fabrics are essentially fibre structures. Perfectly mixed and equalized films of wool are superimposed one on the top of the other until a sheet, say, 40 yards long, 60 inches broad, and 4 inches thick, of a more or less "fluffy" nature, is produced. This under heat and acid is hammered, milled, or felted into a comparatively thin texture known as "felt."

Knitted textures usually consist of one thread interwoven with itself, but there are now varieties of knitted fabrics which do not entirely fulfil this condition. The above two classes, although most important, must in this work give precedence to the third class, the "woven" fabric.

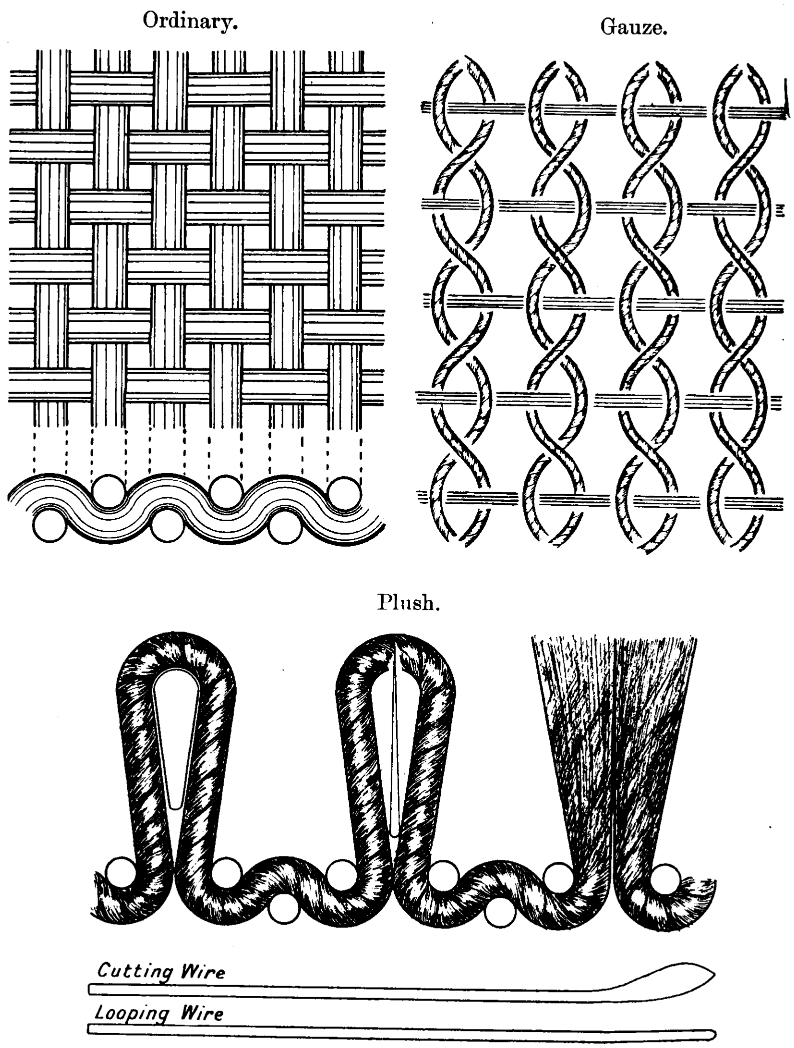


FIG. 41.—Ordinary, Gauze, and Plush Interlacings, *i.e.*, straight thread, curved thread, and projecting thread structures.

Of woven fabrics it is evident that there will be three varieties, along with their combinations, viz., straight thread fabrics, curved thread fabrics and projecting thread fabrics, having their representation in the ordinary woven texture, the gauze texture and the plush texture respectively. (See

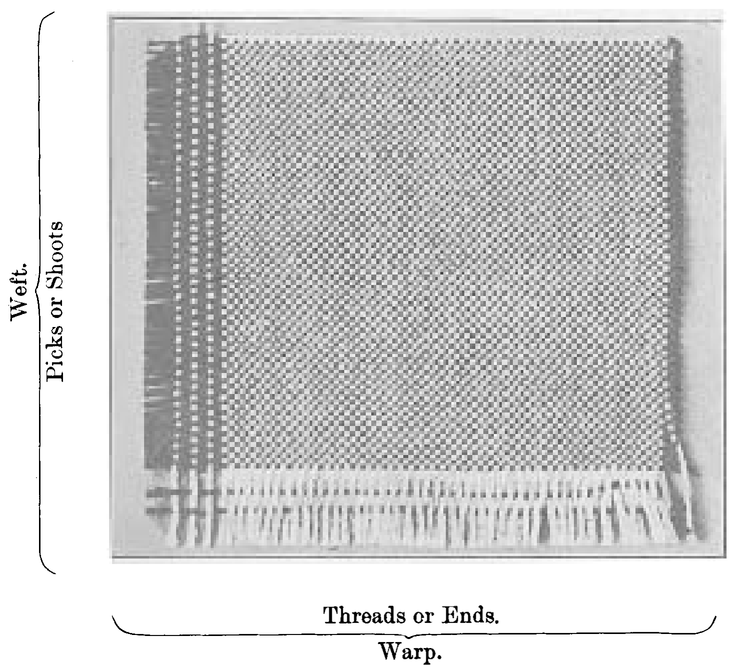


FIG. 41A.—Showing, with a Fabric composed of White Warp and Black Weft, Plain Weave Interlacing.

Fig. 41.) There are also certain special styles which do not well come within the range of any of the above three classes; but these may best be considered as exceptions after the above three classes have been fully studied. All the woven fabrics increase vastly in interest if regarded as

"a mass of balancing strains." The adoption of this attitude results in most interesting developments, especially with reference to curved thread or gauze fabrics.

Of the straight-thread or ordinary fabrics the following variations are to be noted:—

(*a*) Variations in the makes of plain cloths, hopsacks, etc.

(*b*) Rib cloths, plain and fancy, in both warp and weft direction;

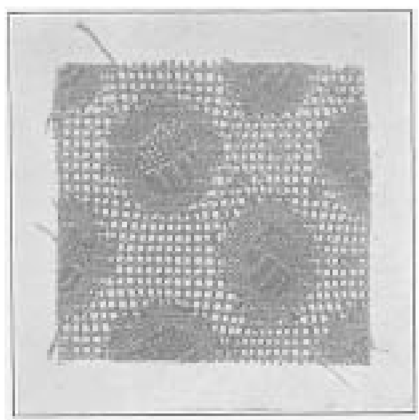


FIG. 41B.—Gauze Ground Fabric upon which a Plain Cloth and Weft Flush Figure is Thrown.

(*c*) Twill cloths, both plain and fancy;

(*d*) Rib-twill cloths of the "corkscrew" type;

(*e*) Sateen cloths, warp or weft face of various qualities;

(*f*) Crêpe cloths, the antithesis of the sateen cloth;

(*g*) Spotted cloths based on the single cloth structure;

(*h*) Figured cloths based on the single cloth structure;

(*i*) Extra warp or weft, or warp and weft figured cloths;

(*j*) Double cloths or treble cloths for figuring or adding weight, or for both figuring and weight.

In Figs. 42 and 42A illustrations (enlarged) of the chief of these varieties are given.

There are many varieties in each of the foregoing classes, but as such would require a treatise larger than the present the reader is referred to the author's work on "Textile Design," and to "Designing for Shaft Work," by F. Donat, of Vienna (published in German only).

Of curved thread or gauze fabrics the following variations are to be noted :—

(*a*) Variation in the number of threads crossing: one

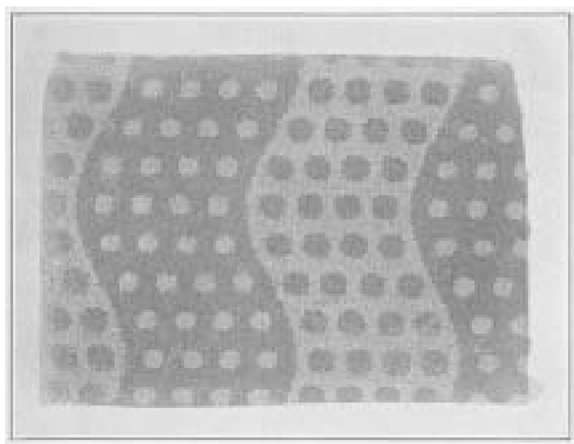


FIG. 41C.—Plush Fabric.

crossing one, two crossing two, one crossing three, one crossing four, etc.;

(*b*) Variation in the number of picks grouped together and in the manner in which they are grouped together by the crossing threads (see Fig. 43 and 43A);

(*c*) Variation in the yarns—thicknesses, colours, etc.—woven together (see Fig. 43B);

(*d*) Variation in the crossings—leno, gauze, plain—which may be woven together;

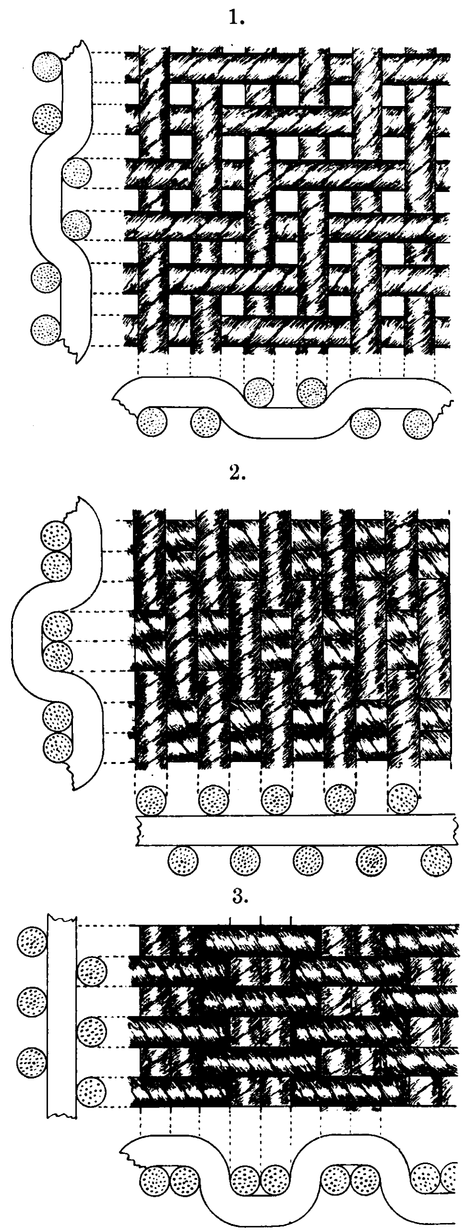


Fig. 42.—1, Ordinary; 2, Warp-rib; and 3, Weft-rib Interlacings.

(*e*) Variation in figuring by various gauze or gauze and ordinary interlacings (see Fig. 41B);

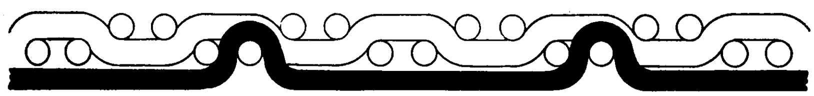
(*f*) Variation by the introduction of extra materials (see Fig. 43C);

(*g*) Variation producible by employing double-gauze structure (see Fig. 43D);

(*h*) Variations by combining gauze and pile structures.

Again, each of these classes has many varieties which cannot be dealt with here.

4.



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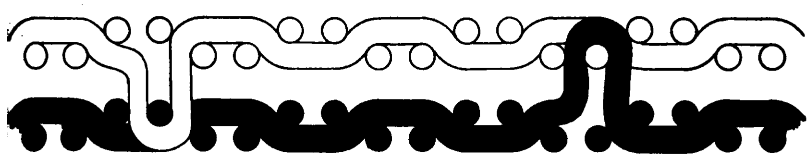


FIG. 42A.—4, Weft-back; and 5, Double Cloth Interlacings.

Of projecting thread structures usually termed "pile" fabrics the two great varieties are warp and weft piles. The former, as will be realized by referring to Fig. 44, are formed by pulling up the warp out of the body of the cloth during weaving, usually by means of wires, to form a brush-like or "pile" surface. The latter are formed by floating certain picks over the surface of an otherwise firmly-woven piece and then throwing these floats up as curls by shrinking the ground texture or as a cut pile by severing these floats either in or out of the loom. In this latter

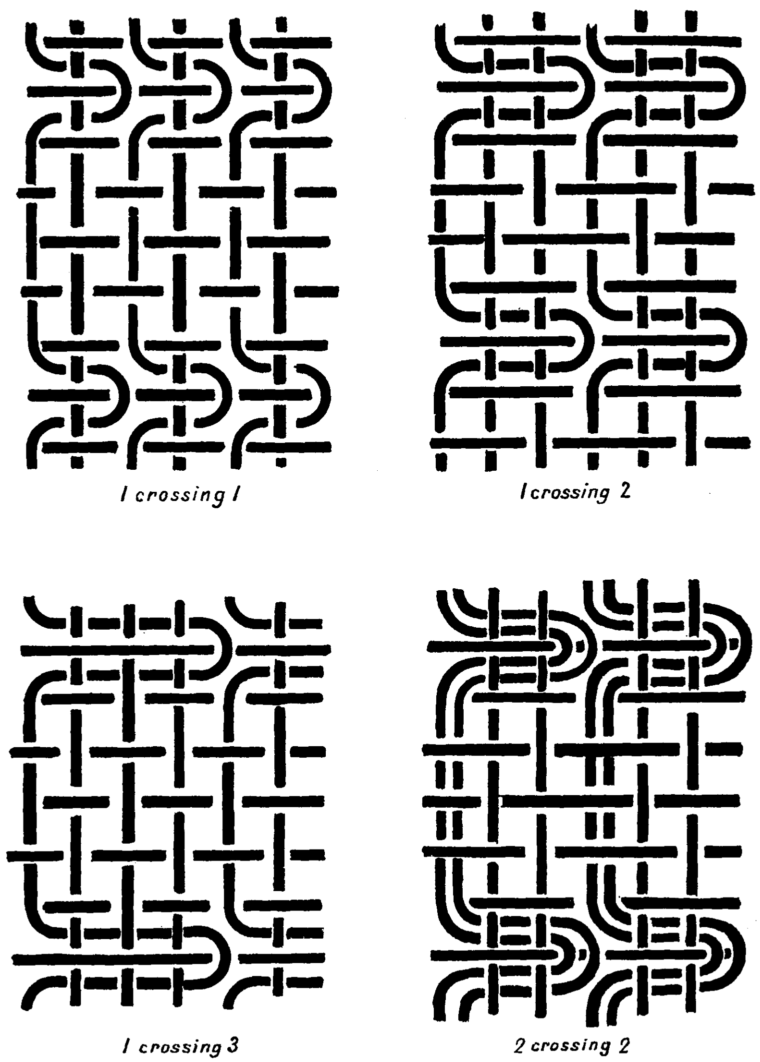


Fig. 43.—Four Varieties of Simple Gauze Crossings.

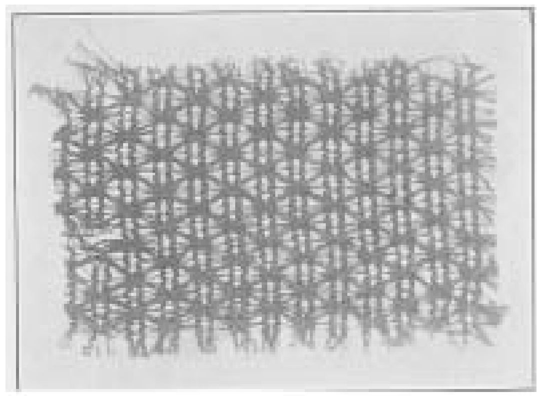


FIG. 43A.—Gauze Structure with Grouping of the Picks as the Characteristic Feature.

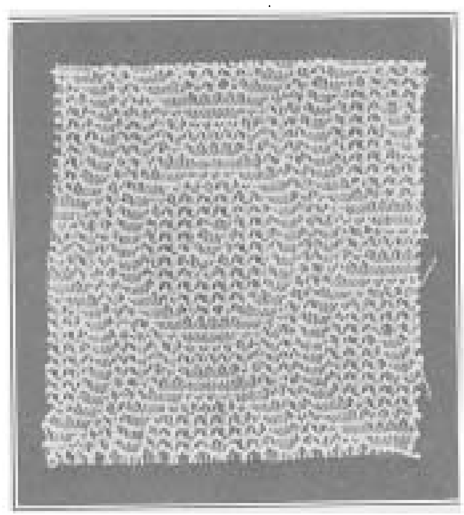


FIG. 43B.—Gauze Structure with Fancy Yarn Introduced.

case some most useful types of pile fabrics are obtained —fustians and corduroys for example—by distributing or concentrating the pile on certain sections of the cloth by the suitable arrangement of the positions where the floating picks are bound into the fabric.

Of pile fabrics the following varieties are to be noted :—

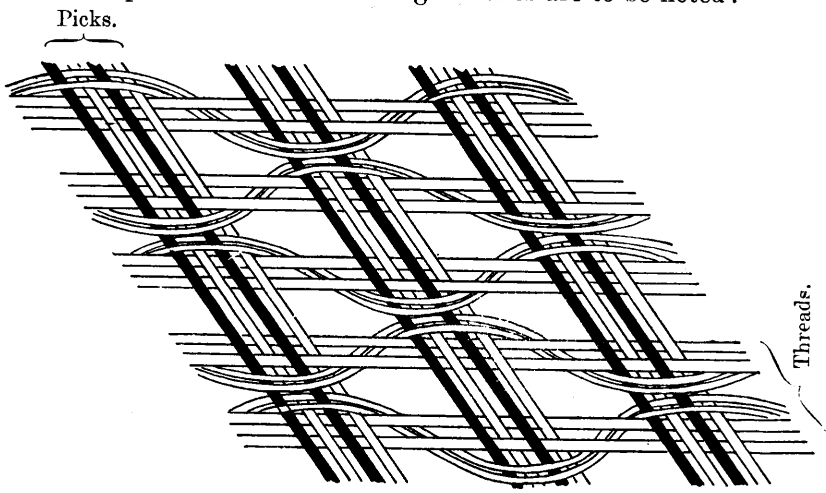


FIG. 43C.—Double Weft Gauze.

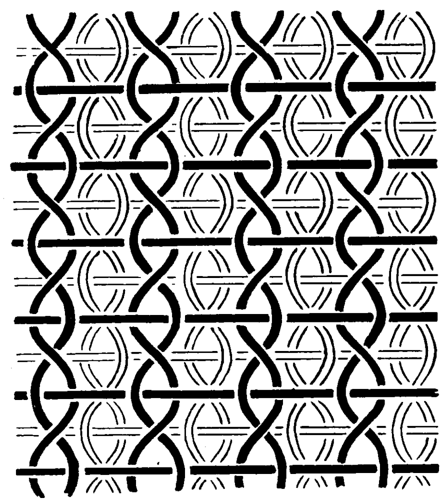
(*a*) Variation in density of pile, so that the ground texture may show through or may be completely hidden ;

(*b*) Variation in length of pile;

(*c*) Variation by the use of cut and looped pile—the difference between the same coloured yarn cut and looped being ample to design with (see Fig. 41c) ;

(*d*) Variation in the form taken by the cut, or looped, or cut and looped piles, such as stripes, checks and figures.

Perhaps in this class a special section should be devoted to varieties of piles produced on the "double-plush" principle as illustrated in Fig. 45; but as these generally speaking lend themselves to the same variations as the other pile fabrics already dealt with, they are considered together. There is no single work which fully treats the



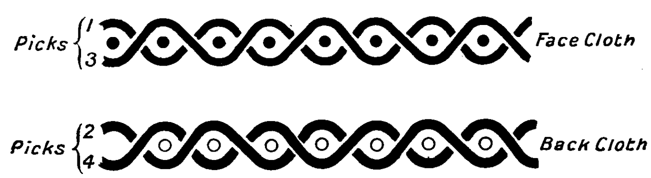


FIG. 43D.—Double Gauze Interlacing.

three sections of warp piles, weft piles and double piles; but the work of Donat already cited may be consulted with advantage.

The Use of Point-paper.—To facilitate designing squared or point-paper is employed Briefly it consists of spaces

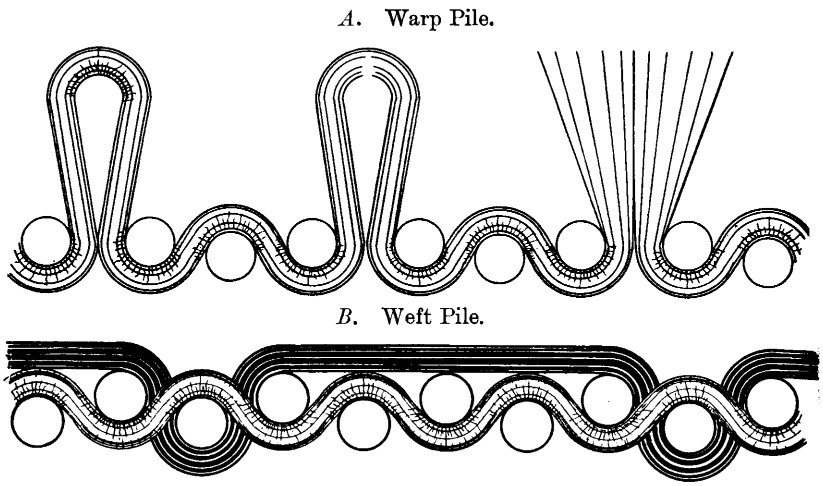


FIG. 44.—Two Types of Pile Fabrics.

lengthwise, representing warp threads, and spaces crosswise representing weft threads, or "picks," as they are termed. *This paper must not be regarded as so many squares,*

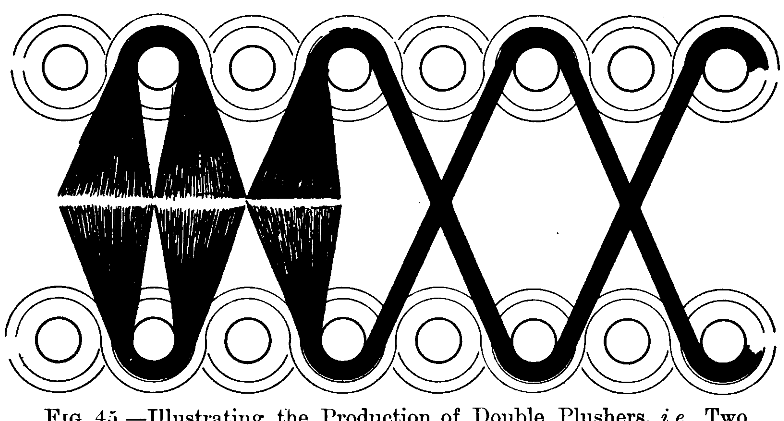


FIG. 45.—Illustrating the Production of Double Plushers, *i.e.*, Two Single Pile Fabrics, face to face.

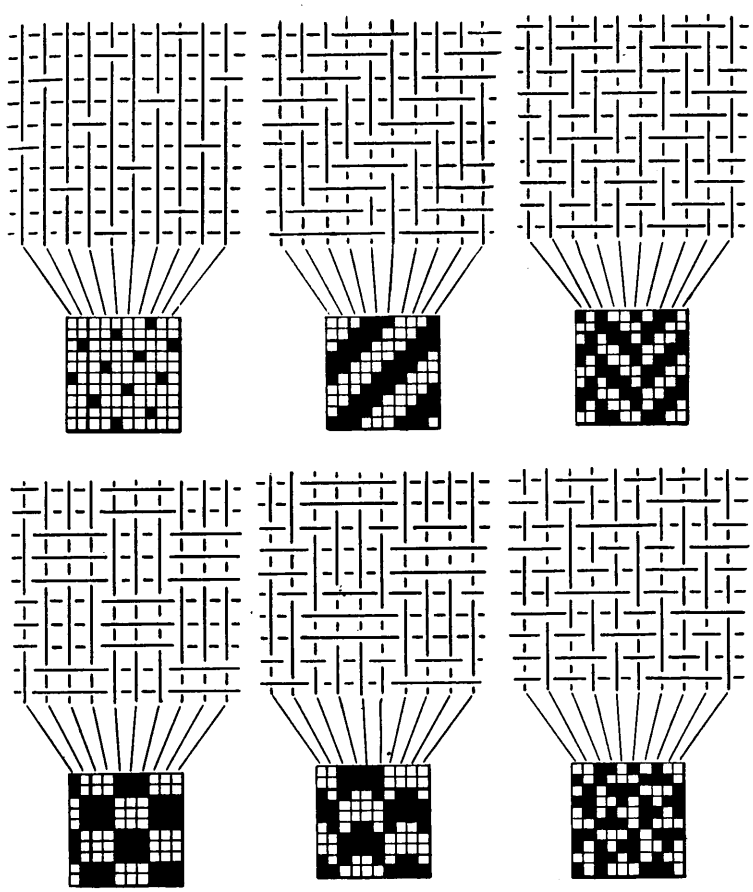


FIG. 46.—Example of the Representation of Simple Interlacings on Point or Square Paper.

but as warp threads—say of a white material—under which lie so many weft picks—say of a dark material. Then whenever weft is required to come over warp, that particular section—*in this case a square*—is marked black. Thus to the well-versed textile designer the point-paper weave does fairly correctly represent the actual appearance of the cloth, although it is obvious that such weaves must be viewed through the eyes of the designer's many and varied experiences. To further elucidate these somewhat brief remarks six examples of interlacing, with their respective paint-paper plans, are given in Fig. 46.

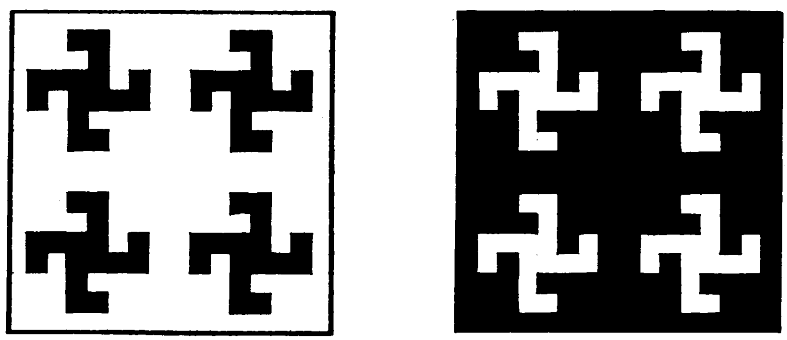


FIG. 47.—Example of the Reversing of Pattern due to Defective Grading of Colour Ranges.

Colour.—Colour may obviously be applied to all the foregoing fabrics. So subtle is the colouring of textiles that the designer well versed in the colouring of one class of goods may, nay, probably will, be unsuccessful in the colouring of another class of goods.

In the abstract colours should be apportioned to the fabric for which they are designed; they should be appropriate and artistic in themselves if solid shades, and in their combinations for multi-coloured styles. Note should also be made that colours cannot be considered irrespective of luminosities,

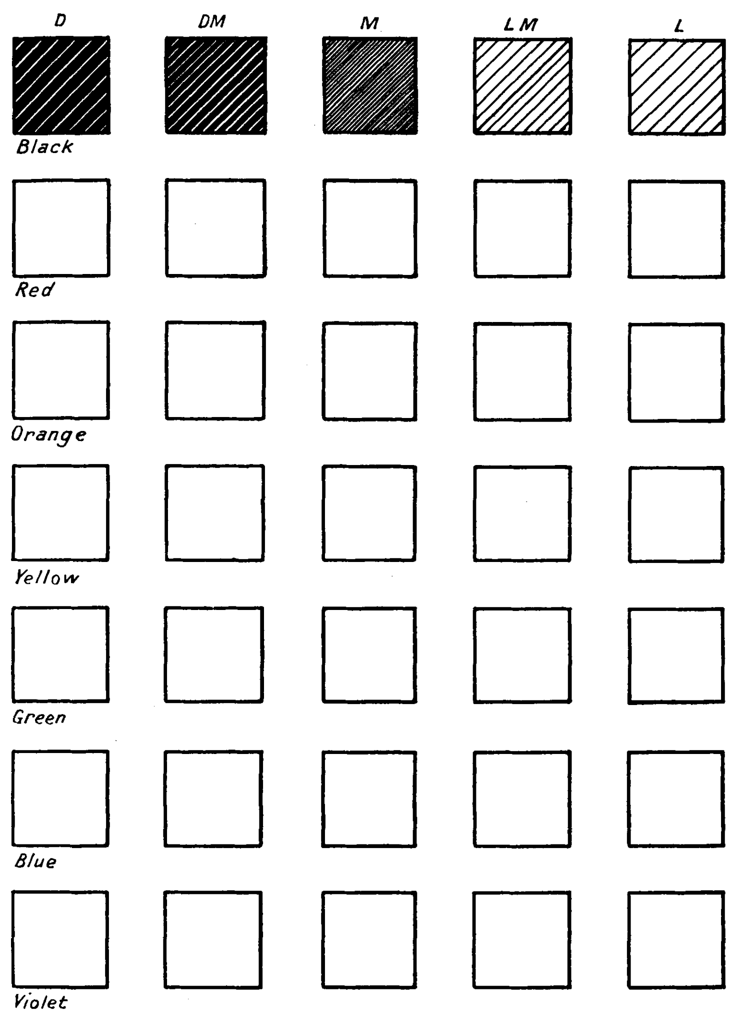


FIG. 48.—Illustrating the Grading of Colour Ranges to obviate reversing of Pattern.

so that in every colour scheme the two features, colour and luminosity, are really brought into play.

From the practical point of view the first consideration should be the fastness of the colours selected to finishing and ordinary wearing conditions. The organization of graded ranges of shades and tints of correct tones and intensities is the next important factor. This will best be effected by basing the ranges selected upon the tints, shades and tones of the spectrum colours. It is not necessary that a complete range of spectrum colours shall be represented. If, for instance, greens are fashionable, the green tints, shades and tones may at least predominate in the selection, and so on according to the prevalent taste in colour. In order that the reversing illustrated in Fig. 47 may be avoided it is very desirable that the ranges of shades should be organized upon the lines illustrated in Fig. 48, from which it will be gathered that so long as the designer takes, say, his ground colours from the same grade of darks and his checking colours from the same grade of lights the reversing of the pattern illustrated in Fig. 47 will be impossible, and hence the spoiling of, say, a range of eight patterns by one of the eight being accidentally reversed will be avoided.

By some such organization of colours as this the designer will find that not only can he do with about half the shades he would otherwise require, but he will also find that his ranges of colours actually inspire him to design. Some of the French pattern firms supply magnificent ranges of colours which the textile designer should always have by him, as such, even if not of direct use, tend to guide one into good methods, and good method in textile design and colouring results in economical production without any real suppression of the artistic feeling and instinct of the designer.

Figure Designing.—This involves a two-fold qualification, viz., the qualification of the artist to create artistic forms and patterns, and the qualification of the cloth constructor not only to render in the fabric the patterns designed, but rather to qualify the artistic qualification so that the limits of textile design may be taken as an inspiration rather than as a limitation.

Brief consideration of the fact that woven fabrics are composed of threads at right angles to one another will result in the limits of textile design being fully realized.

In designing for figures any of the structures mentioned on p. 178 may be employed; but as a rule the designer will be given a typical foundation fabric to design to. The usual limit for the Lancashire and Huddersfield design is about 400 threads, *i.e.*, a cloth 100 threads per inch, about a 4-inch pattern. Bradford, however, largely employs a jacquard figuring with 300 threads, while Belfast and some of the silk and tapestry districts figure up to 1,200 or 1,800 threads by any required number of picks.