# WOOLLEN AND WORSTED

## THE THEORY AND TECHNOLOGY OF THE MANUFACTURE OF WOOLLEN, WORSTED, AND UNION YARNS AND FABRICS

BY

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DIVISIONAL VOL. I

LONDON

The Library Press Limited

26, Portugal Street, W.C.

1916

CHISWICK PRESS: CHARLES WHITTINGHAM AND CO.
TOOKS COURT, CHANCERY LANE, LONDON.

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# PREFACE

In method of construction, plan, and scope, this book claims to set forth the whole scheme of Woollen and Worsted Manufacture, and to examine and describe the types of mechanism employed in Yarn and Fabric production.

To accomplish so comprehensive an object demands unity of design and minuteness of analysis. The whole subject has to be presented and studied with due consideration of its different parts or distinctive units.

Clearly, each section of work in the conversion of a fibrous material into yarn, and of the spun thread into a woven texture, constitutes a separate branch of study. There are special groups of processes—stages in manufacture—mechanical combinations, and routines of practice, in each phase of textile production, which yield problems and subject matter for inquiry. But in a wider sense it is advantageous, if not necessary, to the student of textile technology that they should be explained and understood as active elements in a connected system of textile manufacture.

Further, as the groups of processes, when in combination, give the manufactured product, the effect and bearing of any single group of operations requires to be studied, weighed, and proved.

Woollen and worsted manufacture can only be effectively interpreted when thus analysed and explained; that is to say, an exposition of (1) the processes as separate units of work; (2) of their influence in connection with each other; and (3) of the effects of each on the accuracy and completeness of manufacturing routine.

The survey here given is as unique in extent as it is varied in technical elements. Forty years ago, when the late Professor John Beaumont laid the foundations of the modern textile educational system, a work of this nature would have been regarded as Utopian in conception and doubtful of achievement. Then, educational experts and authorities joined with manufacturers and practical men in discrediting the attempts to systematize textile knowledge and to fashion it into a teachable subject. Both these grades of unfriendly thinkers were happily proved, by results, to have assumed an unwarrantable attitude towards this new departure in educational methods and practice, which has since become, and rightly so, an important part of the national educational machinery. Moreover, it is now a patent fact that the textile craftsman, carding engineer, comber, spinner, loom mechanician, designer and manager, seeking to attain distinction in factory life and organization, must possess technical knowledge gleaned from the best literature on the subjects. I have inspected mills and works abroad in which, from the under foreman to the head superintendent, all classes of workers were qualified by technical training and by intimate knowledge of the literature of their subject. On this ground alone a treatise of this description has grown to be necessary to all who take part in the responsible control of every branch of the woollen and worsted industry. Not to be in possession of textile literature is to lack the chief tools of equipment, the munitions of warfare, for the successful performance of one's duty in the factory; and, as a consequence, to be crippled and handicapped in the industrial race.

The present book is built up and framed on experimental studies and research. It comprises schemes of thought and observation which have been formulated and perfected in close relation with actual factory operations and commercial conditions, and yet carried out in harmony with educational ideas. There is no part of the treatise separate or distinct from the writer's investigations; and, in every phase of the subject, series of experiments—variously duplicated for verification of results—have been conducted, confirming principles, theories, and practice. In this and other directions, as in Yarn Structures, Warp-Shedding Mechanism, Textile Analysis and Microscopy, a substantial body of research has been carried out.

Let the reader in pursuing the pages of the book divest his mind of the least thought that he is traversing the ground in the company of a theorist who has not, by patient effort, analysis, and research, sought to verify practically what he endeavours to teach. At the same time let him distinctly understand that *sound practice* is enriched by *sound theory*. The writer is well aware that all the manufacturing arts in their origin and early stages of progress are in a large measure based on manual skill or handicraft. Carding, Combing, Spinning, and Weaving were successfully wrought before the invention of the Carding Machine by Arkwright, the Combing Machine by Heilman, Holden, and Lister, the Jenny by Hargreaves, the Spinning Frame by Roberts and Crompton, and the Power Loom by Messrs. Barber and Dr. Cartwright.

Practice, the expansion of commercial possibilities, and manufacturing developments, have accumulated stores of knowledge, which, before the publication of technical books, and the introduction of technical education, were only to be had by the privileged few. Education has removed the barriers which frustrated the student's efforts in mastering the whole technology of textile manufacture.

Much that in my student days was regarded as mysteries and formed scattered pieces of knowledge strangely organized into enigmatic practical issues, I have sought by systematic investigation to unravel and clearly demonstrate in these pages.

It would be practicable to dilate at some length on the plan of the work, the subject matter, the character and appropriateness of the illustrations used, and on the theories in manufacture and principles described. Possibly, however, it may suffice in this connection to state these matters in a few paragraphs.

First, then, as to the studies relating to Raw Materials or Fibrous Products, Yarn Construction and Fabric Structure. These are each microscopically and technically made. The spinning qualities of the staples of different materials are dealt with, and also the styles of fabrics to which they are, for trade purposes, applied; the qualities of the yarns resultant from the chief varieties of wool are analysed, and the effect of the system of yarn formation practised is explained. Second, all processes of manufacture are treated of as they are performed on standard types of machinery. Third, textile mechanism utilized in Scouring, Blending, Carding, Combing, Drawing, Spinning, Doubling, Twisting, and Weaving, is profusely illustrated with sectional drawings, photographic views, and diagrams printed in colour.

The various systems of Carding and Condensing involved in the spinning of Cheviot and Saxony Yarns, ranging from thick to fine counts, are explained and compared in detail.

Worsted Yarn preparation, on the English and French principles, is fully considered. Explanatory information is also given of the features in which the several schemes of worsted-thread construction differ from each other.

Principles of design, drafting, and the elements of textile colouring, are extensively illustrated and dissected. Photographic reproductions of many varieties of woven textures, types of weave effect, compound cloths, styles of pattern and colouring, render this section of the work increasingly instructive and suggestive. The influence the scheme of intertexture—in single, backed, and multi-ply structures—exercises on the soundness and efficiency of cloth construction, has received lengthy analysis.

Weave types, design bases, and compound plans, due to the combination of two or more schemes of intersection, in stripe, check, diaper, and diagonal forms; and systems of healding or drafting of single-, double-, and treble-make designs to the lowest workable denominator, with methods of setting for producing correctly-balanced fabrics, are minutely treated.

Theories of weave structure and origination on mat, twill, and sateen bases, and the scale of weave extensions in the threads, picks, or both threads and picks of common weave units, and as applied to typical cloths, are both fully illustrated and adequately explained.

A novel feature, in the weave and design examples, is the photographic representation of the effects in the fabric of the standard types of warp-and-weft interlacing, developed in tints of white, light gray, and in two contrasting shades, in order to emphasize the quality of "weave" as a design resultant in woven manufactures.

In regard to textile mathematics, examples are given, with an explanation of the rules and principles involved, in Blend Costing, the Productive Power of Machinery, and in Yarn and Fabric construction.

The calculations on yarns include problems on the "Counts" resulting from folding two or several threads into one, and on the price per pound of the compound or folded threads. The data applicable to the intersection and diameter theory of cloth structure, and the methods of ascertaining the weight and cost per yard of plain and fancy fabrics, are shown by a series of technical questions with the correct formulae for their solution. The same rule is followed in regard to the calculations on the acquirement of fabrics of different weights from the same or dissimilar counts of yarns, and in problems relative to the alteration of the weight of the fabric without modifying its structural appearance. From the data and arithmetical theories defined, any class of problem in Yarn Counts, Fabric Structure and Weight, Quantities of Warp and Weft Yarns used in the weaving of the piece, and in Costing may be correctly solved. The same principles are equally applicable to the manufacture of cloths made of yarns in which the "counts" are determined in "skeins," "cuts," "yards per oz.," "snaps," "runs," etc., in worsted, cotton, or linen "hanks," and in the French or metric system, based on the number of mètres to the kilogramme.

By the use of the Tables on Systems of Counting Yarns, Methods of changing Yarn Counts, and Methods of counting Reeds, and the mathematical rules stated, the equivalents to a known scheme of weight per yard and costing, are ascertainable, as required, in different systems, that is to say the results obtained for the manufacture of a piece of Cheviot suiting, employing in the calculations the Scotch reed and yarn counts, could be produced in Worsted, Cotton, or French equivalents. Or, providing that identically the same pieces had to be made in a worsted factory, but in worsted yarns instead of woollen "cuts," or in a French mill in yarns spun to the metric base, then all the particulars of construction could be accurately determined for changing from one scheme of yarn counting, setting, and manufacture to the other.

Fabric analysis, comprising, in the main features, the dissection, first, for weave and cloth structure, yarn counts, quality, and fibrous composition, and contraction from the loom to the finished width and weight per yard; and, second, the dissection for reproductive particulars such as plan or design with healding drafts, order of warping and wefting, actual spun counts of the yarns employed based on calculation, setting, reed width, threads and picks per inch, and the data for ascertaining the weight of the piece and each quality and counts of yarns it contains, is a subject of the first importance to the student of textile manufacture. It is, therefore, treated of in considerable detail, using, as examples, Cheviot and Saxony tweeds, fine worsteds of various structures, and vesting fabrics. These —which appear on Analysis Sheet A—are exact photographic views of actual specimens analysed. The style of the pattern, the weave elements, and the structural effects in each illustration are as clearly shown as in the original woven samples.

Following the scheme of analysis portrayed on Analysis Sheet B—a tabular method of recording possessing the advantage of showing at a glance the process by which any particular group of elements has been derived—it will be observed that the routine of dissection is in three divisions, namely, (a) the technicalities proved to enter into the structure of the specimen; (b) the technicalities for looming, and (c) the technicalities of the finished piece.

This system of analysis has three distinguishing features: (i) it reveals each factor in the construction of the specimen dissected; (ii) it ensures absolute accuracy in the work of reconstruction; and (iii) it proves mathematically the results ascertained.

In addition to the research and investigations evident in various parts of the text, as in the diagraphic and other illustrations of the book, reference may be made to the records of original work concisely stated in the following amongst other Tables: Card Clothing Contrasts—Scribbler and Carder; Methods of Setting and Data for using the Rectilinear Comb on various classes of Wools; Costing of Worsted Yarns; Productive Power of Woollen and Worsted Machinery; Types of Woven Fabrics; Sateen Weave Construction; Counts of Yarns in relation to Weaves and Setting; Construction of Picking and Shuttle Box Chains; Methods of Changing Yarn Counts; and Examples in setting based on the Intersection Theory.

I desire to acknowledge the kindness of the following machine makers and textile engineers: Messrs. the Chadwick Machine Co., Ltd., Critchley, Sharp and Tetlow, Ltd., P. and C. Garnett, Ltd., and S. Haley and Son, Cleckheaton; John Haigh and Sons, Huddersfield; Geo. Hattersley and Sons, Ltd., Keighley; Hall and Stells, Ltd., Keighley; Geo. Hodgson, Ltd., Bradford; Hutchinson, Hollingworth and Co., Ltd., Dobcross; J. and W. McNaught, Rochdale; Petrie and Co., Ltd., Rochdale; Platt Bros. and Co., Ltd., Oldham; Prince Smith and Son, Keighley; John Sykes and Sons, Ltd., Huddersfield; Taylor Wordsworth and Co., Ltd., Leeds; Wm. Whiteley and Sons, Ltd., Huddersfield; and Wm. Bywater, Ltd., Leeds; and also my indebtedness to Mr. Henry S. Clough, Keighley; Mr. Alex. Weir, Convoy, co. Donegal; and Messrs. Platt Bros. and Co., Messrs. Prince Smith and Son, Messrs. Taylor Wordsworth and Co., and Messrs. Wm. Whiteley and Sons, for views and plans of various sections of woollen and worsted mills.

R. B.

# CONTENTS

## CHAPTER I

### MATERIALS



## CHAPTER II

### WOOLLEN YARN MANUFACTURE: WOOL SORTING, SCOURING AND BLENDING



## CHAPTER III

### WOOLLEN YARN CONSTRUCTION: CARDING, CONDENSING, SPINNING AND TWISTING

# DIVISIONAL VOL. II

## CHAPTER V

### YARN STRUCTURE—FOLDED AND FANCY TWIST THREADS



## CHAPTER VI

### PRINCIPLES OF FABRIC STRUCTURE: FUNDAMENTAL WEAVES



## CHAPTER VII

### LOOM MOUNTING, OR PREPARATION OF THE YARN FOR THE LOOM

## CHAPTER VIII

### HAND-LOOMS



## CHAPTER IX

### POWER-LOOMS

## CHAPTER X

### WEAVE COMBINATIONS: DRAFTING



## CHAPTER XI

### PATTERN DESIGN



## CHAPTER XII

### COLOUR APPLIED TO PLAIN, TWILLED, AND FANCY WEAVES



## CHAPTER XIII

### COMPOUND FABRICS

# LIST OF ILLUSTRATIONS

# LIST OF PLATES

* Photo-micrographs prepared for the Author by A. Yewdall.

# LIST OF TABLES

# WOOLLEN AND WORSTED

## CHAPTER I

### MATERIALS

1. Methods of Diversifying a Woven Fabric—2. Textile Materials and their Effects in the Woven Fabrics—3. Materials used in Woollen and Worsted Manufactures—4. Wool—5. Properties of Wools—6. Properties of Wools for Saxony Cloths—7. Properties of Wools for Cheviots—8. Properties of Wools for Worsteds and Comparison of Wools for "Woollens" and "Worsteds"—9. Wools of Different Countries—10. Mohair, Alpaca, and Cashmere—11. Wool Substitutes—12. Noils—13. Mungo and Shoddy—14. Difference between Wool and Mungo—15. Mungo Production—16. Extract Wool—17. Flocks—18. Cotton—19. Silk.

1. *Methods of Diversifying a Woven Fabric.*—In the manufacture of textiles the principal methods of modifying the character of a woven fabric are:

I. By the use of a diversity of materials, *e.g.*, wool and mohair, cotton and silk, etc.

II. By combining yarns of different counts and diameters but composed of similar materials.

III. By blending fibrous materials of distinct physical and chemical properties, *e.g.*, cotton and wool, silk and wool, ramie and wool.

IV. By the scheme or system of yarn construction, as for example "woollen" and "worsted," "self-actor" spun and "frame" spun.

V. By the employment of folded and fancy yarns.

VI. By "weave" structure.

VII. By the arrangement or grouping of yarns of different colours in the warp, weft, or both warp and weft.

VIII. By varying the routine of "finishing" the fabric.

These several methods, which are subjective to subdivision and yield many derivatives, may be briefly described.

Class I. Fibrous materials are of such varied physical properties and chemical composition as to produce, when subjected to suitable mechanical treatment, yarns of distinct qualities. This feature is clearly distinguishable in Sections *a* and *b*, Fig. 1. The yarns are of approximately the same diameter, and the weave or fabric structure is identical in the two Sections, and the treatment in finishing after weaving is the same, but Section *a* is made of woollen, and Section *b* of mohair yarns, demonstrating the influence of

*a b a b*

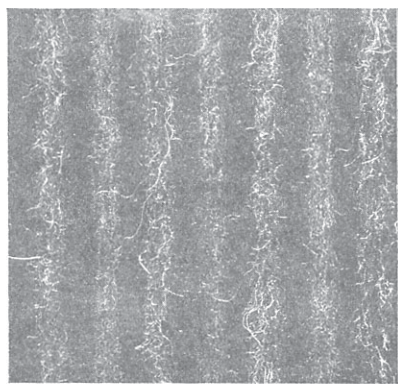

Fig. 1. Stripe in Woollen and Mohair Yarns.

material on the character of the woven texture. Should worsted and silk yarns be similarly combined and in a finer make of fabric, the worsted sections would be clear but lacking in lustre, and the silk sections would be brighter and richer in tone (Figs. 2 and 2*a*).

Class II. In the use of different counts of yarns, there is an important source of diversity of woven surface. Typical examples are given in Figs. 3 and 3*a*. Fig. 3 is plain woven, but the check pattern is quite marked, due to the contrast in fineness of the types of yarns combined. Fig. 3*a* illustrates the same principle of modifying the fabric in a compound texture or one in which, in accordance with the plan of the design, the several thicknesses of yarns may be changed from one side to the other in forming the pattern.

Class III comprises what are termed "cross dyes" or effects arising from the manufacture into one and the same texture of animal and vegetable fibres and therefore of dissimilar dyeing properties. Fig. 4 consists of wool and cotton fibres, the darker or ground shade being wool and the lighter effects cotton. This class may be taken to also include piece-dyed worsted and other fabrics in which certain warp yarns have been prepared prior to weaving to take definite colours in the dye vessel, and these are properly arranged in preparing the warp, so that one process of dyeing may give a striped style composed of two or more shades.

Class IV. Wool may be manufactured into yarn on two distinct systems, and each yields a "type" of thread which is capable of giving a corresponding type of fabric. Fig. 5 and Fig. 5*a* are illustrations showing the difference in the woven surface of woollen and worsted textures. The woollen (Fig. 5) is more fibrous, rougher, and the plan of construction less distinct than in the worsted. They also differ in quality of handle and wearing characteristics.

Class V. There are many varieties of compound yarns consisting of threads of different diameters and materials, as will be subsequently explained. These may be utilized as instanced in Figs. 6 and 6*a*, which are plain woven, in acquiring fancy styles, and a fabric of varied surface features.

Class VI. Figs. 7 and 7*a* are diagonal patterns distinctly showing how weave structure modifies the fabric. They are composed of several textures, each weave forming a different effect and therefore a separate fabric. Specimen 7 comprises twelve builds of texture, graduating from a weft to a warp twill, and Specimen 7*a* a number of dissimilar twills grouped variously. Weave thus constitutes one of the principal sources of design produced in the loom.

Class VII. Colour is a special and important branch of woven design. Figs. 8 and 8*a* are ordinary examples of how the scheme of grouping or arranging the coloured yarns in the warp, or warp and weft, is capable of modifying the effect in the fabric. Only two shades are used, yet Pattern 8 consists of two effects in stripe form, and Pattern 8*a* of four effects in check form.

Class VIII. Finishing routine, as performed in the treatment of woollen, worsted, and union fabrics, is another modifying factor in the manufacture of textiles. See, for example, Figs. 9 and 9*a*. They are made from the same yarn and weave structure, but Fig. 9 has been "clear," and Fig. 9*a* "fibrous" finished. They are not

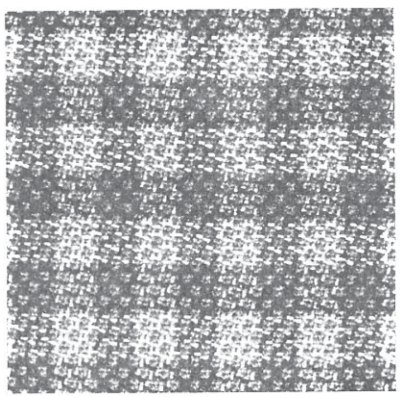

Fig. 2. Worsted and Silk Check. White=Silk.

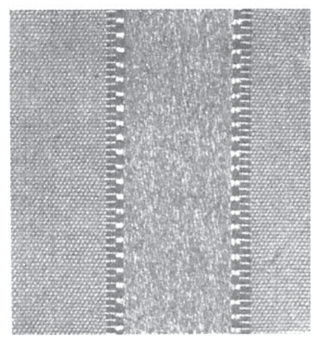

Fig. 2*a*. Worsted and Silk Stripe. White=Silk.

recognizable as having been of the same appearance and technical characteristics on leaving the loom.

2. *Textile Materials and their Effects in the Woven Fabric.*—The materials used in textile manufacturing comprise fibres of an animal, a vegetable, and a mineral origin. Each class of fibre possesses specific properties, which, of a necessity, characterize the woven fabric in which it is used. The quality, softness, elasticity, strength, and lustre of a texture depend, in a primary and ultimate sense, on the nature of the material or materials employed in its manufacture. The exercise of skill in the operations of yarn construction, weaving, and finishing cannot possibly produce a fine piece of cloth from a coarse-

fibred unkind-handling material. In fact, the art of manufacturing does not consist in changing but in retaining the natural properties of the class of fibre utilized: in other words, it consists in reducing the material into a thread-like form or condition, and of converting it into a weavable or commercial fabric at a minimum detriment to the original qualities of the filament. In the routine of manufacture all fibres necessarily undergo modification. Firstly, in scouring and dyeing—chemical action; secondly, in the processes of carding, combing, drawing, and spinning—mechanical treatment—where the filaments are separated, re-arranged, and twined finally together to form

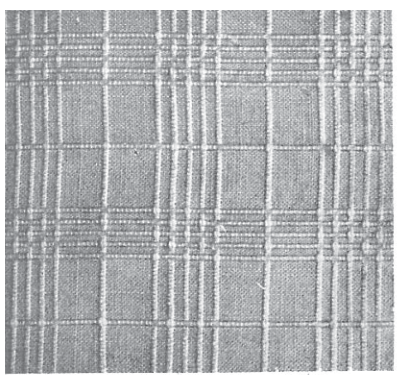

FIG. 3. Check Pattern due to combining fine and thick yarns.

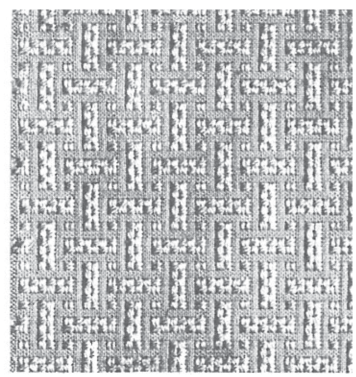

FIG. 3*a*. Compound or Reversible Fabric, effects produced in thick yarns on a ground consisting of fine yarns.

a yarn or thread; and thirdly, in the weaving and the operations of finishing. Yet the natural properties of soundness, elasticity, and lustre of the raw material should be present in the finished product. Allowing this, it follows that fabrics made of wool, hair, silk, cotton, flax, jute, mungo, and other materials do not merely differ from each other on account of having passed through processes of manufacture somewhat different in character, but also, and in a more important sense, a difference results in the properties of the woven fabrics from the special characteristics of the materials of which they have been severally made. Thus a woollen cloth, providing it has been made of a fair quality of wool, is soft and full in the hand, and possesses, in a marked degree, the natural properties of the wool—elasticity, strength, and durability; a cotton fabric, on the other hand, although it may be firm and of fair tensile strength, is comparatively hard and lacking in elasticity and suppleness. Fabrics made of silk are unequalled for richness, brilliance, and fineness. Bleached linen—flax—is of surpassing whiteness. Cloths made partially or wholly of such wool substitutes as mungo, shoddy, and extract, possess, in a measure, some of the qualities of all-wool

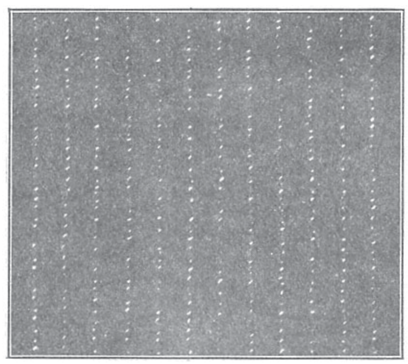

Fig. 4. Worsted and Mercerised Cotton Stripe: Piece-dye, but the cotton in the process not affected by the dyes.

fabrics, but are defective in brightness of colour tone, soundness, and strength.

Some typical examples are given on Plate I, which show how different is the effect in the texture, due to the material or class of fibre used.

Specimen No. 1 is made of twist woollen yarn (wool fibres, Fig. 11) in the warp, and single yarn in the weft, producing a thick fibrous fabric, with the weave moderately clear owing to the twisted or folded thread employed in manufacture. In no other textile material, and in this structure of fabric, would there be a like density and substance.

In the worsted texture, No. 2, there is more distinctiveness of yarns, yet a degree of the fibrous quality is seen,

Plate I

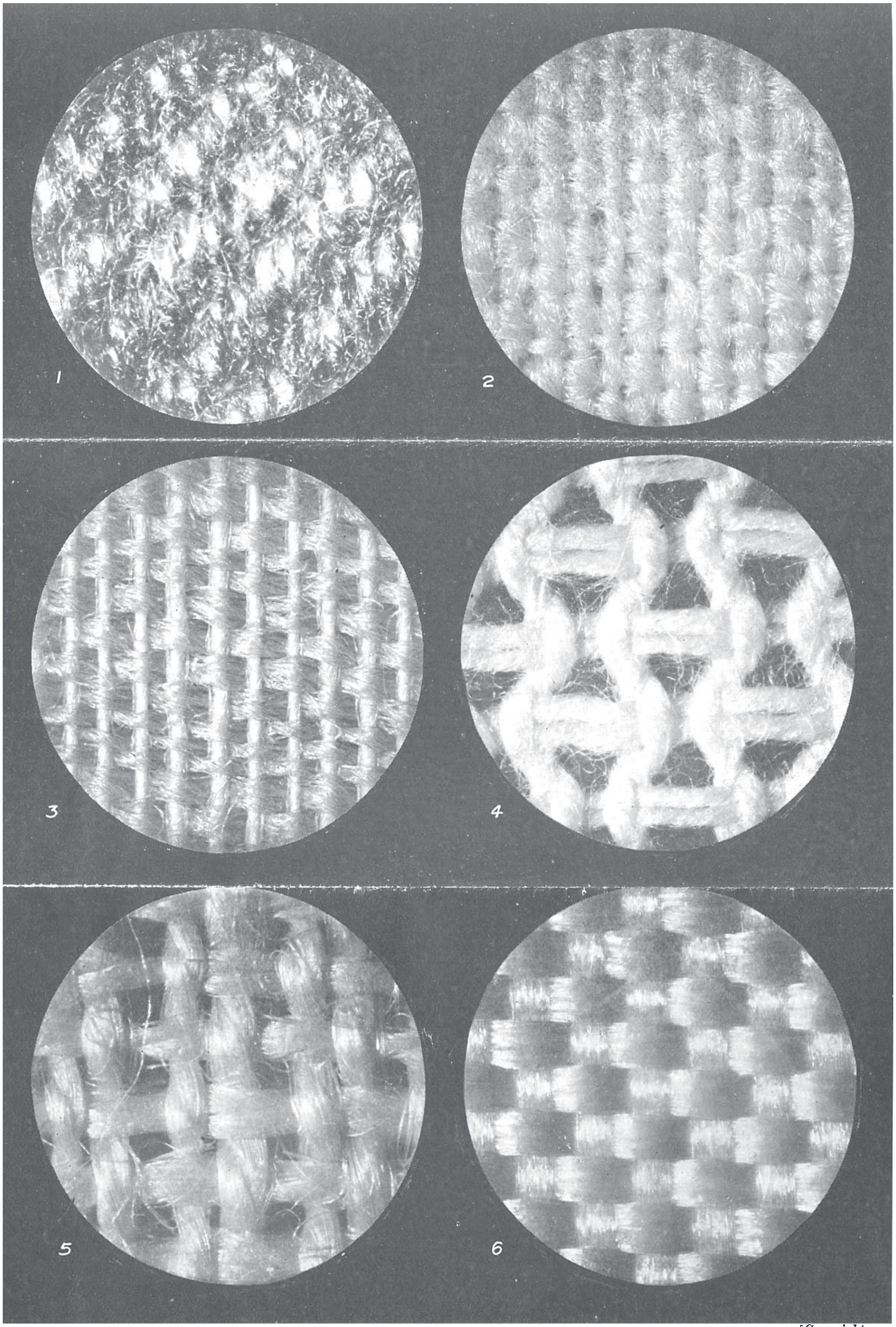

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Photo-micrographic Illustrations of Woven Fabrics.

1. Twist-Warp Woollen Fabric.
2. Botany Worsted Fabric.
3. Cotton-Warp and Worsted-Weft Fabric.
4. Linen Gauze.
5. Ramie Warp and Ramie Weft Fabric.
6. Silk Texture.

*Fold-out rotated 90° to fit on page.*

filling up the interstices between the threads of warp and weft.

Specimen No. 3—cotton warp and worsted weft—clearly shows the difference between a cotton thread and a worsted thread, the fibres of the worsted spreading and those of the cotton being compact: as a result, more defined colour effects are producible in cotton than in woollen or worsted yarns.

The gauze principle of weaving of the linen (flax fibre, C, Fig. 12) sample, No. 4, emphasizes the distinctness

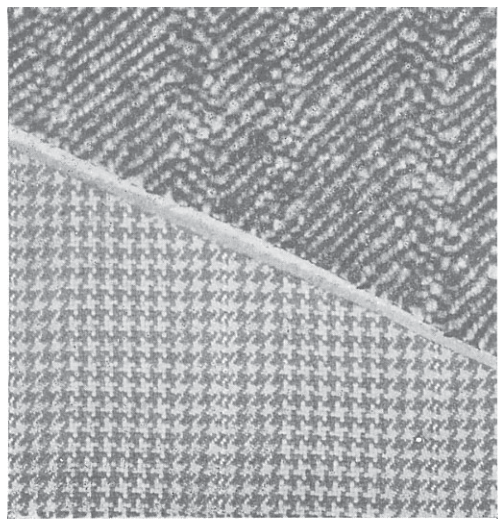


FIG. 5.

FIG. 5a.

FIG. 5. Striped Woollen (Cheviot).
FIG. 5a. Striped Worsted (Botany).

of the warp and weft threads. The compactness of the fibres, the solidity, firmness, and roundness of the threads are qualities which give to linen textures clearness of figure or design, as in table-covers and damasks.

Specimen No. 5—ramie, fibre B, Fig. 12—has similar qualities to linen, and has a brightness of effect, both in the yarn and in the texture.

The prevalent tone of silk (fibre E, Fig. 12), that of lustre, is seen in No. 6, constructed of a mat weave to develop this quality. No such brightness of textural surface is obtainable in other classes of textile fibres.

It is not necessary to multiply illustrations of the diversity of textile fabrics resulting from the manufacture of different classes of filaments; for, in addition to the fibres referred to, cashmere, camel's hair, alpaca, jute (D, Fig. 12), China grass, and other materials are made into several descriptions of woven textures. Not only is it practicable, however, to produce a variety of fabrics from different types of fibres as shown, but also when limited to the use of one class of material, as, for example, that of wool. Some wools, for instance, the finest Merinoes—Tasmania, Port Philip, Sydney, New Zealand, Cape, and Saxony—are suitable for the manufacture of high-class woollens; others,

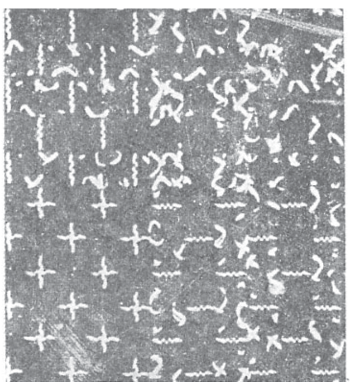


FIG. 6. Effects produced in Fancy Twist Yarns.

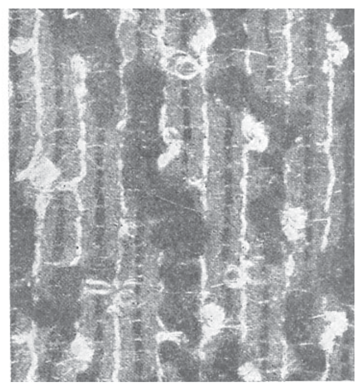


FIG. 6*a*. Effects produced in Curl and Knop Yarns.

also Merinoes, but of a somewhat longer staple, for Botany worsteds; longer still and not so fine in the hair for cross-bred worsteds; strong in the fibre and of a fair length for cheviots; long and lustrous in staple like Lincoln and Leicester for dress fabrics, and so on for each distinctive class of woollen and worsted textures manufactured. Hence, if wool were the only textile fibre known, it would be possible by its use to produce a wide range of fabrics in the same weave or scheme of interlacing warp and weft and without the aid of colour.

3. *Materials used in Woollen and Worsted Manufactures.*—The fibres used in woollen manufacturing comprise wool and wool substitutes including shoddy, mungo, extract,

flocks, stockings, pulled waste, and cotton. The better qualities of Saxony cloths are made of fine Merino wools, the lower qualities of wool and mungo, or of mungo. Similarly the better qualities of cheviots and tweeds are made of pure wool of medium length of staple and strong fibre; on the other hand, the inferior qualities are largely manufactured from shoddy, pulled waste, and such wool

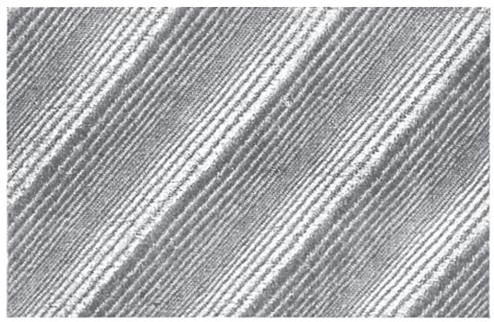


FIG. 7. Shaded Diagonal composed of Twelve Weave Structures.

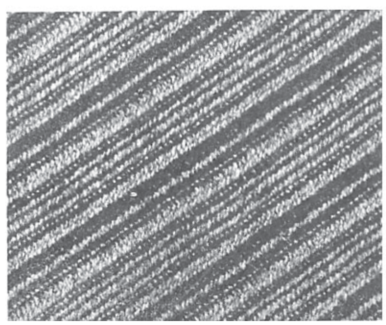


FIG. 7*a*. Diagonal consisting of Fine and Loose Weave Textures.

substitutes blended in a way to bring the fabrics in at a marketable price. Cotton is used in several forms. Firstly, it may be blended with fine-fibred wools to increase the spinning length of the material and reduce the felting property of the fabric as in flannel manufacturing; secondly, to obtain a cheap yarn; and thirdly for warp yarn as in the union trade, the warp of the fabrics being cotton and the weft mungo or shoddy.

Wool, alpaca, and mohair are the chief materials used in worsted manufacturing. There is not the same facility in the English system of processes of worsted yarn construction for the use of other fibres as in the woollen industry. The Continental scheme, which is being increasingly practised in this country, does, however, in the mode of blending, allow of the use of cotton and silk noils in combination with wool. This will be explained in a subsequent chapter.

4. *Wool* (see Fig. 10 and 11).—Wool, the natural product of the sheep, is the most valuable fibre used in woven, knitted, and felted manufactures. From the earliest times it has been employed in the production of textile fabrics.

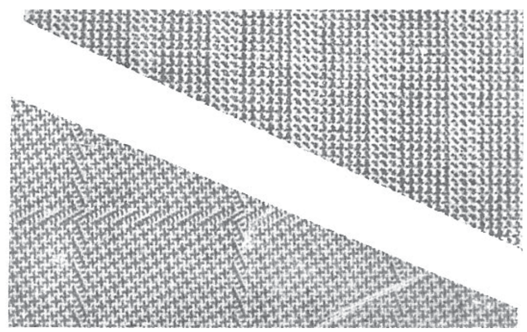


FIG. 8.

FIG. 8*a*.

FIGS. 8 and 8*a*. Patterns due to the methods of grouping two shades of Warp and Weft Yarns.

Before the invention of the arts of spinning and weaving, the skin of the sheep, with the wool on, was used as a garment or covering. By what means it was first converted into a thread is not known. It is said to have been performed in this primitive fashion: an instrument resembling an inverted spinning top was fixed near the ground to the peg of which the prepared flax or wool was attached, drawn out into a thread-like condition, and the "top" set in motion, the spinner meanwhile further attenuating the material into which twine or twist was being rapidly inserted. Such an operation would result in the spinning of "lengths" of weavable yarn, and is not unlike, in principle, the drafting and spinning on some modern machines. Whatever the method originally devised, it is conclusive that at a very early period in the invention of the practical arts, the soft, warm, lustrous, and fibrous quality of wool, would recommend it to the prehistoric producer of woven fabrics.

Wool has been defined as a very fine hair. This definition is theoretically correct. Strictly, however, hair and wool are two distinct fibres. Thus while hair (that of the rabbit and beaver for example, or cow hair used in the making of low-class plushes) is stiff and straight, wool generally is curly, flexible, elastic, and wavy. When camel's hair, and the fibre of the Angora goat or mohair, are considered, then the resemblance which these filaments bear

FIG. 9. Tweed Pattern, fibre removed from the surface of the fabric.

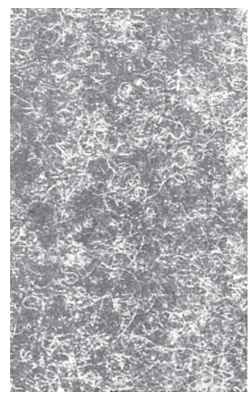


FIG. 9*a*. Tweed Pattern same as fig. 9, but fibre raised on to the surface.

to wool is more pronounced; but even here the same disposition of straightness and stiffness is apparent.

Microscopically, these fibres have a different formation. They are not identical in physical structure. Hair possesses a comparatively smooth, level surface, with the marginal scales flatter than in the typical wool fibre in which such scales have free edges as is noticeable in Figs. 10 and 11. Both fibres are solid and not tubular like cotton. When a transverse section of the wool fibre is microscopically examined it is seen to consist of three distinct features: (1) the marginal scales; (2) the inner or spindle-shaped cells forming the principal part of the filament; and (3) of the core, medullary or central cells. The lustrous and fulling properties of the wool are due to the uniformity and compactness of the outer scaly sheath; and the elasticity of the fibre depend on the spindle-shaped cells.

The microscopic appearance of several wool fibres is shown in Fig. 10 and Fig. 11. The former have been sketched from microscopic examination, and the latter are photo-micrographs. In Fig. 10, *a* is a typical wool fibre; *b*, mohair; *c*, a kempy fibre; *d*, Merino wool; *e*, shoddy; *f*, cashmere, and *g*, Lincoln wool. It will be observed in both series of illustrations that the outer scales are cylindrical in shape, completely encircling the fibre, and fitting within each other, their free marginal edges more or less protruding. These scales vary in size and number in different wools. They are the largest in lustre wools, of which Lincoln, Leicester, and Romney Marsh are important types, and the most numerous and uniform in dimensions in the fine Merino wools of Australia, New Zealand, Tasmania, Cape Colony, Argentine, Saxony, and Silesia.

5. Properties of Wools. The term "clothing" is applied to wools specially adapted for woollen manufacturing, distinguishing them from "combing" wools used in the production of worsted yarns. The properties relate to fineness of fibre, felting, strength and elasticity, length of staple, softness of handle, and purity of colour.

Fineness of Fibre. The best class of wool grown by any breed of sheep, both in respect to fineness of fibre and quality of staple, is termed "lamb's" on account of its being clipped when the animal is about six months old. The second clip which is a degree thicker in fibre and longer and stronger in staple is styled "yearlings," and all the subsequent growths are indiscriminately designated "fleece," which is still slightly coarser in the hair and of an increased length than the first two yields. In spinning high counts of yarns, it is necessary to use wools having a fine fibre and dense staple. Wool thick in the hair is not capable of being spun to the same length as a fine wool. When it is required to spin a woollen thread equal to over

12,000 yards to the pound, or approximately $\frac{1}{100}$th part of an inch in diameter, or, in the case of worsted, a thread to nearly six times this number of yards to the pound (approximately $\frac{1}{240}$th part of an inch in diameter), obviously a wool possessing a fine fibre, and a staple uniform in length is essential. Wools capable of being spun into threads of such fineness (amongst which may be classed Tasmania, Port Philip, Cape, and South American) are invaluable in making yarns for twisting purposes, or for yarns composed of two or more single threads and technically described as "folded," "several ply," or twist threads.

FELTING PROPERTY. When a lock of wool (*i.e.*, a

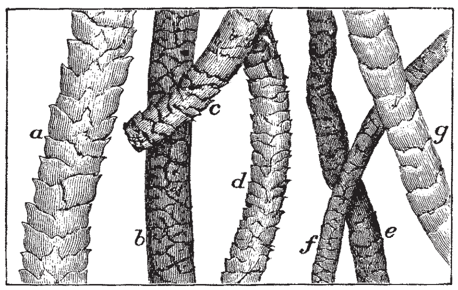
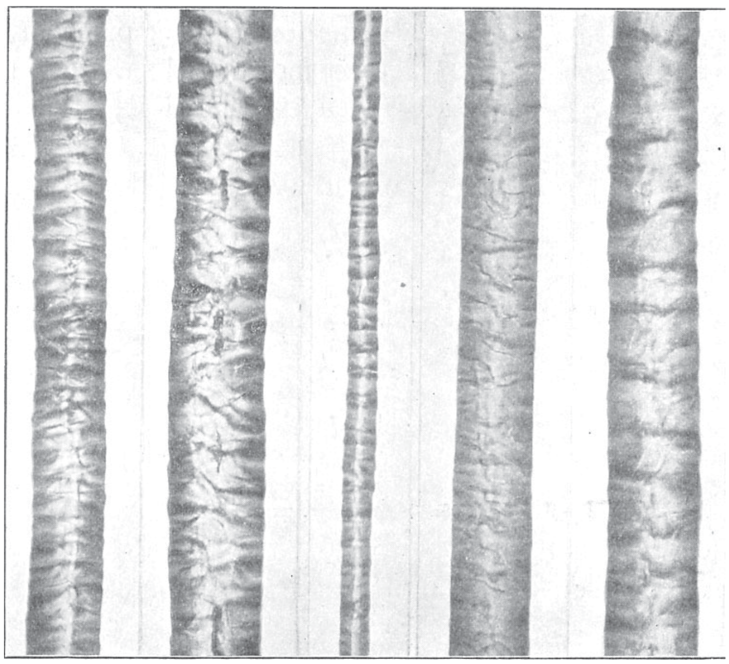



FIG. 10.

number of fibres) is passed between the forefinger and thumb in a reverse direction to the order of growth, or from the tip of the lock to the root, the external serrations or scales are more or less evident. This peculiarity in the physical structure of the fibre distinguishes wool from other materials employed in textile manufacturing. It lies at the basis of the milling or felting power—the property in wool which causes a fabric of which it is composed when saturated with a soapy solution and subjected to heat and pressure, to contract or shrink in length and width, and increase in thickness, substance, and density. For example, fine Saxony wool, of acknowledged superior milling quality, contains on an average from 2,700 to 2,800 serrations in a lineal inch of fibre. The best grown Australian Merino, another wool of sound felting strength, contains 2,400, but Leicester wool, of comparatively inferior felting quality, only 1,800 serrations to the inch. Generally the degree of felting power is consistent with the multiplicity of serrations, but there are exceptional wools. Cape wool, for instance, although fine in fibre and well serrated is not comparable with Saxony in this property. It has the physical structure of an ex-



A B C D E

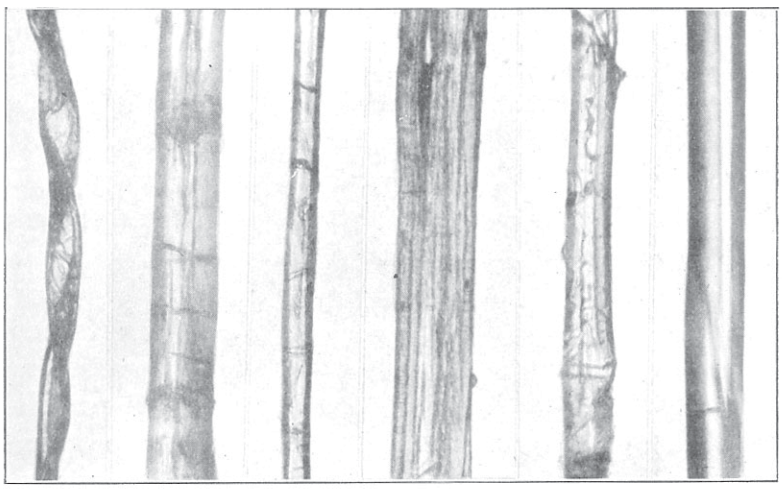
FIG. 11. Typical Wool Fibres.

(A) Southdown. (B) Cheviot. (C) Merino. (D) Mohair. (E) Lincoln.

cellent felting wool, but it is classed as a secondary wool in this particular. Port Philip and Buenos Ayres may also be contrasted as two wools which would, if the milling characteristic depended solely upon the multiplicity of serrations in a given length of fibre, be similar to each other in this relation. But, on the other hand, they are distinctly different, Port Philip being a wool of superior felting and Buenos Ayres only of moderate felting quality.

The causes to which this property in wool is due may be summarized as: (1) the number and uniformity of the serrations or outer scales in the fibre—when these are chemically removed wool is rendered more or less unshrinkable; (2) soundness and elasticity of staple; (3) density of staple; (4) breaking strain of the fibres; and (5) waviness or crimpiness of the lock—lamb's wool is the most superior in this characteristic.

Strength and Elasticity. These form two of the most important qualities of wool. The strength and weaving properties of the fabric are dependent upon them. Whether



A B C D E F

Fig. 12.

A = Cotton. B = Ramie. C = Flax.
D = Jute. E = Silk. F = Artificial Silk.

a fabric is fine or coarse, if made of wool, it should handle elastic and lofty.

The term elasticity as applied to wool denotes the power it possesses to assume its normal condition after being subjected to pressure. The extent to which this property is present in sound wool may be shown by comparing it with cotton and mungo. If a sample of good Egyptian cotton is taken in one hand, and a sample of Australian or New Zealand wool in the other, it will be apparent how superior the latter is to the former in point of elasticity.

As the materials are pressed the cotton yields with a minimum amount of resistance, and is comparatively cold and "unkind"; the wool resists the force applied and possesses a soft, full, lofty handle.

Compare in the second place a union fabric made of cotton warp and mungo weft with a Scotch cheviot made of pure wool. The superior fulness, elasticity, and substance of the Cheviot is immediately realized or appreciated, the natural strength and springiness of the wool imparting to the texture qualities which are non-existent in the cotton and mungo production.

Length of Staple.—This, as has been indicated, is a quality more requisite in certain classes of worsted than woollen-yarn manufactures. By staple is meant a group or lock of fibres, which have grown together on the animal's body. "Staple" varies from what may be termed scarcely a definable length in short wools to from fifteen to twenty inches in long wools. The finest wools as to diameter of fibre are generally short in staple.

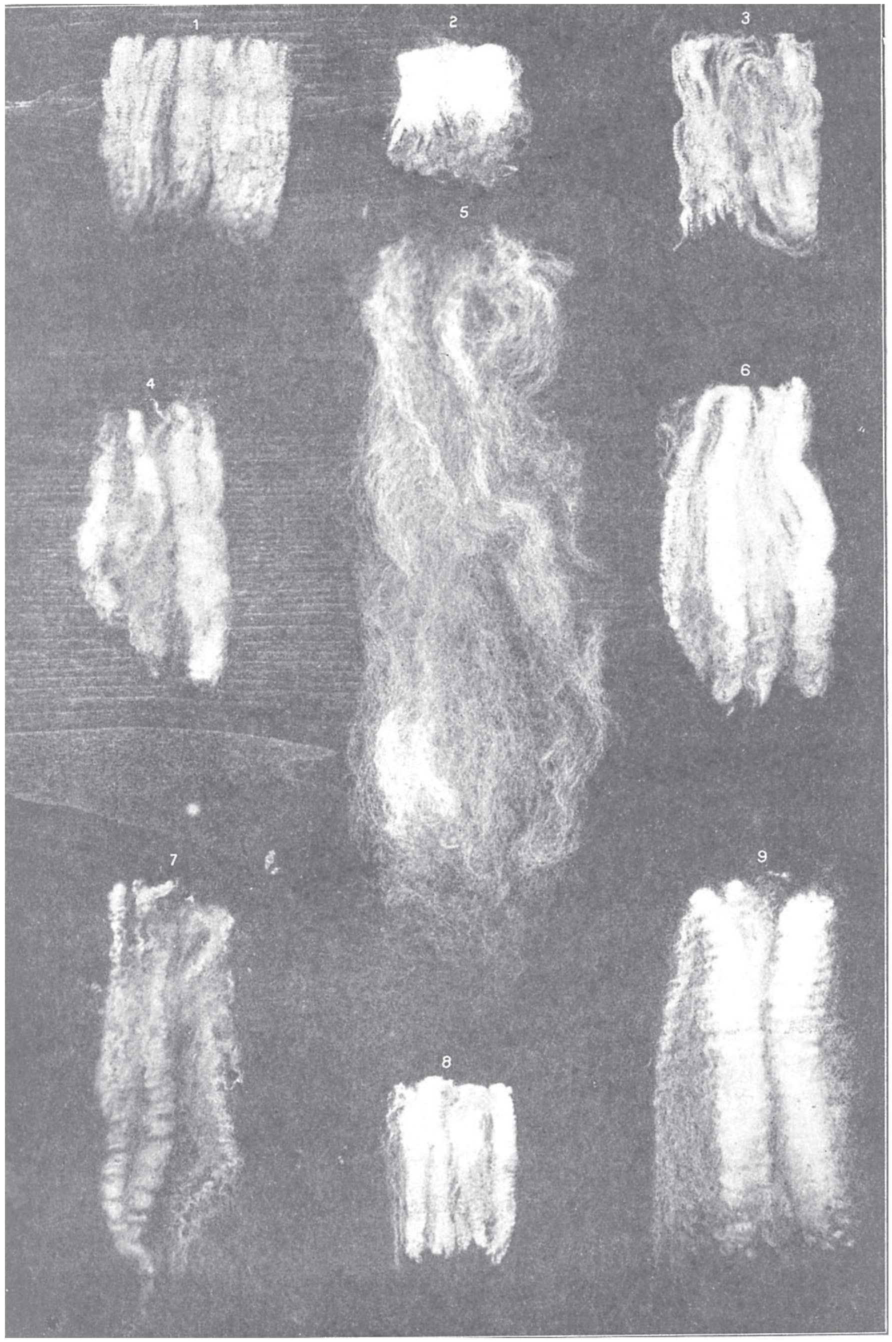
Wools are classed as "short," "medium," and "long-stapled." Length as well as fineness of fibre determines the kind of yarn for which a wool is best adapted. For example, in making serge worsted yarns and in which a comparatively thick and strong thread is needed, a wool from three to five inches in length may be selected, whereas for Saxony yarns the length of the fibres may not exceed one inch. As a result of using a long wool in the former instance, a more or less lustrous "wiry" thread of open structure is formed; while in the second instance, the short wool produces a dense compact yarn, and of exceptional milling power due to the quantity of fibres of which it is composed.

The extent to which wools vary in length is shown in Plates II, III, IV and V.

Other qualities of the lock or staple, such as waviness, density, and uniformity of length or otherwise of the fibres in several specimens will be observed.

Specimen 1 is a typical Merino Lamb's (Australian) notable for its waviness of lock, fineness of fibre, and high spinning

## Plate II.




TYPICAL SHORT- AND MEDIUM- STAPLED WOOLS AND ALPACA.

1. Merino Lamb's. Average length 2″.
2. Lamb's (South American). Average length $1\frac{1}{2}$″.
3. Merino Greasy Super Clothing. Average length $2\frac{1}{4}$″.
4. Sussex Downs. Average length 3″.
5. Alpaca. Average length $7\frac{1}{2}$″.
6. Greasy Fine Botany. Average length $3\frac{1}{4}$″.
7. Cheviot. Average length $4\frac{1}{2}$″.
8. Skin Wool (Merino). Average length 2″.
9. Greasy Fine Cross-bred (Australian). Average length 3″.

property. No. 2 is a sample of River Plate lamb's, shorter in growth and more tender in staple than the Australian. The short wools, used in the manufacture of fine Botany yarns, are illustrated in the third specimen which is a very fine-fibred wool, dense and strong of staple, with the individual fibres of a similar length, which is a characteristic common to sound wools. The Sussex Downs, so well suited, on account of its spinning qualities, for flannels and tennis fabrics, is sketched in No. 4. As compared with the greasy fine Botany, No. 6, it is deficient in elasticity, strength, and brightness of colour. The superior lustre of the Botany, combined with the fibres in the staple being of a similar length, produces a combed "top" of characteristic smoothness and evenness, and one into which but an inappreciable number of unstraightened fibres have entered. There are some points of resemblance between Nos. 6 and 9, but the cross-bred is neither so dense in the lock nor so fine in the hair as the Botany. It is, however, a good combing wool for medium counts and qualities of yarns.

In the long wools, Plate III, the waviness of the lock of fibres is pronounced, but there are fewer weaves to the inch, and the fibres are stronger, thicker, and straighter. The Lincoln and Leicester "hogs" possess curliness and a degree of lustre almost comparable with mohair. These wools, because of their exceptional brightness, and, when scoured, snow-white colour, are used in the manufacture of lustre yarns for dress, curl texture and mantle fabrics. The Yorkshire and Irish "hogs," Nos. 3 and 6, are wools of a coarser quality and less lustre, but they are useful in the spinning of serge and Cheviot yarns for suitings and costumes.

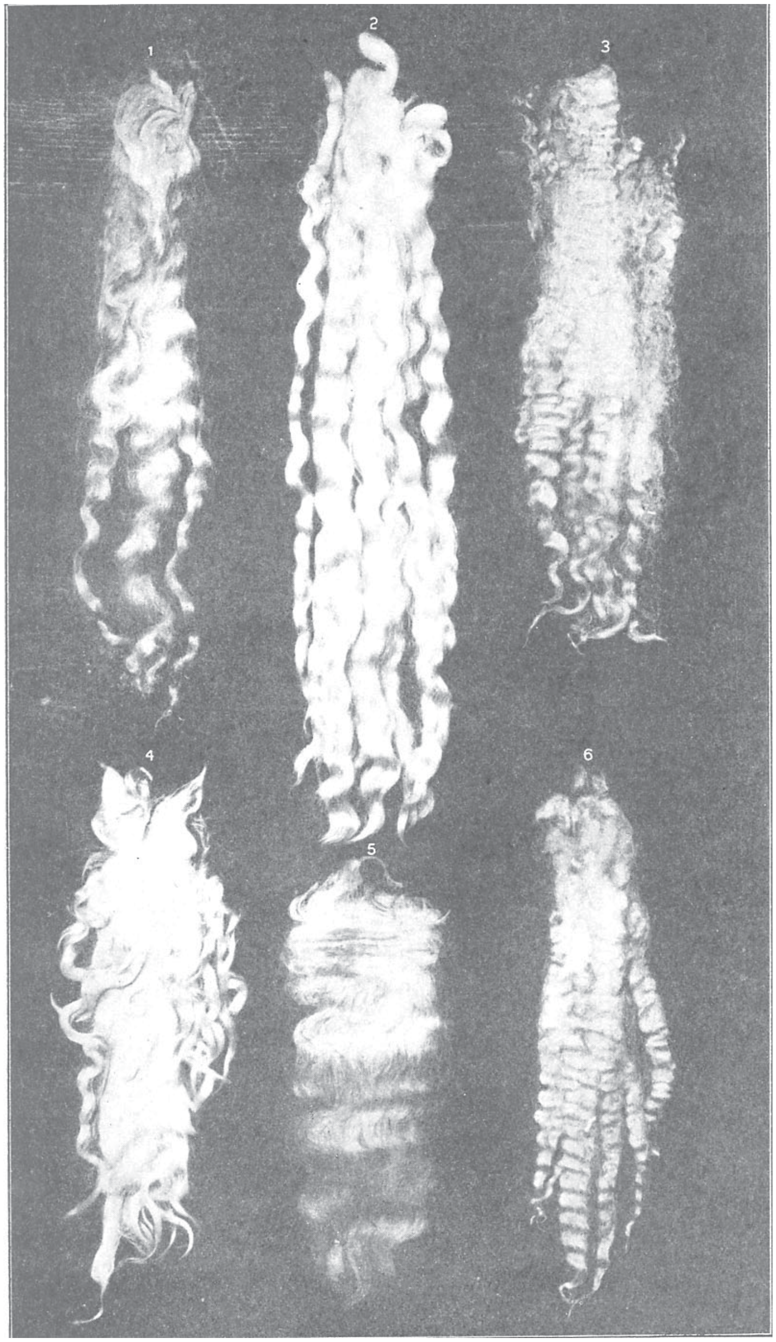
On comparing the mohair and alpaca specimens it will be seen that these textile materials differ from each other in various features. Structurally (see Figs. 10 and 11) they have a similar surface, but they differ in fineness, softness, colour, and length of staple. As regards the two former qualities, alpaca is the superior material, but mohair is the brighter in colour, the more wavy in staple, and of greater strength of fibre. As regards spinning property, alpaca may be spun to the higher counts.

Softness of Handle varies with the quality of the wool. It is essential to the manufacture of fabrics fine in the make, particularly Saxony cloths and Botany worsteds. In many special types of textures for rugs, shawls, mantles, and costumes it is also required. For serge and Cheviot fabrics, fullness, crispness, and elasticity of handle are more important. Naturally, for softness of handle, the finest grown wools have to be used, but for those of the Cheviot character coarser-fibred and stronger-stapled wools are suitable.

Purity of Colour is a sixth property. In piece dye fabrics, and other materials to be dyed medium or dark shades, a clean white colour is not of such importance as in dyeing bright and light colours. Some classes of wool after scouring are a pure white, free from yellow-tinged tipped staples, and such may be dyed evenly to the brightest shade. A clean white is also essential in wools for yarns intended for use in the undyed or scoured condition. It should be observed that certain wools, amongst which may be mentioned some classes of East Indian, Egyptian, and Spanish, also wool from the black-faced breed of sheep, are not white but fawn, gray, or brown, and are frequently spun into yarn and made into cloth in the natural shades.

6. *Properties of Wools for Saxony Cloths.*—Saxonies comprise the finest qualities of woollen cloths in wool-dyes, piece-dyes, and fancies. It therefore follows that wools must be employed with a fine fibre, a sound, short staple, and of superior felting power. Nearly all classes of Saxonies are milled to some degree, the wool and piece-dye cloths—beavers, meltons, doeskins, etc.—being excessively felted, while ordinary fancies are also run for a period in the milling machine to obtain a firm, compact texture. In addition, the wools must impart to the cloths softness of handle. Especially is this required in thick-felted raised overcoating, rugs, wraps, and even fine

PLATE III.




MOHAIR AND TYPICAL LONG-STAPLED WOOLS.

1. Lincoln Hogs. Average length 10½″.
2. Leicester Hogs. Average length 12″.
3. Yorkshire Hogs. Average length 10″.
4. Mohair. Average length 8″.
5. English Greasy Lustre. Average length 6¼″.
6. Irish Hogs. Average length 8″.

Saxony costume fabrics. Moreover, there must be density of staple to give the requisite raising quality which is characteristic of what are designated "face" cloths, which are covered with a nap of fibre developed after milling in the raising operation. Lustre is also important in these wools, otherwise the brightness of surface, which is such a feature of the face-finished fabrics, could not be satisfactorily developed.

7. *Properties of Wools for Cheviots.*—Here wools of a strong, elastic staple, moderately thick in the hair, springiness of handle, and varying from three-and-a-half to six inches in the length of fibre are suitable. Though ordinary Cheviots are not milled to the same extent as Saxony cloths, yet fulling power is valuable and necessary when manufacturing heavy overcoatings such as Irish friezes and rugs. Brightness and freshness of colouring being distinguishing features of fancy Cheviot suitings, costume, and other fabrics, the wools require to be of a good colour, otherwise carefully sorted to remove any yellow locks before attempting to dye clean, bright shades.

8. *Properties of Wools for Worsteds and Comparison of Wools suitable for Woollens and Worsteds.*—Worsted manufacturing is divided into two great branches, namely, Botany and Cross-bred fabrics, or fine and medium qualities of textures. In the former the finest wools are employed, and in the latter what are termed Cross-bred wools. As differing from the woollen trade the wools are classed in qualities, 30's, 40's, 60's, 70's, etc., indicating the counts of yarns for which they are applicable. It does not necessarily follow that they are spun to these counts as there is a margin both above and below the quality quoted to which the wools may be appropriated, but it is not sound practice to spin to the extreme length of the wool. Milling property is, of course, of less value than in the woollen industry, but other qualities sought after in clothing wools, such as softness, elasticity, and trueness of growth, are all important. Purity of colour is also essential. The fancy worsted trade is one in which richness and bright-

ness of colour tone affect the character of the style, and this, in either woollen or worsted manufacturing, is only obtainable by using wools which scour a clear white.

It may be useful here briefly to contrast the distinctive qualities of wools suitable for the typical worsted and the typical woollen.

Reference may be made, in the first place, to British-grown wools. Two series of specimens will be examined.

In specimens *a* to *e*, Fig. 1, Plate IV, are represented the long wools of the Lincoln and Leicester types, with lustre, waviness, and brightness of staple, possessing some of the qualities of mohair. These wools are chiefly suitable for the construction of worsted yarns: some of them could not be satisfactorily treated on the woollen principle or on the machines used for woollen yarn making. The length of the staple makes them unsuitable for yarn production by means of woollen carding, which would break up the staple and not be an economical method. But that very unsuitability is the cause of their usefulness as wools for worsted yarns, in which the true feature is evenness and regularity of construction. Generally, it is considered desirable in the processes of yarn manufacture to retain and not diminish the average length of the fibre. Yorkshire and Nottingham samples of somewhat similar qualities are shown at *f* to *k*.

The medium and shorter-stapled wools, Fig. 2, Plate IV, (British demi-lustre and Southdown types), approach what is understood as the Cheviot quality of material: a degree of lustre is lost, but more fineness of fibre and fullness of staple acquired. These and some Cross-bred wools are suitable for fabrics of the Cheviot description, and also for cross-bred worsteds.

Specimens of the finer grown imported wools are illustrated in Figs. 1 and 2, Plate V. They show a difference in staple and fineness of fibre when compared with the British-grown wools, and suggest the classes of fabrics for which they may be used, whether woollen or worsted.

In Fig. 1, Plate V, the upper series (Queensland and

# Plate IV.

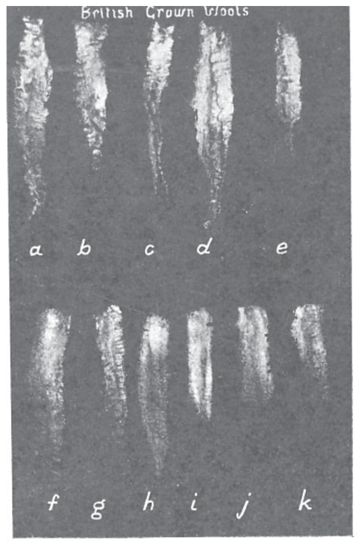



Fig. 1.

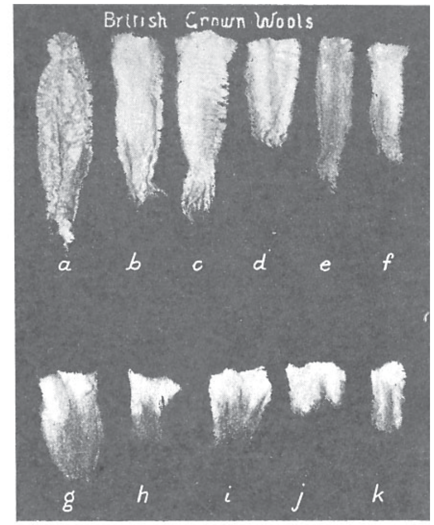



Fig. 2.

BRITISH GROWN WOOLS.

Fig. 1.

(*a*) Lincoln Hog.
(*b*) Lincoln Wether.
(*c*) Leicester Hog.
(*d*) Nottingham Hog.
(*e*) Nottingham Wether.
(*f*) Yorkshire Wolds Hog.
(*g*) Yorkshire Wolds Wether.
(*h*) North Half-bred Hog.
(*i*) North Half-bred Wether.
(*j*) Nottingham Forest Hog.
(*k*) Nottingham Forest Wether.

Fig. 2.

(*a*) Selected Irish Hog.
(*b*) Selected Irish Wether.
(*c*) Super Irish Hog.
(*d*) Super Irish Wether.
(*e*) Super Stafford Wether.
(*f*) Super Stafford Wether.
(*g*) Pick Shropshire Hog.
(*h*) Pick Shropshire Wether.
(*i*) Southdown Teg.
(*j*) Southdown Ewes.
(*k*) Sussex Teg.

New South Wales, super combing and clothing) are suitable either for carded or combed yarns.

The wools in the second row (Queensland super-lamb, Tasmanian super-fleece, New South Wales 2nd lambs, and Ercildoune, 1st quality), showing diversity of staple, may be used for different classes of manufacturing. The New South Wales 2nd lambs could only be treated on the woollen system of yarn production. For worsted-yarn making on the Continental system, in which the comparatively short-stapled wools of River Plate and the Argentine are largely used, this short length of staple would not be selected. The Ercildoune is one of the very fine qualities suitable for spinning worsted yarns of high counts, approximately 120's.

Samples *i*, *j*, *k*, *l*, are cross-bred wools. There is a decided change in the texture of the staple when compared with specimens *a* to *h*, the wools returning in character towards the coarser English breeds.

The next series of specimens, Fig. 2, Plate V, are Cape wools.

Samples *a*, *b*, *c*, *d*, are of the Botany type for worsteds: *e* and *f* of the Saxony or Merino type for woollens, being shorter in staple and not so suitable for combing; *g*, *h*, and *i* are from the Orange River Colony, Merino wools showing six, ten, and twelve months' growth; the six months' may be used for woollen, and ten and twelve months' for woollen or worsted yarn manufacture.

9. *Wools of different Countries.*—Soil, climate, food, and skilful farming all affect the character of the wool produced by any particular breed of sheep. English sheep imported into Australia in the course of time yield a finer quality of wool than in this country, the staple gradually becoming more uniform in length, and the fleece evener in fineness throughout. The Downs' wools are said to be softer and cleaner in staple when the sheep graze on the rich pasture land of Kent and Sussex, than if fed on the herbage grown on the more sandy soil of Norfolk or the chalk hills of Wiltshire, where they have found to assume

a somewhat harsh and dry appearance. Careful attention to the animals is also a cause to which the growth of fine wool is more or less due. Formerly Spanish wool was esteemed one of the finest grown; however, since the importation of merino sheep into Germany by the Elector of Saxony, from Spain, in consequence of unremitting care having been exercised in breeding, etc., a better wool both as regards regularity of staple and smallness of fibre and other essential features has for some period been produced in Germany than in the latter country.

German Merino Wools are fine in quality and general characteristics. Saxony and Silesian are the two most important. They are both wools of excellent clothing properties. The fibre is fine and contains a large number of serrations to the inch; staple short, strong and elastic, felting power superior, and colour good. These wools are used for the finest woollen fabrics where much milling is required, as in doeskin and similar fabrics, also for the better class of felts, such as those applied to piano hammers.

Colonial Wool (see Plate V). Large as the quantity of colonial wool—from Australia, New Zealand, Tasmania, the Cape, and South America—shipped into this country is, its commercial and manufacturing value can only be understood when its varieties, qualities, and fineness are taken into consideration. British wools are not suitable for the purposes to which colonial merino wools are applicable. Some of the principal of these wools will be described.

Port Philip, Sydney, and Adelaide are three typical Australian wools coming chiefly to this country, but also in considerable quantities to Germany, France, Belgium, and America. The first of these is one of the most useful wools grown, and is suitable for the best qualities of yarns, whether woollen or worsted. Though its fibre is not so fine as Saxony, yet it is a wool that spins well, and generally makes a true thread. It possesses a sound staple of a fair length, while its colour is invariably good. Being an excellent milling wool, it may be employed in the manufacture of fabrics requiring a good amount of felting.

PLATE V.

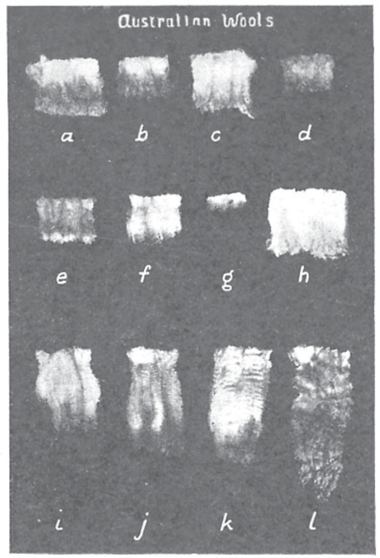


FIG. 1.

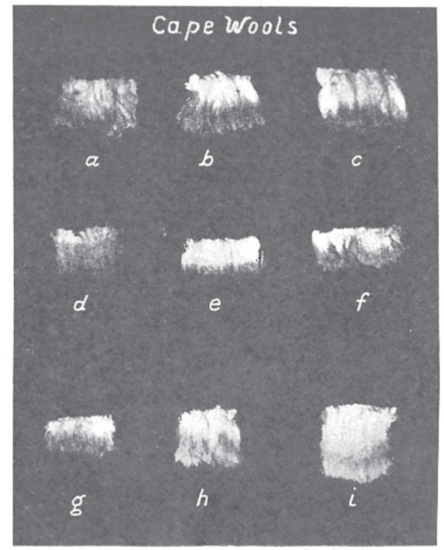


FIG. 2.

AUSTRALIAN AND CAPE WOOLS.

(*a*) Queensland Greasy Super Combing.
(*b*) Queensland Greasy Super Clothing.
(*c*) N.S. Wales Greasy Super Combing.
(*d*) N.S. Wales Greasy Super Clothing.
(*e*) Queensland Greasy Super Lambs.
(*f*) Tasmanian Greasy Super Fleece.
(*g*) N.S. Wales Greasy 2nd Lambs.
(*h*) S. Wilson Extra Superior 1st Quality Ercildoune.
(*i*) Victorian Greasy Superfine Quarter-bred.
(*j*) Victorian Greasy Superfine Half-bred.
(*k*) Victorian Greasy Superfine Three-quarter bred.
(*l*) New Zealand Greasy Lincoln.

(*a*) Western Cape Greasy Combing.
(*b*) Kaffrarian Greasy Combing.
(*c*) Karoo Greasy Combing.
(*d*) Natal Greasy Combing.
(*e*) Kaffrarian Greasy Super Clothing.
(*f*) Eastern Cape Greasy Clothing.
(*g*) Orange River Colony 6 to 8 months' Fleece.
(*h*) Orange River Colony 10 months' Fleece.
(*i*) Orange River Colony 12 months' Fleece.

SYDNEY WOOL usually possesses a fine fibre and a medium length of staple, but is occasionally wanting in strength. Sometimes it is defective in colour, containing yellow locks, which prevent it from being dyed into light shades. As the felting property is high, it is a wool that may be employed to advantage in making goods of a doeskin type.

ADELAIDE does not compare favourably either with Port Philip or Sydney in general character. While only moderately fine in the hair, the staple is not of a uniform length, nor can the colour be said to be exceptionally good. However, it mills moderately well, and is a fairly useful wool in the manufacture of both woollen and worsted goods.

VAN WOOL, grown in Tasmania, possesses many excellent clothing properties, being small in the hair, long and strong in staple, of a bright, snow-white appearance, and felts remarkably well. It is suitable for both combing and carding purposes.

The fibre of NEW ZEALAND WOOL is moderately fine, the staple sound and of a medium length, while its colour and milling properties are all that can be desired. As it generally imparts a full, substantial handle to the woven fabric, it is a wool highly esteemed for blending with mungo. It is also largely used in both woollen and worsted yarn production.

CAPE WOOL, from the Cape Colony, has a fine fibre, is generally short in staple, and rather deficient in strength, while that known as Eastern Cape, although improving in growth and quality may contain bright, dead fibres, termed "kemps." These, if not carefully picked out, as they do not dye along with the healthy wool, produce faulty places in the woven fabric. It is an indifferent milling wool, but possesses a fair colour. It is used in the manufacture of many varieties of fancy fabrics in which felting property is not important. Sometimes this wool is also blended with others possessing strength and elasticity of staple in the production of fine yarns for twisting purposes.

The wool coming from BUENOS AYRES, South America, is usually fine in the hair, but liable to be dirty and burry. It also lacks strength and elasticity of staple, and is deficient in milling power. After destroying, by carbonizing, the burrs, and other vegetable matter in this wool, continental manufacturers use it largely in worsted yarn spinning. River Plate Wool is of similar properties to Buenos Ayres.

Odessa is an important Russian wool, with a strong staple, fibre of medium thickness, and colour good. The latter characteristic occasionally causes it to be used in making yarns to be employed in the white state. Australian and Odessa wools, when blended together, produce very satisfactory cloths. Odessa wool is also suitable for a diversity of fancy woollen fabrics.

British Wools (see Plate IV). These are divided into two classes—the long or lustre wools, and the short-stapled wools. In the former class are included Lincoln, Leicester, Romney Marsh, and the Black-faced breed; while South Down, Hampshire, Oxford, and Norfolk Downs, as well as Cheviot, Welsh, Shetland, and Irish, belong to the short-stapled and medium-stapled classes. Lincoln and Leicester are the most important of the lustre wools. Possessing a long, bright, silky, and strong staple, and also being fairly fine in the hair and of a good colour, they are suitable for a large variety of combed or worsted yarns. Leicester is somewhat smaller in fibre than Lincoln, but its staple is not so soft and lustrous. Romney Marsh resembles Leicester in general properties, and is also used for similar textures. The Black-faced, or Highland breed is, strictly speaking, a medium wool, its staple being of a middle length; it is, however, technically classed as "long." This wool possesses a coarse fibre and varies very much in quality. It is applicable chiefly to the manufacture of rugs, Scotch carpets, and blankets.

Short-Stapled Wools: South Down is one of the more valuable short-stapled wools. Though somewhat harsh and brittle, it possesses a fine fibre, about one-eleven-hundredth part of an inch in diameter. Its milling property is only moderate. The shorter varieties of this wool are carded and made into flannels and other light woollen fabrics, while the longer qualities are combed.

HAMPSHIRE only differs from the preceding in being somewhat longer and coarser in staple, while OXFORD DOWNS is of a more open growth still. NORFOLK DOWNS is comparatively a fine, soft wool, but slightly deficient in strength and elasticity. CHEVIOT is a fair average wool. The staple is of a medium length, handle elastic, fibre sound and strong, milling property good, and colour bright. It is employed in the production of certain classes of fancy woollen and worsted cloths.

WELSH WOOL, which lacks waviness of character, is used largely in the manufacture of the flannels of this name. SHETLAND is not unlike Welsh wool in general character. It is principally employed in the fabrication of knit goods of a shawl and neck wrap class.

IRISH WOOL possesses a strong, thick hair, is moderately long in the lock and is of a fair colour. Manufacturers of low and medium class tweeds, that is, of fancy woollen cloths not requiring fine-spun yarns, find it a useful wool.

10. *Mohair, Alpaca, and Cashmere.*—These are three materials chiefly used in the manufacture of fabrics for women's wear. MOHAIR is obtained from the Angora goat. Its staple is lustrous and silky in appearance, of good length, and hangs in wavy ringlets. The colour is a milky white. Along with woollen yarns, it is used in the manufacture of Astrakans, or fabrics covered with short curls. Another description of textures in which it is utilized is plushes for decorative purposes. In such application lustre imparts a desirable richness to the pile, which may vary from one-eighth to half an inch in length.

ALPACA WOOL is derived from the Peruvian sheep, or llama. Like mohair, it possesses a soft, lengthy staple, but the fibre is not so silky in appearance. It is principally employed in the production of dress fabrics. The natural colours are white, brown, fawn, and black. The original South American races were skilled in the manipulation of alpaca; and tombs have been discovered in Peru, containing materials woven or knitted of yarns made of the wool of the llama goat.

CASHMERE is another fibre commercially classed as wool. It is the product of the goats of Thibet, which are covered with felted tufts of hair of a black or dark-brown colour, underneath which grows a brownish-grey down that can be separated with care. This down is the Cashmere of commerce. The soft, fine, silky texture of this material has caused it to be appropriated to the manufacture of Cashmere shawls.

11. *Wool Substitutes.*—In the manufacture of so-called woollen cloths, various materials are used as substitutes for wool proper. The employment of such fibres has tended to cheapen, to a very considerable extent, the productions of the loom, and make it feasible to produce a sound fabric at a low price. In a general sense trade has been expanded by the use of manufactured fibres.

The following are the most important and valuable wool substitutes now in use: noils, mungo, shoddy, extract, and flocks.

12. *Noils.*—Noil is the short, curly fibre removed in combing wool for worsted yarns. It is therefore the pure wool. It does not, however, possess the same degree of elasticity and wavy fullness as the original fleece from which it is extracted.

Noils are of four classes—Botany, English, Mohair, and Alpaca. The first class is the outcome of combing Australian and other fine wools. The second class is obtained from English wools of the Lincoln and Leicester type; while Mohair and Alpaca noils result from combing the fibrous products of the Angora and Alpaca goats.

BOTANY NOILS are the most valuable. Such noils occupy an important place in the materials used in the production of fancy woollen fabrics. They are blended with wool in making yarns for shawls, and are also suitable for mixing with cotton in spinning fine twist threads.

ENGLISH NOILS are of a coarser and broader quality, but are, nevertheless, used for similar purposes as Botany, only in lower classes of manufactures. Cheviot fabrics consume a large proportion of English noils, many cloths thus designated being made entirely of noil. Sometimes these noils, when used in the black, are mixed with black shoddy, or with shoddy and cotton, the latter fibre assisting the materials to spin to a greater length.

Mohair and Alpaca Noils are much brighter in appearance, as well as softer and more silky in the hand, than the two preceding kinds. They possess but little milling property, and are, therefore, not selected for cloths where felting is essential. In combination with shoddy and cotton they are spun into weft yarns for low grades of fabrics. One important branch of industry for which these noils are useful is that of the Scotch, or Kidder carpet manufacture. As the chief essentials in yarns intended for this application are strength, brightness, and thickness, Alpaca and Mohair noils are suitably adapted to their production.

13. *Mungo and Shoddy.*—Although these materials are obtained from different sources, yet, as the mechanical operations through which the rags pass are practically the same, they may be considered together. Both fibres are wool products, being obtained solely from woollen cloths. Mungo is the result of grinding into a soft, fibrous form rags of a hard character, such as milled cloths, whereas shoddy originates from soft rags of the blanket class, and also from knitted goods. There are two descriptions of mungo—*new* and *old*. The former is produced from new rags, *i.e.*, tailor's clippings, pattern clippings, etc., while old mungo is got from fragments of cloth that have, at one time, appeared in a made-up garment. The smallness of the cost of these materials, as well as the diversity of shades in which they can be obtained—for mungoes and shoddies can be purchased in the black, brown, blue, or almost any colour or mixture desired—cause them to be employed in many classes of woollen goods. The method of applying mungo or shoddy to the better qualities of fabrics with

a warp surface consists in blending them with wool in the formation of the weft thread. In other cloths, mungo forms the bulk of the material used in the construction of the backing yarn, or the thread used in producing the underneath surface of the texture. The method of introducing this fibre into low goods is somewhat different from the preceding. Here it is the principal and the most expensive material used in the composition of the fabric, the weft thread generally being mungo simply, and the warp cotton. Both warp and weft yarns used in medium-priced fabrics are usually a combination of wool and mungo, the proportions varying according to the quality of the texture produced.

14. *Difference between Wool and Mungo.*—The properties of a good wool are necessarily of a superior character to those of mungo. Under the microscope (see *d* and *e*, Fig. 10) there is not always a marked dissimilarity between the fibres, the filaments of some mungoes being in a far more perfect state of preservation than others. Sometimes the fibres are partially stripped of serrations, but probably others might be examined from the same handful of material possessing, when microscopically examined, the complete mechanical development of the wool fibre. Evidently the difference between mungo and wool does not arise in the main from any necessary dissimilarity in the structure of the fibres. Practically, mungo possesses no definite length of fibre—staple, as compared with wool, it has none—while in elasticity and strength it is also deficient. Doubtless some of these deficiencies are due to the mutilation of fibre occasioned in the grinding process to which the rags are submitted, and in which filament is forcibly torn from filament, causing, as a natural consequence, the material to be short, brittle, and wanting in elasticity.

Of course the milling power of mungo depends entirely on the nature of the wool used in making the cloth from which the fibre has been obtained. If the rags ground up were originally made from an excellent fulling wool, then the mungo would possess a certain degree of felting property. Shoddies, though longer in the fibre than mungoes, do not usually felt so well—the wools employed in the production of the rags from which they are recovered being principally of an inferior fulling power.

15. *Mungo Production.*—Rags intended for conversion into mungo pass through various processes before they assume the fibrous appearance of wool. *Dusting* is the first

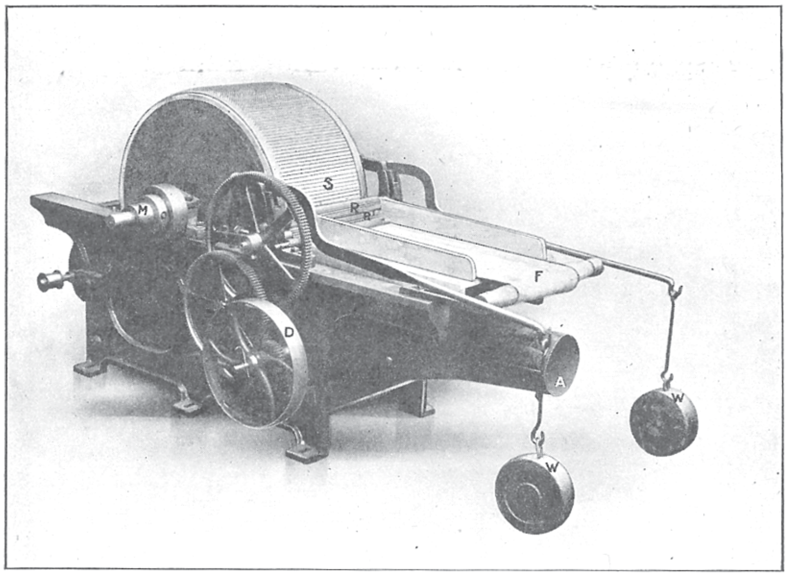



FIG. 13. Improved Rag Grinding Machine.

F = Feed Sheet.
R, R[1] = Fluted Rollers.
S = Swift or Cylinder.
A = Discharge Funnel.
W = Weights on Roller Levers.
D = Driving or Belt Pulley.

operation. It consists in shaking the dust and dirt out of the rags before they are transferred to the hands of the sorter, who classifies them according to quality and colour. Considerable care and judgement have to be exercised in this preliminary work in order to ensure the production of a regular and uniform stapled material. Both old and new rags are submitted to this process. As many as from twenty to thirty varieties have been collected from one bale.

SEAMING follows sorting. It applies solely to rags obtained from cast-off garments, and consists in removing all the cotton threads used in stitching. The rags are now oiled to soften the material and facilitate grinding. The machine in which this, the principal work in mungo production, is effected is shown in Fig. 13. It consists of feed-sheet, fluted rollers, main cylinder, or swift, and funnel for conducting the mungo out of the machine. The swift s, which is the leading feature of the machine, is inclosed in the framework; it is about 18 inches long, 42 inches in diameter, has a surface space of 1,638 square inches, and contains from 12,000 to 14,000 strong iron teeth. The speed at which it runs varies from 640 to 800 revolutions per minute. The rags, having been spread on the feed-sheet F, are conveyed to the fluted rollers, on emerging from which they are seized by the teeth of the cylinder, which not only separate thread from thread, but literally tears fibre from fibre, and thus reduces the whole to a flossy, wool-like state. As the rags are ground up, the material is forced down the funnel A, and thus finds an exit from the machine. Any hard fragments of cloth only partially torn to pieces fall into the cage, from whence they are replaced on the feed-sheet. The weights, W, allow the upper fluted roller to rise should the machine be overcharged, and by this means admit of the rags being conveyed without retention direct off the feed-table on to the cylinder, which continues to throw them into the cage until the machine gets properly cleared.

16. *Extract Wool.*—This material is obtained from rags of which the threads are composed of cotton and wool respectively, as in dress stuffs with a cotton warp and mohair or lustre worsted weft, or in low union fabrics which have a similar warp thread, but thick woollen weft. As the object in extracting is to recover the animal fibre, the vegetable thread is destroyed by a process of carbonizing. To effect this the tissue is steeped in a solution of sulphuric acid and water, and then heated in an inclosed chamber. This drying process causes the water to evaporate, leaving the concentrated sulphuric acid to act upon the fabrics, destroying the vegetable matter they contain,

or, at any rate, reducing it to such a condition that it powders when friction is applied. Washing-off now takes place, to remove the acid from the reclaimed woollen thread. This effected, the material is run through a coarse, open carder, which gives it the required woolly appearance of a textile fibre.

The effect of the acid bath alluded to upon a "union" fabric is shown in Fig. 14. Originally it had a cotton warp and lustre worsted weft, being a plain-woven structure. The warp at A has been decomposed, leaving the weft, threads made of wool fibre, hanging loosely together. This is the reclaimed material which, after washing and preliminary carding, becomes the "extract" of commerce.

"Extract" is not a good wool-substitute as regards milling, and lacks elasticity, strength, and soundness of

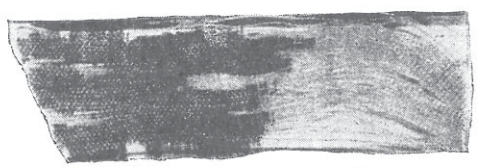


FIG. 14. Dress Fabric after Carbonizing.

staple. It can be obtained in a variety of colours, and is used in the manufacture of low tweeds, and also, when blended with wool, in the production of medium-class fancies.

17. *Flocks.*—These are soft, fluffy fibres removed from the woven fabric in the processes of cloth milling, raising, and finishing. They are of three kinds—"milling," "cropping," and "raising." The first class, which is formed in the milling or fulling machine, is of more value in textile manufacturing than either cropping or raising flocks. White "fulling" flocks are suitable for blending with wool in the production of several grades of cloths. They are also used by woollen yarn spinners for yarns intended for a variety of applications—suitings, dress fabrics, shawls, travelling rugs.

CUTTING OR CROPPING flocks are the fibres removed from the cloth in the cutting operation. Such flocks are not often selected by manufacturers as a fit material for yarn making, and then only for cloths of a very inferior quality, being principally used in the production of flock-papers for decorative purposes. In silk winding, and gassing, a species of "flocks" is obtained which, like the cutting "flocks" described, are so short in fibre as to be unfit for the ordinary kinds of textile work; but are also found useful in the manufacture of wall paperings.

RAISING flocks are derived from the teazles of the "gig," which retain a quantity of the short fibre, drawn from the surface of the cloth in the raising process. Such fibres, when removed from the teazles, are designated raising flocks, and are similar in character to those formed in the fulling process; hence they are employed for like purposes in textile productions.

18. *Cotton* (A, Fig. 12).—Wool and cotton fibres not only differ from each other in physical structure but also in those special properties which they both possess, making them highly suitable for clothing purposes. The cotton fibre is short, fine, and brittle, possessing the appearance of a flattened and somewhat twisted tube, or resembling a wrinkled, twisted, irregular ribbon. Commercially, cotton wool is divided into long and short stapled, the former being used for warp and the latter for weft yarns; but these distinctions are by no means always adhered to, the two qualities being blended in such proportions as will result in making a cheap and satisfactory thread.

The length to which cotton may be spun is remarkable, as many as 252,000 yards of yarn having been spun from one pound of material, *i.e.*, 300's counts. Its spinning quality causes it sometimes to be mixed with wool to facilitate the production of cheap and finely-spun yarns. The fineness and strength of the cotton fibre, and its downy nature, are at the basis of its spinning capabilities. The diversity of fabrics in which it is used is proof of its adaptability to textile threads; thus it is employed in the production of fine lace, muslins, calicoes, sheetings, velveteens, cords, and fustians. In addition to being blended with wool and other materials in woollen cloth production, it forms the warp thread in union cloths; and it is also used, on account of its fineness, in making various styles of compound textures, where its function is to bind the yarns employed in the formation of the face to those constructing the back of the texture.

19. *Silk* (E, Fig. 12).—This fibre is also utilized to some extent in the production of woollen and worsteds. Of all fibres it possesses the least diversity of physical structure, resembling, when magnified, a transparent glass rod, showing but few surface creases. It is a longitudinal body of flexible gum, totally void of cellular structure termed *sericin*. When the fibre is heated to 110° C. it loses its natural moisture, and at 170° C. it decomposes.

Silk threads, in the better qualities of fancy woollens and worsteds, are twisted with worsted or woollen yarns; but they are also applied to vesting and other fabrics in the form of distinct or separate threads to give tone and richness to the pattern. These constitute the two principal methods of applying this fibre to textiles made of wool and like materials.

The silk imported into this country is of two classes—that which arrives in the hank form, and is wound direct from the cocoon, and receives the name of *neat* silk; and, second, *spun* silk, or the thread which results from combining and spinning the cocoons which are too entangled to be wound, and the waste made in the winding process. Before silk is capable of being used as a warp or weft it is converted into one of the following forms: *singles*, *tram*, and *organzine*.

*Singles* is a reeled thread to which twist has been added to give it strength and firmness. *Tram*, used as weft, consists of two or more reeled threads twisted firmly together. *Organzine*, or *thrown* silk, is formed of several "singles" twisted, one with the other, in a contrary direction to that in which the twine is introduced into the individual threads of which the *organzine* is composed.

Strength and lustre are the characteristics of silk yarns. There is no weavable thread, in proportion to its fineness, comparable in elasticity with that obtained from silk. An ordinary silk ribbon will sustain as much tension and friction as a woollen fabric which has been felted for several hours and is many times its thickness. The lustrous quality of silk is, however, the one most esteemed in textile manufacturing. Mohair is the chief animal fibre which possesses anything approaching its bright, shiny appearance. China grass and jute—both vegetable fibres—are more or less lustrous, but they are incapable of being spun to the same degree of fineness as silk. Alpaca and mohair are employed in dress manufacturing to obtain a similar brightness of surface to that developed in silk.

Artificial silk (F, Fig. 12) is a material possessing some of the richness and lustre of the natural product. It may, moreover, be dyed brilliant and permanent colours; but there is one important disadvantage to its use, namely, its inflammability. When methods have been discovered of reducing this, its value as a substitute for silk will be enhanced.

# CHAPTER II

## WOOLLEN YARN MANUFACTURE: WOOL SORTING, SCOURING AND BLENDING

20. Sorting—21. Wool-Washing—22. Detergents used in Scouring—23. Wool Dusting Machine—24. Wool-Steeping—25. Hand Method of Scouring—26. Scouring by Volatile Solvents—27. Scouring Machines—28. Utilization of Waste Scour Solution—29. Drying—30. Teazing—31. Burr-Extraction—32. Chemical Burr-Extraction—33. Oiling—34. Blending—35. Preparing the Blend—36. Fearnought—37. Pulled Waste Machinery.

20. *Sorting.*—The initial process in wool manufacturing is that of sorting or classifying the fibres of the fleece, as clipped from the sheep's body, according to length, fineness, elasticity, and soundness of staple. The necessity for this operation arises from the wool varying in quality in different sections of the fleece. Coarse, fine, strong, and tender locks being present in the wool in its natural condition, it is, until sorted, unsuitable for textile purposes. An attempt to utilize it in the fleece state would result in the spinning of uneven, faulty, and unsatisfactory yarns. About thirteen or fourteen sorts may be obtained from one fleece, but very frequently not more than five or seven are made, and in some branches of the Cheviot industry only three. The following table shows the relative qualities of the wools grown on the various parts of the body of a merino sheep:

| | |
|---|---|
| 1. The shoulders.<br>2. The sides. | The wools grown on these parts are distinguishable by length and strength of staple, softness of feel, and uniformity of character. They are usually the finest wools found in the fleece. |

| | |
|---|---|
| 3. Lower part of the back. | This is also a wool of good, sound quality, resembling in staple that obtained from the shoulders and sides, but not so soft and fine in fibre. |
| 4. Loin and back. | The staple here is comparatively shorter, hair not so fine, but the wool on the whole of a true character. In some cases, however, it is rather tender. |
| 5. Upper parts of the legs. | Wool from these parts is of a moderate length, but coarse in fibre, and possesses a disposition to hang in loose, open locks. It is generally sound, but liable to contain vegetable matter. |
| 6. Upper portion of the neck. | The staple of the wool clipped from this part of the neck is only of an inferior quality, being frequently faulty and irregular in growth, as well as full of thorns, twigs, etc. |
| 7. Central part of back. | This wool is nearly like that obtained from the loins and back, being rather tender in staple. |
| 8. The belly. | This is the wool which runs quite under the sheep, between the fore and hind legs. It is short, dirty, and poor in quality, and frequently very tender. |
| 9. Root of tail. | Fibre coarse, short, and glossy, and the wool often runs with kemps or bright hairs. |
| 10. Lower parts of legs. | Principally a dirty and greasy wool, in which the staple lacks curliness and the fibre fineness. Usually it is burry, and contains much vegetable matter. |

| | |
|---|---|
| 11. The head.<br>12. The throat.<br>13. The chest. | The wools from these parts are in some places classed together, all having the same characteristics. The fibre is stiff, straight, coarse, and covered with fodder, the wool also being kempy. |
| 14. The shins. | This is another short, thick, straight, and shinny-fibred wool, commonly called shanks. |

Such terms as picklock, prime, choice, super, head, seconds, abb, and breech are applied to the several varieties into which the fleece is divided. *Picklock* comprises the best qualities of the wool, as regards fineness of fibre, elasticity, and strength of staple ; *prime* is a similar wool to the preceding, only of a slightly inferior character; the staple of *choice* is true, but the fibre is not so fine as prime; *super* is similar in general properties to *choice*, but not, as a rule, so valuable; *head* includes the inferior sorts and the wool grown on this part of the sheep; *downrights* is derived from the lower parts of the ribs or sides; *seconds* consists of the best wool clipped off the throat and breast; *abb* contains the skirtings and edgings of the fleece; while *breech* consists of short, coarse fibres obtained from this part of the animal's body. "In the worsted trade these names are not used, the following being those generally adopted: blue, from the neck; fine, from the shoulders; neat, from the middle of the sides and back; brown-drawing, from the haunches; breech, or britch, from the tail and hind legs; cow-tail, when the breech is very strong; and brokes, from the belly and lower part of the front legs, which are classed as super, middle, and common, according to their quality. For finer sorts of wool there are no special names, and Botany and similar fleeces are sorted according to their numbers or the counts of yarn they will spin to, such as 50's, 70's, 80's, and so on." [1]

The sorter prepares for the work of classification by

[1] Bowman, "Structure of the Wool Fibre."

spreading the fleece on a table with a wire cage surface, through which a portion of the dust, sand, and other hard particles of matter in the wool falls into a drawer beneath, during sorting. The centre of the back of the sheep forms an indefinite line down the middle of the fleece, which the sorter follows in dividing it into two portions before commencing the actual work of analysis. His work may be said to consist, firstly, in removing a portion of the loose vegetable substance the fleece contains, such as seeds, twigs, etc.; and, secondly, in cutting off the hard tufts of fibres which have by some means or other got fastly adhered together. These preliminaries having been attended to, he proceeds to analyze the fleece carefully, casting the locks according to quality into different skeps with which he is provided. He judges of the wool mainly by its softness of handle, and by thickness or density of growth—weakness of staple, harsh or unkind handle, and want of rankness of hair, are all indications of an inferior wool.

21. *Wool-Washing.*—Wool is naturally impregnated with a greasy substance termed yolk or *suint*, an unctuous varnish caused by the perspiration of the skin, and partly by the animal secretion which lies at the root of each hair finding its way to the tip of the fibre. Yolk is a compound of potash and animal fat. It also contains small quantities of acetate of potash, lime, and chloride of potash. Such is the amount of foreign substances present in some wools that they lose as much as seventy per cent. of their weight in scouring. Certain merino wools contain, in addition to yolk, a considerable proportion of earthy and greasy matters, losing on an average nearly two-thirds in weight during the washing process. The chemical composition of fine merino wool in its natural state is as follows:

| | |
|---|---|
| Earthy substances . . . . | 26.06 |
| Suint, or yolk . . . . . | 32.74 |
| Fatty matter . . . . . | 8.57 |
| Earthy matter fixed by grease . | 1.40 |
| Clean wool . . . . . . | 31.23 |
| | 100.00 |

Several of these substances are recovered by chemical agents from the waste scouring solution, previously conducted into large tanks, and pass into commerce under different forms and under new names. The yolk, for example, after having been separated from the other ingredients of the waste lye, is utilized in the production of a soap said to be specially valuable, on account of the animal fat it contains, for medical purposes. Crude carbonate of potash is obtained in considerable quantities from the residuum of the used scour liquor. Another substance which results from a method practised in chemically treating this solution is a class of oil used to some extent in lubricating rags for shoddies and mungoes.

Now the object in scouring is not simply to remove the greasy product from the material, but also the dirt and other extraneous matter with which the wool may be covered. This should be effected without injury either to the physical structure or chemical composition of the fibre. A wool thoroughly cleansed should be a pure colour, handle soft and elastic, dye readily, produce a true thread, and untimately form a texture full and supple to the touch. On the other hand, wool only partially scoured resists the action of mordants, and takes a streaky colour, the dyes not penetrating the fibre, but remaining on the surface. Indifferent scouring endangers good scribbling and spinning, and also causes the woven fabric to be hard, stiff, and unkind. A generally accepted opinion amongst manufacturers is, that if the raw material is only partially cleansed, each of the subsequent processes will to some extent suffer therefrom; the imperfections arising from this cause becoming, in some cases, the most perceptible in the finished cloth. For these reasons too much intelligence and skill cannot be exercised on this preliminary process of cloth manufacture.

22. *Detergents used in Scouring.*—Potash, carbonate of soda, silicate of soda, ammonia, and soap are all more or less used in wool-washing. Soda is sometimes employed alone in scouring wools of a coarse, open growth, but