FIBRES FOR FABRICS

A. E. GARRETT

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FIBRES FOR FABRICS

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FIBRES FOR FABRICS

BY

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B.SC. BY RESEARCH (LOND.)

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PREFACE

THE Author does not intend this publication to take the place of, or even to supplement, any of the useful books already published dealing with the preparation of the various fibres, the spinning of the fibres into yarn, and the weaving process.

Rather, it has been produced in response to many requests from various parts of the country, and it is hoped will meet a long-felt want among those engaged in dry goods warehouses and in retail establishments.

It is not even claimed to be complete in any branch, but only an introduction, to lead to the study of other books dealing in detail with some branch of the subject.

The Author would like to acknowledge his indebtedness to *The Textile Mercury* for much useful information which he has obtained from that excellent periodical.

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CHAPTER I

COTTON

What it is.—Cotton is by far the most important textile fibre derived from the vegetable world, and is, moreover, quite distinct botanically from any other fibre used in the manufacture of fabrics. It consists of tufts of unicellular hairs which envelop the seeds of a shrubby plant belonging to the order Malvaceæ (better known as the order of the Mallows). When the pods containing the cotton and seeds are ripe, they burst open, and the tufts of cotton swell, until the *bolls*, as they are called, are as large as small apples. The cotton is held firmly in the pod by some of the withered parts which close in upon it, but yet remain open enough for the cotton to be easily picked. The actual seeds are about as large as small peas slightly flattened.

The cotton fibre begins to appear long before the seed has reached its full growth, and the cells of the cotton develop from the surface of the seed.

The length of the fibre varies considerably (from 1½ to 2½ inches), the longest, generally, being those which have grown on the crown of the seed where the cells first begin to appear, and the shortest are always found at the base of the seed.

It seems to be a very doubtful point whether the cotton fibres attain their full length until the pod opens and the fibres are exposed to the ripening influence of air and sunlight.

Species of Cotton Plant.—There are two great families or typical divisions of the cotton plant, viz., (1) those which are indigenous to the Old World, and (2) those of the American Continent. There are many points of difference between plants of these two divisions, but perhaps the chief are: (*a*) the seeds of the Asiatic variety are never black, and (*b*) the curvature at the base of the leaf lobes is compounded of two opposite curves, and is not heart-shaped as in the case of the leaves of the cotton plant of the New World.

One of the most important facts, commercially, with respect to these two great varieties, is the great difficulty of interbreeding them. All varieties of the cotton plant are known by the family or generic name of Gossypium, and it may be as well to continue the description of the plants by referring them to the three great centres of production—United States, India, and Egypt—and also by introducing their botanical names.

American Cottons.—There are a great many varieties of cotton plant grown in America, but they can easily be distinguished from those grown in India by their more profuse growth, and also by the fact that the young shoots are thick and have an irregular section. It is generally sufficient to divide the plants into two sections: (*a*) those of the Gossypium barbadense, and (*b*) those of the Gossypium hirsutum, or (*a*) the smooth, and (*b*) the hairy-leaved kind.

To the first variety belongs the well-known Sea Island cotton, so called because it was first cultivated on a line of flat islands lying off the coasts of Georgia and South Carolina. The seeds of this plant are black, and the flowers are yellow, with purple spots at the bases of the petals. The fibre, or staple, is the longest, strongest, and finest of any variety. The length of the fibre may reach 2½ inches. The plant, if left to itself, grows to a height of 20 feet, but when cultivated as an annual its height is only about 3 feet.

The Sea Island cotton was first cultivated in the United States towards the close of the eighteenth century, having been imported from the Island of Anguilla, one of the West Indian Islands. It was at first believed that it could only be cultivated with success in the south-east States of the United States, but it has, for many years now, been proved that it can flourish in Egypt, Queensland, and elsewhere.

The Gossypium hirsutum species has white blossoms and flourishes best inland, and often on the more elevated parts; hence it is very frequently known as "Uplands."

There are, however, two somewhat distinct types of this variety—one, with green seeds and relatively hardy constitution, the other with white or greyish seeds. The latter succeeds better in the more southern States, and produces a longer and more silky staple. The cotton from both varieties is exported under the name of "American" or "Orleans."

Indian Cotton.—All the Indian cottons, if we except the cotton-tree of the Hindoos, and one or two wild varieties found in Scinde, belong to the variety known as Gossypium herbaceum. This plant grows to a height of only 4 or 5 feet, and the cotton obtained from it has a somewhat moderate length of staple (1 to 1½ inches). This variety is also grown in the Greek Islands and Asia Minor, and is mixed with American Uplands, which also grows there, and exported under the name of "Smyrna."

During recent years perennial or tree cottons have received much attention in India, as some of these furnish cotton of fine quality. They were formerly limited to a few plants in gardens, and their cotton was only used for making the sacred thread worn by Hindoos of high caste. The American tree cottons are much more susceptible to changes of climate than the Indian forms, hence it does not appear likely that they will ever be introduced in great quantity into India. The growth of American annuals may undergo an increase, but it will only be in those lands which do not favour the indigenous variety. The tree variety yields no cotton the first year, and is also particularly susceptible to the prevalent insect and fungoid pests of India.

Egyptian Cotton.—The short staple variety grown in Egypt belongs to the Gossypium herbaceum, but of course other varieties (in particular Sea Island) have been introduced, and it may be said that the chief characteristics of Egyptian cotton are length, strength, and uniformity of fibre, showing very great equality of growth, which probably is due to the very uniform climate which the country enjoys. In Egypt, although cotton has been largely grown for many centuries, it is only since Mehemet Ali in 1821 introduced Sea Island cotton that the cultivation has attained commercial importance.

There is a species of cotton plant indigenous to *South America,* known as the Gossypium peruvianum. It is of the tree variety and attains a height of 10 to 15 feet. In the region of the Andes it bears fruit until the beginning of the frosts. The cottons are known on the market as "Pernams" and "Maranhams." In Brazil the Orleans variety has been introduced, and is extensively cultivated. This cotton from Brazil is known as "Santos."

Climate necessary for growth of Cotton Plant.— In order that the cotton plant may come to perfection a long summer free from frosts is absolutely essential. A study of the areas in the United States under cotton cultivation would, at first glance, make it appear that the areas had become more restricted during late years. Looking carefully into the position of districts once included in the cotton-growing areas, and bearing in mind at the same time the prevalence of severe frosts, even very far south in the great Mississippi valley, the probable reason of the neglect of some of the lands may be guessed at. So much importance is attached to absence of frost during the seven months in which the plants are coming to maturity that exhaustive observations have been carried out in the cotton-growing districts of the United States, and the dates of the first and last killing frosts tabulated for whole series of years.

The reason for this is that the plants are peculiarly sensitive to frost. Should a killing frost occur before the cotton fibre is ripe its development is stopped, and, as its use as a textile fibre depends largely upon its perfect development, the commercial value is much depreciated. (This will be better understood after the reading of the chapter dealing with the microscopic structure of the cotton fibre.)

Another important feature of the climate is that there should be a sufficient but not excessive rainfall. The question of weather conditions is in fact the most important of all. This will be clearly seen by comparing the yield in 1898 with almost perfect weather conditions with that of 1903 with very adverse conditions. In the former year the yield of cotton was 220 lbs. per acre, while in the latter it was only 168 lbs. per acre.

Soil.—The cotton plant has also a great preference for light, loamy, or sandy soils, which receive and retain the heat, while the subsoil holds up a good supply of moisture. This forces the plant into the most luxurious development. Where the soils are too rich the plant develops too much foliage. Cold, damp soils, such as clay, are altogether unsuitable. The nature of the climate and soil necessary can be best appreciated by referring to the mode of growth of the plant in some of the chief areas of production.

Cultivation in the United States.—The area under cultivation is almost limited to the States in the south-east. There is very little cotton grown to the west of 99° W. longitude, as the rainfall further to the west is quite insufficient. Again, to the north of 37° N. latitude the likelihood of killing frosts occurring during the period of growth is so great that the production is at all times uncertain. In the extreme south, *i.e.*, in the lands actually bordering on the Gulf of Mexico, there is an excessive amount of moisture, so this belt is given over to the growth of timber instead.

In 1906–7 there were 32,049,000 acres under cotton in the United States. In the south-east, after excluding wastes, forests, swamp,

&c., the amount of arable land is under 400 million acres. If one-tenth of this were under cultivation for cotton, and the yield were on an average 200 lbs. per acre, it can easily be seen that the maximum production that could be expected from this region would be 16 million bales of 500 lbs. each. For the year ending September 1, 1903, the total crop was 10,758,326 bales, and for the year ending August 31, 1907, it was 11,668,575 bales.

The belts of greatest production are limited to two comparatively narrow strips. One of these strips lies in the valley of the Mississippi between the towns of Memphis and Vicksburg, and is chiefly composed of lands known in the States as "Bottoms." The river, flowing in a tortuous course through a country which is very flat, has from time to time deviated from its bed during periods of flood. The lands enclosed between the old and new courses of the river became known as Bottoms. Two of these, Yazoo Bottom on the left bank of the river, and Tensas Bottom on the right, are particularly productive for cotton. The second strip is in the State of Alabama, in a region stretching from 32° 20′ N. latitude to 34° N. latitude, and from 85° 30′ W. longitude to 89° W. longitude. This region might be called the true "Uplands."

In both these strips the soil is rich in lime, and this then must be looked upon as favouring the growth of the cotton plant.

Throughout the cotton area of the United States the plants are set in rows, the individual plants being a good distance apart so as to enable the ground to be well cleaned. In all the parts where rain is more abundant the land is ridged up on either side of the roots to enable the excess of moisture to drain away. The plant has a long tap-root, which enables it to obtain the necessary moisture from a depth below the surface, if the soil is not too hard, so that the plant has more need to fear excess of moisture than drought.

As the main object is to obtain the finest possible cotton fibre, the plant is not allowed to produce too much foliage, and hence is carefully pruned, and one or two inches are cut from the top of the stem when it has grown sufficiently tall.

The time of sowing the seed in the United States is March or April, and the time of picking, August to the end of the year, and sometimes even later.

On the older cotton lands it has, of course, long been necessary to manure the soil. This has, however, not been so widely practised, as there was a tendency to take up new lands when the old ones began to fail. In some districts, as in Georgia and South Carolina, it has long been the custom to return in some way to the soil the essential ingredients removed by the cotton plant. Among the methods of doing this may be mentioned that of feeding cattle on the cake made from the cotton seed, and allowing the cattle at the same time to graze on the land. Sometimes the cake itself is used directly as manure. In some districts (particularly in South Carolina) there are found rocks containing phosphates. These phosphatic nodules, as they are called, are ground up and used as manure.

The Sea Island variety is grown chiefly in the northern part of the peninsula of Florida. This kind does not flourish in inland districts; in fact, it seems to thrive best not only where there is salt in the soil but also where salt is present in the atmosphere. The quantity of Sea Island cotton produced is always very small, relative to the whole amount, *e.g.*, in the year ending September 1, 1903, only 102,634 bales of Sea Island cotton were produced out of a total of 10,758,326 bales.

In *India* the mode of cultivation is quite different, as is also the climate of the lands on which the bulk of the cotton is grown. The chief cotton-growing lands are those situated round the native state of Berar, which lies to the east of the Western Ghats, in about the latitude of Bombay, although cotton is also grown in the valley of the Upper Ganges.

The cotton lands are of a very peculiar geological formation. The whole district known as the Deccan must, at some remote period of the earth's history, have been the scene of a huge crack in the earth's crust, and a gigantic outpouring or overflow of lava. The soil, which has long been known as the "Black Cotton Soil," consists of decomposed basaltic trap, which contains lime like the Alabama district of America. This soil has such a peculiar retentivity for moisture that even when the outside layers appear quite parched up, there is sufficient moisture present in the soil to enable the plants to grow. The average rainfall in the district in which the cotton grows would be altogether inadequate for the cultivation of the lands were it not for this peculiarity of the soil.

In India the cotton seeds are sown broadcast, and, as a rule, mixed with other seeds. One of the reasons for this is, that the close vegetation helps to prevent the excessive evaporation which would otherwise take place from the soil, *e.g.*, for the year ending May, 1907, the total acreage in the central provinces with cotton as sole crop was 450,812, while 1,076,088 acres were under cultivation with cotton as part crop. The total acreage under cotton in India in 1906–7 was 22,344,000.

Cotton is also largely cultivated in the provinces of Agra and Oudh, and the "Bengal" cotton generally comes from these provinces and the Ganges Doab.

The yield in India is everywhere not so great as in the United States, probably very largely due to the superior care given to cultivation in America. The Indian lands receive much less manure, and there are no new lands to open up.

In *Egypt* the cultivation is confined to the lands of the Delta and Middle Egypt, where the necessary amount of irrigation can be supplied at regular intervals during the seven months of growth. The climate of this region is so dry that it is absolutely essential to irrigate the cotton lands some eight or nine times during the season. This is done at regular intervals, the lands, for the time, being completely submerged. This state of things would, of course, be fatal to the plants in the United States, but the excessive dryness of the atmosphere seems to enable the plants to flourish even with occasional excessive quantities of water at their roots. During the whole time of cultivation the climate is so very uniform that, when the water is plentiful for irrigation purposes, it is not surprising that the cotton as a whole is superior to that of any other country, and that the yield per acre is also proportionately greater.

The sowing of the cotton seeds begins in Upper Egypt about the middle of February, and terminates in the first fortnight of April in the most northerly provinces of Lower Egypt; occasionally, however, it may be continued until the end of April without any detriment to the crop. The harvest commences in Upper Egypt in the second week of August, and in the Delta by the first or second week in September. By the end of November the season is regarded as over, even in the most northerly districts. There are usually three pickings—the first, of best quality, represents about 50 per cent. of the total, the second yields about 40 per cent. of the total, and the third the remaining 10 per cent., which is generally of inferior quality.

Of all the countries which were the chief sources of supply at the end of the eighteenth century, only Brazil is among those which contribute a fair percentage to the world's supply at the present time. Now the United States, India, and Egypt supply at least nine-tenths of the raw cotton of commerce.

In 1790 the raw cotton came from quite different quarters. The British West Indies then supplied 70 per cent. of the total, the Mediterranean countries 20 per cent., Brazil 8 per cent., while the United States and India together supplied less than 1 per cent., and Egypt none at all.

It must not for one moment be concluded from the above figures that the British West Indies ever supplied anything like the amount supplied by the United States at the present day, for 70 per cent. of the raw cotton of commerce in 1790 would form a very much smaller percentage of the cotton on the markets now.

Brazil in 1906 exported some 31,698 metric tons of cotton, *i.e.*, about 140,000 bales of 500 lbs. Of this quantity, Great Britain took 23,265 tons. It must be remembered, however, that Brazil has long since begun to use a good proportion of its raw cotton in its own manufactures; in 1906 the amount consumed in this way was estimated at over 50,000 metric tons. The cotton production of this country is on the increase, and there is plenty of scope for this. There are plenty of fresh lands suitable for the growth of cotton, and there are also plenty of opportunities for better cultivation in the lands where cotton is already grown, as in many cases the plants can hardly be said to be cultivated, for the fibre is simply taken from the plants, season after season, until either the plants or the soil are too impoverished to produce more. A new planting is then done, and the process repeated. The cotton produced in Brazil is, therefore, as might be expected, not up to the standard of good American.

No account of cotton production would be complete without some mention of the possibilities of various parts of our Empire for that occupation. When we remember the climate and soil necessary for the successful growth of the cotton plant, the regions where it is likely to succeed commercially are soon limited. Canada, New Zealand, South Africa, and a good portion of Australia are out of the question, but Queensland, British West African territories, British East Africa, the regions of the Upper British Nile in the neighbourhood of Fashoda, and Central Africa or Nyassaland, together with North-East Rhodesia, may become important as centres of production.

In the case of *Queensland*, it has been known for a long time that the Sea Island variety of cotton thrives well; although, of course, there are parts of this vast country where either the rainfall is too great or too small, yet there are numerous stretches of country in which cotton could be produced with advantage, the great amount of sunshine in a measure compensating for occasional droughts ; for if the plants are well grown, they are able to do with, relatively, a small amount of moisture. In 1905 the cotton crop was about 120,000 lbs., and this was mostly of the Uplands variety.

One of the great difficulties which the growers in Queensland have to meet is the labour supply. This has always been an important consideration, as may be seen by the effect the abolition of slavery had upon the production of the *West Indian Islands*. These islands are once again, however, introducing the commercial cultivation of cotton. Of these islands, it is said that those likely to be most productive are the Granadines, St. Vincent, the southern portions of St. Lucia, Barbadoes, Montserrat, the south-east parts of Antigua, Nevis, St. Kitt's, and the Virgin Islands. Antigua alone produced, in 1906, 53,550 lbs. of good cotton fibre.

In *British West African lands* there are indigenous cotton plants, but very little, if any, attention was paid to the cultivation of the cotton until the British Cotton Growing Association was formed. Of course a good deal will have to be done, both in West and East Africa before the cotton produced there figures very largely in the world's total, yet progress is being made. In West Africa the cotton has been used by the natives in the manufacture of material for ages. American cottons have now been introduced, and the natives prefer this, as it is finer than the indigenous variety. One peculiarity, however, in the usual method of growing the cotton makes the American variety less suitable. The cotton is grown with other plants, such as maize, &c., which, in the case of the American cotton, whose height is only about 4 feet, soon overshade the plant and so hinder its growth. The indigenous variety, which grows to a height of 8 feet or more, can hold its own in this respect. This, of course, will in time be remedied by growing the cotton as a crop by itself—in fact, it has already been started in some districts by the natives, who find that the returns obtained are much better in this case.

There is no doubt that a great impetus will be given to the growth of cotton in Nigeria, by the opening of central ginning stations. One has just (1908) been opened by the Governor of the colony at Oshogbo. This town can be reached by rail from Lagos, and the factory is expected to be able to deal with 12,000 bales annually.

In *East Africa* cotton grows well on a belt of land some miles from the coast, and fibre of good quality has already been received from this district. Now that the railway is opened from lands in the interior of British East Africa to Mombasa, and communication with the interior is being improved, we may confidently hope for an increase in production from this quarter.

In the valley of the *Bahr-El-Ghazal* there is plenty of very fertile land admirably adapted for the growth of cotton, but the cost of transport has been so enormous as to prevent any serious attempts to introduce cotton. In this district, again, the improvement of communication in the valley of the Nile will, in all probability, bring about, in course of time, many important changes.

In *Nyassaland* cotton seeds have been introduced from Egypt, and good crops have been reared for some years past. From the adjoining lands of *North-East Rhodesia* cotton comes now to Liverpool, nearly 30,000 lbs. weight being received at that port during September, 1907, and it is understood that a great increase in the area of land under cotton is about to take place.

In the *Island of Ceylon* cotton is cultivated only to a very small extent (400 acres), owing to the many crops which pay better. It was thought that the coast-lands were suitable for Sea Island cotton, but experiments have proved this not to be the case, and it is hardly probable that much increase in the amount of cotton grown will take place, while tea, rubber, cocoanuts, &c., pay so well.

Other countries, besides those already mentioned, produce cotton on a small scale. Perhaps it is hardly fair to include *China* among such as these, since that country produces some 7 or 8 per cent. of the world's total. So much, however, of this is used either in China itself, or in Japan, that it may be hardly said to enter into the consideration of supply for other countries. The valley of the Yangtse Kiang is the most important part of China for cotton production, and more of that commodity from this district may find its way on the general market when the communication with the interior is improved. Nevertheless, it must be remembered that there is an enormous home market, and as the manufacturing industries increase, so more material will be required for home consumption.

Japan has long since ceased to grow sufficient for its own use, and now imports enormous quantities of raw cotton, chiefly from India and China, American cotton only being used in comparatively small quantities.

Cotton-growing has also been introduced by *Russia* into her *Central Asian provinces.* As far back as 1900 there were about 1,000 square miles under cotton cultivation, and the returns were of a very satisfactory nature. Of course, a good proportion of the cotton fibre which is exported from these lands finds its way to the mills of Lodz and Moscow, but there are mills in the immediate neighbourhood which make use of some of the crop.

In some districts the cold nights are apt to have a deterrent effect on the plants, while in others locusts are responsible for much devastation.

The *Island of Cuba* is also well suited to the growth of cotton; in fact, an American expert has said, "I consider conditions in Cuba from every standpoint more favourable to the successful cultivation of cotton than conditions in the cotton belt of the United States, and that with proper preparation of the soil, careful selection of the seed, and frequent cultivation, the Sea Island cotton grown in Cuba will be far superior to our best varieties. The native wild cotton resembles the Egyptian variety in texture, and has a clean, black seed, with a staple somewhat longer than our best Uplands."

In *Mexico* the production of raw cotton is steadily increasing, the increase during late years being more especially due to an extensive system of irrigation on the Nazas River reclaiming and planting a large area of land with cotton. Some parts of Mexico, in which cotton was formerly grown with success, have abandoned the cultivation owing to the difficulties of irrigation.

This is by no means a complete account of all the lands where cotton is grown, but for further information the reader is advised to consult current issues of such papers as the *Board of Trade Journal* and the *Textile Mercury*.

Cotton Pests.—There are other difficulties which beset the grower than those of climate, soil, and suitable seed. In Mexico and Texas a cotton boll weevil has been for some years a source of great anxiety. In 1903 it was stated that this pest was making headway from the south into American lands at the rate of about 60 miles per year. This pest is very difficult to eliminate, and it was so destructive that in one year (1902) alone the crops in Texas were diminished by as much as 400,000 bales.

There is also the danger of importing this weevil into countries where cotton seed is introduced, for its larvæ bores its way into the cotton seed.

A kind of moth known as the cotton gold-tail is very common in India, and it has also been found to do much damage to the cotton crops of Uganda in Central Africa.

In the Sudan a variety of small beetles have been doing considerable damage to the cotton.

Manufacture.—The cotton is picked after the pods have burst and the fibres are ripe. All the cotton should be picked before the killing frosts occur. The pickers grasp the boll in the hand, and pull it away from the pod, with as little of the pod substance as possible.

The raw cotton so obtained has to be further prepared before leaving the districts where it has grown, as it contains seeds and other impurities—in fact, only one-third is pure cotton, two-thirds seeds, &c. These impurities are extracted from the cotton fibre by a process known as *Ginning*.

English cotton goods were spoken of as early as the sixteenth century, but these were not in reality cotton goods at all, but were made of wool. Manchester, Kendal, and parts of Wales carried on this manufacture. The precise date at which Manchester began to produce the real cotton goods is difficult to determine, but certainly as early as 1640, since buyers are mentioned as being in Asia Minor at that date. Throughout the seventeenth century cottons (as calico) were imported from India, and it was not until the eighteenth century that this state of things was reversed.

The change was largely due to the long series of inventions which took place in England at the end of the eighteenth century, and which ultimately revolutionised the textile industries.

The *Spinning Jenny*, which was the first machine by means of which more than two yarns could be spun at the same time, was invented by Hargreaves in 1764, and patented in 1770. The machine invented by Arkwright, and known by the name of the *Throstle* or *Waterframe*, appeared in 1769.

From these originated, in 1779, a machine which was an improvement on both. This was invented by Crompton, and being a cross between the jenny and the throstle, became known as the *Mule*.

A little later (1793) a *gin* was invented by Eli Whitney for removing the seeds, &c., from the cotton, and this gave a great impetus to the exportation of raw cotton from the United States.

Although it is not intended to give a complete account of the various processes through which the cotton goes before it becomes cotton cloth, a few short explanatory remarks will be here given, since, omitting details, the various short fibres are spun and woven in practically the same manner.

The cotton fibre, after passing through the gin, is exported in the form of large bundles or bales of about 500 lbs. weight. In order that the space occupied by the raw cotton may be as small as possible, the cotton is firmly compressed into these bales, so the first operation necessary on arriving at the factory is to open up the bales and still further to clean the raw cotton (*Opening* and *Scutching*).

In these processes all the matted fibres must be disentangled, while dust, sand, seed, leaf, and all extraneous substances must be removed.

Next, the cotton fibres are subjected to a series of processes which have for their object the straightening out of the fibres, and for these the cotton passes through the *lapping* and the *carding* machines. After this, the aim is to get the fibres more or less parallel to one another and in a more or less continuous form, known as a *sliver*. The machines used for this are known as *drawing frames*. In these the sliver is also drawn out until it is of the necessary uniform thickness, and in some of the last machines through which the sliver passes a small amount of twist is also imparted to it ; this must be accomplished without the fibre being strained, doubled, broken, or injured in any way, as otherwise it will be found that the strength of the yarn is relatively small. The main twist is, however, placed upon the material in the *spinning frame*, and it is then the yarn of commerce, and is ready for use in weaving the various fabrics for which it is intended.

Naturally, the amount of yarn on the market soon began to increase so much that the looms then in use could not cope with it, and the next step was the invention of the *power loom* by Cartwright. His first machine made its appearance in 1785 ; this he improved and patented in 1787, but even this had to be greatly improved before weaving could be done by it as cheaply and rapidly as in the old hand looms.

Other spinning machines have made their

appearance since the time of Crompton, and of these the *ring* spinning frame was in operation in the United States as early as 1832, but it is only in recent years that it has met with much success in England, although it is now preferred for some classes of yarns.

Just about the time when these improvements and inventions were being made in the spinning and weaving machines, steam was coming into use, and in 1790 Arkwright applied this to the cotton industry.

Circumstances favoured England in these early days, for just at the time when these Englishmen were doing so much to develop textile industries in the factories, the Continental countries were in such an unsettled state, owing to the Napoleonic wars, that at the close of the year 1815 England had obtained such a start that it has taken the best part of a century for others to come into very serious competition with her.

It must of course be expected that as manufactures improve and increase in other countries, competition will become more keen and markets more restricted.

In each case of the principal textiles, *i.e.*, cotton, wool, silk, and flax, it is well known that there are a great variety of grades which differ from one another in their properties, some being suitable for one purpose, some for another. On this account it is easy to understand that the raw material can be best disposed of in large markets, and that the number of these markets will be limited. Hence it is that Liverpool and Manchester (especially since the opening of the Ship Canal) are the two great centres for the disposal of the raw cotton in England.

In judging the grade of the cotton fibre many factors have to be taken into account, such as the length of the staple, the fineness of the fibre, and the strength of the fibre. The length of the staple various considerably, the Sea Island and Egyptian varieties yielding some of the longest fibres as well as some of the finest. Colour and freedom from impurities also are taken into account when classifying the cotton into grades.

Naturally, there are a great number of these grades in common use, even from cotton obtained from a single source, and although standard samples of each grade are always kept, the changing nature of the cotton crops makes it desirable that a certain degree of freedom should be left in this respect.

The ordinary American cottons are classified broadly as good ordinary, low middling, middling, and good middling; Egyptian varieties as fair and good fair; Indian as fair, good fair, and good; while Brazilians are middling fair, good fair, and good.

The cotton manufacture of the British Isles is centred in South Lancashire, and there is no part of this country so well suited for this industry. It enjoys the great advantages of easy access to great ports on both sides of England, which serve as distributing centres for the goods produced, plenty of coal for its engines, and iron mines and works at no great distance. Yet there is no doubt that it is to its climate that South Lancashire owes its success in the cotton world.

The industry is divided into two great branches —spinning and weaving. The chief centres for spinning cotton yarns are Manchester, Oldham, and Bolton, while cotton-weaving is carried on in the more northerly towns of Burnley, Blackburn, Preston, &c.

Now, on consulting a good map of the county, it will be seen the spinning towns are all situated in a natural funnel formed by the Pennines and an offshoot to the west. To explain this one must understand that moist air is required when the finest yarns are being spun, as in dry air the strain would be too great and the yarn could not be produced. Now the moisture-bearing winds are those which blow from the west or south-west, and in this neighbourhood, meeting with resistance to their eastward progress in the form of mountains, the air rises, becomes cooler, and so much of its moisture condenses.

It is not so much the rainfall as the continual moist nature of the atmosphere which is so important in this case. Before the opening of the Manchester Ship Canal attempts were made to establish spinning factories for the production of fine yarns at Liverpool, but none met with success, for although Liverpool is not far distant from the spinning centres, it is too far to partake fully of the great advantages of a moist climate.

Even the site of a mill in the spinning district itself is not without its intrinsic value, for it is found much preferable to have sites facing the west than the reverse condition. That these climatic conditions are a distinct advantage will be better understood by consulting returns as to exports of yarns, &c. It will be found that it is mainly in the export of fine cotton yarns that England is able to hold her own.

In the United States of America there have long been very important and flourishing cotton manufacturing industries. At first these were exclusively situated in the New England States, and it is these that are still the chief producers of the better-class goods. But it is to the rapidly growing industry in the southern cotton growing States that we must look for keen competition, especially in the coarser kinds of cotton fabrics.

Modern mills with the best and latest machines have been springing up with great rapidity in the States of North and South Carolina and Georgia. Here cotton is grown in the neighbourhood of the mills—in fact, so near that many of the mills receive their supplies of raw material direct from the planters' waggons.

Thus, not only is the carriage of raw cotton saved, but there is no need for compressing the cotton into bales. Perhaps, however, the great advantage which these mills possess over those situated in the New England States and in Lancashire is the abundance of cheap labour.

America finds a market for her surplus cotton goods in the northern provinces of China and in Manchuria, especially for goods of a heavy, coarse nature.

A cotton manufacturing industry on modern lines has grown up in India since about 1876. The chief centre here is Bombay. This city, although not actually on the cotton fields, is in sufficiently close proximity to the best cotton-growing lands to be able to easily obtain its necessary supplies of raw material. There are, however, several great disadvantages with which Bombay has to contend.

The machinery, and also coal, have to be imported, and that from lands some thousands of miles distant. To balance this there is, of course, plenty of cheap labour, and a good home market for the coarser and cheaper kinds of cotton cloths. India also had for many years a good run of trade with China and Japan in coarse yarns and material.

Japan has, however, extended and improved her own cotton manufacturing industries to such an extent that she can not only largely supply her own needs, but can spare a large quantity for export to China. While India has thus lost a valuable market for her manufactured cotton goods, she has found one for her raw cotton, as Japan has long since outdistanced her own supply, and it is from India that she obtains a good proportion of the raw cotton used. The other countries supplying raw cotton to Japan are China and the United States.

The first cotton factory in Japan in which steam-power was employed was started at Kagoshima in 1865–7, but it was not until 1880 that any real progress had begun.

The chief centre of cotton manufacture in Japan is in the south of the main island in the neighbourhood of Osaka. Here it is that the land is most fertile, and cotton and rice can be grown as well as other foodstuffs.

A large population has grown up in this neighbourhood, and so there are two important factors in the success of a manufacture assured, viz., plenty of labour and a good home market.

But Japan has for the last few years been face to face with one of the great troubles which have long been known to other manufacturing countries. The people are fond of an outdoor, free life, and it is extremely difficult to get them to remain sufficiently long in the factories to become really efficient. All kinds of things have been tried in order to tempt the girls to remain, such as a bonus after so many years' service, and savings banks in the mills giving high rate of interest. None, however, have succeeded, and it seems that a higher rate of wages is the only possible solution.

Cotton mills have also been established in China. Three foreign-owned cotton mills started work in Shanghai in 1897, and the yarn produced in these mills is found to be superior to that of Bombay and Osaka, both in colour and quality. There are besides a large number of cotton-spinning mills owned by the Chinese, and the industry is steadily growing.

To come nearer home, there are very important cotton manufactures carried on in several of the European countries. In France there are important centres in the north and north-east. Rouen is the chief port for importing raw material, as well as being the chief town engaged in the industry. St. Quentin is also an important market and manufacturing town.

In Germany, Bremen is the port which imports the bulk of the raw cotton, and thus has the greatest raw cotton market. The manufactures are carried on in a great many different parts of Germany, for in that country there is no great centre such as we have in England. Mülhausen in Alsace Lorraine, and Chemnitz in Saxony are perhaps two of the principal towns engaged, the latter often being spoken of as the Saxon Manchester.

Russia, which is the only country of Europe not importing large quantities of Lancashire cottons, has important manufactures of its own, carried on more particularly in the great centres of population, such as St. Petersburg, and Narva on the Baltic, Moscow in the interior, and Lodz in Poland. To gain some idea of the importance of the Russian cotton industry, it may be stated that in February, 1908, four of the largest cotton-spinning firms at Lodz formed a joint company, representing a capital estimated at £3,000,000.

Austria, Belgium, Spain, and Italy have each considerably more than one million cotton spindles at work.

Lastly, in the north-east of Switzerland cotton is used for the making of trimmings and embroideries. Since 1899 the value of embroidery exported from Switzerland has been, on the average, over 110,000,000 francs yearly, their best customer being America. Lately, however, partly owing to competition from France, Germany, Russia, and America itself, but also to want of enterprise, the industry has received a marked check in its progress.

The chief countries for the importation of cotton goods from England are India, China, the Continent of Europe, and the United States, although the latter has a greater number of spindles than any other country except the United Kingdom. On the average three-fifths of the total quantity of cotton goods exported in 1905–7 went to markets east of the Suez Canal. India took 38 per cent., China about 10½ per cent. The United States of America and Canada together took about 2 or 3 per cent., while all the countries of Europe taken together took about 11½ per cent.

Until the end of the eighteenth century the woollen manufactures of England were more important than cotton, yet in about twenty-five years after this more cotton than woollen goods were exported, although wool was produced at home while all the raw cotton had to be imported. In order to understand the cause of this great change one must consider the markets for cotton and woollen goods respectively.

In the case of cotton goods the consumption is practically universal, while woollens are mainly required in countries situated in the temperate zone and colder regions, and of these many will have woollen manufactures of their own. Again, the greater number and more important of the markets for cotton goods must be reached from the manufacturing centres by sea, and no country has such advantages in this respect as England.

Nevertheless, as other countries develop their industries we must not be surprised if our English cotton industries do not increase at a similar rate, but must rather be satisfied if we can successfully hold our own.

CHAPTER II

WOOL

THE wool of the sheep or goat is a particular kind of hair, which, however, differs from ordinary hair in its microscopic details, and particularly in its scaly and wavy nature.

A general knowledge of the *minute structure* of wool is essential, in order that one may understand the value of the fibre in the textile industries. A single fibre, when magnified to about 150 diameters, can be seen to be marked transversely by a series of very distinct and apparently irregular striations. These are in reality the edges of the overlapping scales of the wool. In the very finest short-stapled kinds there may be as many as 4,000 of these scales to the inch; but in the long-stapled variety there is not usually more than about 2,000. The number of these scales is of the utmost importance, since it is largely owing to their presence that it is possible to spin up the short wool fibres. The scales are attached at their bases only, so that if a single fibre could be bent and then examined the scales would stand out from the fibre as in the diagram [III., p. 158].

Now, if two fibres are so placed that their scales run in opposite directions, it will at once be apparent that the scales will interlock with one another, and the fibres will become more or less firmly bound together. Now, of course, although the wool fibres are laid more or less parallel to one another, it is clear that the scales of the fibres will go, some in one direction and some in the opposite, and so in the yarn the fibres will become more or less firmly interlocked. The under surfaces of the scales are, however, of a serrated nature, so that the fibres do not always close up to their fullest extent; but should some soap, or any similar substance, be applied to the yarn so as to lubricate the under surface of the scales, and then the yarn be subjected to a certain amount of rubbing, the individual fibres will more firmly interlock, and the yarn consequently will shrink. From this one can readily understand how it is that many woollen materials shrink when they are washed in an unsuitable manner.

The wavy nature of the wool is also of great importance to the spinner, as the natural folds enable the fibres to spin up more readily to form yarn. The number of waves per inch varies greatly, there being a far larger relative number in the short-stapled kinds of wool.

These two properties of the wool fibre enable the wool to be made into a kind of cloth without undergoing the processes of spinning and weaving, for some wools possess these properties to such an extent that it is only necessary to wet the fibres and gently beat them in order to make them join together, to form a fabric which is sold for various purposes under the name of *felt*.

There are a great many different kinds of wool, the best being that known as *Merino*. This wool is the finest of all wools, and has a diameter varying from $\frac{1}{2500}$ to $\frac{1}{2000}$ of an inch. It has also a larger number of scales per inch than other varieties, these in some kinds reaching as many as 4,500 per inch; hence this kind of wool has a natural disposition to felting.

Merino wools are now obtained from widely different sources; Australia sends us some of the very finest, while that from Saxony is also fine. Cape Colony also produces merino wool, and so does the Argentine Republic. The kind known as Buenos Ayres merino comes from the latter country, and has usually a somewhat harsher feel than other merinos.

Of late years, however, the sheep farmers in Australia and elsewhere have found that it is more economical to obtain a somewhat inferior fleece and a saleable carcase than to rear sheep entirely for their wool. Hence a good deal of cross-breeding has taken place, therefore much wool arrives on the London market under the general name of *cross-breds*.

The *English wools* may be roughly divided into three classes. First, the short-wool sheep, which are descended from the merino type; such are the Southdowns and other sheep native in the South of England. Secondly, the pure lustre wools, which are represented by the Leicester and Lincoln breeds. The wool of these is long and strong, the fleece is, as a rule, large, and the fibre has a fine, silky lustre, and the wool a good general colour. The last class is the wool of the mountain breeds. The Cheviots and black-faced sheep of Scotland and Wales belong to this breed. The wools of these vary considerably, according to the locality in which the sheep have been reared, that of the Scotch sheep being coarser and longer than the Welsh wool.

England has long been largely dependent upon imported wool for the carrying on of her great woollen manufactures. The chief sources of supply are Australasia, South Africa, and the Argentine Republic. The first is the most important wool-grower in the world, more wool being produced there than in all the countries of the Continent of Europe put together.

The sheep originally introduced into *Australia* were of the merino type, but other breeds have since been tried, and a good deal of cross-breeding has taken place. The most important of all sheep-rearing districts are those situated in the colony of New South Wales. In that country are the large tracts of land watered by the rivers Murray and Darling. The lands known as the Riverina, and further north as the Darling Downs, are the homes of many millions of sheep. The whole of this district has one great drawback, *i.e.*, the frequent occurrence of droughts. The rain-bearing winds are of an easterly nature, and hence have had to cross the mountains before reaching these lands. On this account the rainfall is in some parts at all times small, and very often insufficient. In the dry season the large rivers become mere strings of pools, and the sheep cannot find sufficient pasture to exist. Nature has, however, provided two plants, which in some measure help to sustain the flocks during these trying times. One of these is a kind of grass with deep-seated roots. This grass is eaten by the sheep, as it was also by the kangaroos; hence the name "Kangaroo-grass." The other is a kind of shrub which, in times of drought, has a peculiar withered appearance, and yet retains a relatively large amount of moisture and nourishment for the sheep. This plant can grow on those soils, which contain more salt than ordinary soil, and is known by the name of "Salt-bush." How these droughts affect the sheep farmers may be imagined when it is stated that owing to droughts between 1895 and 1899 the number of sheep was reduced by 20,000,000.

It must not be forgotten, either, that the damage is not to be entirely estimated by the number of sheep which succumb to the drought. Those which remain are in such a poor state that the wool produced by them is for some time of a very inferior nature.

Queensland is the next most important wool-producing colony, and then Victoria. There are important wool markets in these colonies at Melbourne (Port Phillip), Sydney (Port Jackson), and Brisbane. A large proportion of the wool is exported, as there are no important wool manufacturing industries carried on in the colonies themselves. Most of the exported wool finds its way to the London market, and a good deal of this enters into our *entrepôt* trade, *i.e.*, it is re-exported without undergoing any manufacturing process in England, since more than half of the colonial wool is really consumed on the Continent. I might mention here that not very many years ago the London wool market was not only the greatest in the world, but was practically the only one of importance in Europe. Now, however, other ports, such as Dunkirk in France, Hamburg in Germany, and Antwerp in Belgium, have very important raw wool markets. In the case of Antwerp it will easily be seen that London may have a formidable rival as a distributing centre for the Continent, since the wool can be sent direct from Antwerp to the manufacturing centres without break of bulk, while in the case of London it must be shipped to some Continental port and then be redistributed. Down to 1888 the largest number of bales of colonial wool sent direct to foreign ports was only 5·8 per cent. of the total imported into Europe and America, but in 1899 the amount so imported was upwards of 20 per cent. of the total.

New Zealand—particularly the South Island—also rears large numbers of sheep. In this case, however, the sheep were reared originally for their mutton, and are English breeds. Still, large quantities of wool are received from this country, as well as frozen mutton, although it may not be of so good a class as the Australian wools. The following facts will give some idea as to the more important details of sheep farming in Australia.

The number of sheep on December 31, 1906, was estimated to be 103,548,330.

The wool season 1906–7 was the largest on record, the total production being 2,090,188 bales. Of this the Australian woollen mills used only 40,000 bales. The average value of the wool was £14 3s. 11d. per bale, so that the total value was £29,671,961.

During 1906 about 16,000,000 sheep were slaughtered.

In the case of *South Africa* the great sheep-rearing lands are those districts in Cape Colony known as the Karoos, the Orange River Colony and Transvaal. The Karoos, especially those more to the west, are lands which receive a very precarious and small rainfall, and the sheep have but little pasture during the dry season. A kind of salt-bush (Karoo bush) thrives here too. This bush has very remarkable roots, extending downwards for great depths—some have been traced for 30 feet down—therefore this plant can grow where it would be quite impossible for grass to exist.

When the rains do occur the vegetation is profuse and grows most rapidly. The more eastern part of the Karoo is the district where most of the sheep are reared, and Uitenhage may be taken as one of the most important centres of this industry. The wool is mainly exported from Port Elizabeth and East London, and a great deal of it finds its way to the London market, although of late years a considerable quantity has been shipped to Hamburg direct. The wools from Orange River Colony and Transvaal are exported *viâ* Port Elizabeth. Port Natal also exports wool to some extent.

In the *Argentine Republic* (River Plate) sheep are reared, and the wool produced is almost entirely exported. Although this country has a very large area, yet the sheep-rearing lands are restricted by climatic circumstances. In the far South cold winds and rains prevent the successful carrying on of sheep-farming, while in the more inland westerly parts the liability of drought is a great drawback. With these disadvantages there are still, however, large quantities of wool produced here. The city of Buenos Ayres is the chief market and port. The wool exported from Buenos Ayres finds its way very largely to Dunkirk and other Continental ports, and only comes on the London market in relatively small quantities. One of the reasons for this is that the wool usually contains large quantities of vegetable matter known as "burrs." These burrs can only be extracted by the use of a special burring machine, or by chemical means. The Continental industries are of later development than our English woollen industries, and provision has been made for dealing with this kind of wool in such a manner as to be detrimental to some of the Yorkshire mills.

The greatest wool producers of the world, then, are: Australasia, the Continent of Europe, Argentine Republic, United States of America, the United Kingdom, and the British colonies in South Africa. The order given is that of relative importance, and the total crop for the year is now, as a rule, considerably over

2,000,000,000 lbs. weight, three-fourths of which is supplied by the first three named.

In the natural state the raw wool is far from clean. In the course of grazing the sheep will pick up all kinds of impurities in its fleece, such as sand and other dirt, as well as burrs and other parts of plants. Then a certain amount of grease is also present on each wool fibre, which keep the fibres from matting together when on the sheep's back. This natural covering of grease is known as the *Yolk*.

The wool is exported from the countries where it is produced in the form of bales. The wool in these bales is nearly always greasy, and it is surprising what a small proportion of wool these bales actually contain. As a general rule, less than 50 per cent. of the total weight of the bale is clean wool, the remainder being dirt, grease, vegetable fibres, &c.

From this it will be understood that one of the first and most essential steps in the preparation of the wool for its manufacture is the removal of this extraneous matter. For this purpose the wool has to be washed and scoured. Now, seeing that wool is so easily injured by alkaline solutions, it must be washed with water suitable for that purpose. Water containing lime would, of course, be especially unsuitable for *wool-washing;* and, in fact, it is by no means so easy as it appears to find suitable water. Hence it is that such places as Verviers, in Eastern Belgium, have secured and held their importance as wool-washing centres for hundreds of years. Wool is sent from all the surrounding parts to this town simply for the sake of its washing. The small stream which supplies the necessary water has been dammed up so as to supply the water in sufficient amount.

The waters of the Yorkshire streams are also suitable for this purpose, and this, no doubt, had a great deal to do with the establishment of woollen mills in that district.

Mohair is the wool produced by a goat, which originally had its home in the highlands of Asia Minor, and is often known as the Angora goat. Until 1856 it was solely produced by that country; and it was due to Mr. Mosenthal that this goat was introduced into Cape Colony. Several attempts were made to secure a flock of these animals, and they were at last obtained, and brought to England in August, 1856, and kept grazing in Victoria Park for a time. About thirty of these goats were eventually sent to South Africa, and it was found that the climate of that country, especially that of the dry, open plains, is very suitable for their rearing, and their number has gradually increased until at the present time the amount of mohair exported from South Africa is even more than that from Asia Minor.

An important industry in connection with the manufacture of goods from mohair was established in Yorkshire by Sir Titus Salt, and the town of Saltaire has grown up as the result.

The finest mohair is obtained from the young goats, which are clipped for the first time when they are about six months old.

The total crop of this fibre varies, but in 1899 it had reached over 25,000,000 lbs. weight, of which South Africa supplied rather more than half.

It must be remembered that alpaca and mohair are two distinct materials. *Alpaca* is the wool of a goat which inhabits the mountainous districts of the West of South America. In this same region, at different elevations, are also found the *Llama*, and *Vicuna* goats, which supply a limited amount of fine wool fibres for the textile market.

Camel-hair is also classed with wools.

The sheep wools can be roughly divided into three classes, the division depending upon the clip.

The first clip, which differs from all others in the fact that the ends of the wool fibres are pointed, and in the great difficulty experienced in separating the fibres, is known as *Hog* or *Hoggart Wool.* All other clips are classified as *Wether Wool.*

The wool which is taken from the skin of the slaughtered sheep is known as *Skin Wool.* When examined microscopically this wool can be readily distinguished by the small pieces of skin, &c., which adhere to the root-ends. The process of pulling the wool out of the skins is sometimes rendered easier by some preparatory process, such as sweating.

As wool, even if obtained from the same fleece, will differ considerably in its suitability for certain purposes, it is apparent that in wool from any single flock there will be many different grades, suitable for the manufacture of quite different materials; hence it is that the first, and one of the most difficult operations, is the *sorting* of the wool, and persons engaged in this work must be chosen on account of their experience, for the sorter has to judge of the quality of the wool, partly by touch and partly by the appearance.

When the wool is particularly dirty, and the dirt is of such a nature that it can be shaken out, the wool is passed through a machine in which it is thoroughly shaken. This machine is known as a *Battering Willy*, and the wool is very apt to be damaged when subjected to this process. The wool is then washed and sometimes dried.

It must be understood that there are two distinct branches of the wool manufacture, which are often spoken of as the *Worsted* and *Woollen* manufactures respectively. In the first case the object in the processes preparatory to the spinning of the yarn is the treatment of the fibres in such a manner that the individual fibres retain their individuality, and the yarn, when produced, is composed of fibres which are more or less parallel to one another, and is practically free from loose surface fibres. On the other hand, in the woollen yarn no such great care is observed, as the object is not to produce such a uniform yarn, but rather one which will, more or less, felt with its neighbours when subjected to the various finishing processes which the woollen cloths undergo.

Hence it is that wool, which is destined to produce worsted yarn, must have all the very short fibres removed from it, and this has led to an erroneous idea that all worsteds are produced entirely from long-stapled wools, while woollens are entirely short-stapled. While it is quite obvious that the long-stapled varieties lend themselves more readily to the preparation of worsted yarns than the short-stapled, yet it is quite incorrect to state that only long-stapled wools are used for worsteds.

After the cloths have been woven up they are subjected to various finishing processes, which differ according to whether they are worsted or woollen cloths. In the case of woollen the nap is sometimes raised by means of the prickly head of the teasle plant, and sometimes the nap is cut down to produce a somewhat velvety kind of surface. Now if this process were resorted to in the case of worsteds it would practically render useless all that which has been accomplished after much care and expense on the production of the special yarn. Again, woollens are often subjected to a process known as *Milling* or *Fulling*, by means of which the yarns are made to felt and the material to shrink, but this is only carried out to a slight extent in the case of worsteds.

A gloss is imparted to the surface of the fabric by means of pressure, and various other processes are necessary before the material is ready for the market; but for these the reader is referred to books which deal with that branch of textile industry.

Quite a large trade exists, particularly at Dewsbury and Batley, in Yorkshire, in which old cloths and waste material from factories are made use of in the preparation of an inferior quality of cloth. The old cloth is torn up, and is then, so to speak, remanufactured. Such material is known by the names of *Shoddy* and *Mungo;* the former name being usually applied to cloths made from spinning wastes and from loose-textured goods, while the latter is confined to that made from hard twisted and felted materials.

When the woollen manufactures were first set up in England they were placed where there were plentiful supplies of water free from lime and suitable for wool-washing; where there was an abundance of fuel (forests), cheap provisions, and good sheep farms near at hand from which to obtain supplies of the raw material. In those days the kind of wool which could be most easily obtained settled the precise nature of the manufacture: if long-stapled, then worsteds; if short, then woollens. In these early times, before the factories were established, the woollen manufactures were more scattered than they are now, *e.g.*, in the seventeenth century woollen goods were manufactured in Kent, Wiltshire, Oxfordshire, Devonshire, Gloucestershire, Norfolk, Suffolk, and Essex, as well as in Yorkshire and Lancashire, and even this is not by any means a complete list.

It will be remembered that in the South-East of England at this time the great bulk of the population was settled, and enjoyed the above-named advantages, but as prices of rent, &c., rose the industry was gradually forced westward, and the sheep reared on the Cotswold and Mendip Hills supplied the wool for an important industry. It is interesting to note that the name "worsted" is derived from Worstead, a village near Norwich, in which the industry was formerly carried on.

There is really no proof as to the date of the first time when wool was woven into cloth in England, but it certainly dates back some two thousand years. We are told that there were very important manufactures of woollen goods at Winchester during the Roman occupation of the country, but during the stormy times which followed the evacuation by the Romans in 410 A.D. these industries declined, if they did not altogether cease. It is not until some three hundred years after this that the sheep is mentioned in British history, and then only with reference to its price.

About the middle of the tenth century the woollen industry sprang up in Flanders, and it is to the artisans of that country that England owes the real beginning of this industry. The first group of Flemish workmen came over to this country in the reign of William the Conqueror. They first established themselves near Carlisle, but later on, in the reign of Henry I., they had to remove to Pembrokeshire. Two other companies of Flemings came afterwards, one in the reign of Edward III. and the other in that of Henry VII. From the eleventh to the fourteenth century, however, it appears that large quantities of English wool were exported to Flanders to supply the manufacturers there.

Leeds is first mentioned in connection with the woollen industry in the time of Edward III.

The French Protestants who, near the end of the seventeenth century, took refuge in England, contained among their numbers many who were skilled in various branches of the woollen industry.

Yet, from the beginning to the end of the eighteenth century the quantity of the home-grown wool was ample for the supply of raw material for the English manufacturers, and, although the industry maintained a fairly steady condition, yet no sound progress was made until the end of the eighteenth century, when the inventions of Hargreaves, &c., already referred to, took place.

The woollen industry of the present day is much more scattered than the cotton. The chief manufacturing centres, are, however, situated in the *West Riding of Yorkshire*, Leeds, Bradford, Huddersfield, Halifax, Dewsbury, &c., being some of the towns engaged.

At Bradford all branches of the worsted manufacture (for it is well to bear in mind that it is the worsted branch of the industry which is chiefly carried on in Yorkshire) are carried on. Halifax has its manufactures of lighter worsteds, baizes, and carpets, while Huddersfield is responsible for high-class fancy and plain fabrics.

This region is admirably suited for such an industry for the following reasons: A plentiful and cheap supply of good coal is an essential factor, and this is at hand. Easy access to good ports (Hull, Liverpool, &c.) is important, since much of the finished cloth and yarns must be exported to find purchasers; and the water is plentiful and suitable for wool-washing.

In the *West of England*, at the towns of

Frome in Somersetshire, Trowbridge and Bradford in Wiltshire, and Stroud in Gloucestershire, there have been, for a very long time, important broadcloth industries. This district, therefore, was at one time almost solely responsible for the woollen branch of the industry, but competition has forced the mill-owners to undertake the manufacture of worsteds also. It can be easily imagined that this did not meet with much success at first, as the workers were more accustomed to the other branch, and the result was that the prices of materials had to be such (if they wished to compete with the Yorkshire mills) that the amount of profit was extremely small.

Blankets are made at several places outside both these areas, viz., Rochdale in Lancashire, Welshpool in Wales, and Witney in Oxfordshire. *In Scotland* the most important centre of the wool manufacturing trade is the Tweed Valley, although the industry is scattered up and down the country, at Stirling, at Kilmarnock, and even as far north as Aberdeen. Then, of course, there is the renowned Harris tweed industry, and many tartans, &c., are still made in the homes of the people. The real homespuns that are made by the crofters have the peculiar waterproof property, which is believed to be due to the oil which is left in the wools used. In imitation homespuns the peculiar smell and the oil are introduced artificially, with varying degrees of success.

It is the Tweed Valley towns, Galashiels, Hawick, &c., which are responsible for the Scotch tweeds, and it may be worth mentioning how the name "tweeds" first came to be applied to these cloths. One might naturally suppose it arose from the fact that they were produced in the Tweed Valley, but this is not all the truth. Some goods were sent to London from this district invoiced as "twills," but the clerk was not renowned for good handwriting so it was misread "Tweeds." The name, once applied, caught on, and has been retained to the present day.

There are very important woollen manufactures in the *North-East of France.* The towns of Roubaix and Tourcoing are in the centre of the industry, which is, perhaps, the largest fine-wool industry in the world. It is in this region that large quantities of "*woollen*" cloths for ladies' dress materials are manufactured, and this centre has many distinct advantages for such an industry. A glance at a map will show that it is geographically about midway between London and Paris, the two great markets for the material which it produces. The land in this district is also fairly flat, and there is an excellent system of communication by rail and water to the ports (Dunkirk, &c.) and Paris. In fact, it may be mentioned that most of the waterways in the district are what are known to the French Government as first-class. Hence the manufactured goods can be very easily distributed and the raw material can be easily imported. This is important, for although sheep are reared in the near neighbourhood yet most of the raw wool has to be imported.

A good deal of this comes from Buenos Ayres, but some of the best of our English wool also finds its way there.

Then, again, the South Belgian coalfield has a continuation into this district, and coal can thus be obtained at a fairly cheap rate.

It might be stated here that at Bradford, and also at Roubaix, there are what are known as *conditioning houses* for wool. These are a great benefit, as reliable information can be obtained at these places with respect to any kind of wool or woollen fabrics, *e.g.*, the amount of moisture contained, strengths of yarns, &c.

The conditioning of wool is optional to the parties concerned, and in some quarters prejudice against this has occasioned loss of trade.

It seems reasonable that those who manufacture a genuine first-class article ought to welcome this kind of thing, as the good points of their wares are brought so much more markedly to the front by so doing.

Unfortunately, however, some have not viewed the matter in this way, and orders have been lost through refusing to comply with conditioning, as in the case of trade with the Chinese, where, according to reports, much trade has sometimes been lost to this country through our representatives not trying to ascertain the want of the people, but simply offering stock in hand for sale, on the principle of "take it or leave it," while representatives from other countries have found out what was required and have supplied the want.

In the *United States of America* there are extensive woollen manufactures, but still a great quantity of cloth and yarn has to be imported. A great advance, however, has been made since about 1895, and the importation of woollen goods has gradually diminished in amount.

In Germany the woollen manufactures are very scattered, some being carried on in the neighbourhood of the Rhine at Barmen and Elberfeldt, while others are in existence in the far east of the country in the towns of Silesia.

Russia has woollen manufactures carried on in its great centres of population, such as Moscow and Lodz (Poland).

These latter countries are not so much competitors with England in neutral markets, but since, as their industries develop, they are more able to meet the home demands, markets will gradually be closed to English goods.

A good proportion of the woollen and worsted goods imported into Brazil and other South American countries are of English origin, and in Western China the trade in wool manufactured goods is mainly in the hands of the English and Indian merchants.

As in the case of cotton, so in wool—there are *natural enemies* to the success of the farmer. In the wool, first of all, there is the burr-producing plant, which is known to botanists as Xanthium spinosum. This plant grows with very great rapidity, and when once it gets a footing it is very difficult to exterminate. The burrs get mixed up with the wool, and then, as previously mentioned, special means have to be adopted in order to get rid of these before the wool is spun.

In South Africa the sheep are also very liable to a scab disease. This is really an animal parasite, which fixes itself on the sheep, and not only renders the wool useless but often kills the sheep. Then there are the times of drought, and, in some cases, the natural delicacy of the breed of the sheep, with which to contend.

Finally, it might be instructive to consider the amount of wool used by the chief manufacturing countries of the world and the supply which it is necessary to obtain from elsewhere.

The figures given are those for 1905:—

The United Kingdom consumed 437,000,000 lbs., of which 302,000,000 lbs. had to be imported.

The United States of America consumed 537,000,000 lbs., of which 242,000,000 lbs. had to be imported.

The German Empire consumed 389,000,000 lbs. and imported 339,000,000 lbs.

France consumed 351,000,000 lbs. and imported 260,000,000 lbs., while

Russia consumed 380,000,000 lbs. and imported of this only 20,000,000 lbs.

CHAPTER III

SILK

IT is well known to every one that many caterpillars weave around themselves a kind of covering, preparatory to undergoing the change from the caterpillar to the chrysalis state. The cocoon of the silkworm, from which the raw silk of commerce is produced, is such an envelope spun by the domesticated silkworm.

The life-history of the silkworm is very interesting, and as it is by no means an easy task to rear good silk-producing worms, a brief description of the various changes which this little creature undergoes will not be out of place.

The eggs are laid by the silkworm moth, on paper or other suitable material, and these eggs must be kept in a dry, well-ventilated, cool place. It can easily be understood that strong, healthy worms can only be produced from good eggs, so that these must naturally be properly cared for. When exposed to changes of temperature the eggs are apt to hatch out prematurely, and only weakling worms result. If the eggs are intended for export they should be packed as soon after being laid as possible, and are best sent in the autumn. Early in the spring the eggs are sometimes washed in water, at a temperature of 65° F. to 70° F., and then dried in a warm room.

The exact time at which the eggs hatch out depends upon the temperature of the air in which they are kept, *e.g.*, in Italy they hatch out in April, while in England the early part of June would be more probably the time.

Silkworms are now reared in properly ordered establishments, so the natural tendency for premature hatching out can be avoided by keeping the temperature of the room in which they are kept at about 50° F. When the hatching-out time arrives, the temperature of the room is raised gradually (about 4° or 5° per day) until it reaches 70° F.

The eggs will not all hatch out at once as soon as the necessary temperature is reached, but worms will be hatched at intervals for some days.

Those which are hatched out on any one day are kept as far as possible by themselves, since all the various changes which they subsequently undergo will, as a rule, occur at the same time.

In order to remove the worms as they are hatched out day by day, the eggs are covered with muslin, and the healthy worms crawl through to the upper surface of this fabric. All the eggs will not produce healthy worms, and this will be one means of separating them, as the weaklings will probably not crawl through the muslin.

These very young worms should be fed on the youngest leaves of the mulberry, cut into very fine pieces. Just sufficient food should be given them, and for this purpose they ought to be fed several times during the day. The ribs and harder part of the leaves form the bed on which the worms lie. This should be changed at intervals, as their excreta (together with old leaves) is apt to cause fumes which may be detrimental to them. On no account should the worms be handled. As this is the case, a kind of net with a suitable mesh (or thin cardboard with holes of right size) is spread over them, and when some fresh food is sprinkled on the top of this the healthier worms crawl through. If any are left behind, they can be placed with those which are a day younger.

As the worms increase in size they have to change their skins, or moult as it is called. This takes place four times during the life of the silkworm, and great care must be taken during this moulting, as the worms are then very delicate.

When the time has arrived for the great change from caterpillar, or worm, to chrysalis, the spinning process is commenced. It can be seen that the first threads spun are the outer ones, and as the spinning goes on, so the covering becomes thicker and closer to the body of the worm. By the end of about twenty-four hours the worm is usually hidden from sight, but it takes a full week for the spinning of the cocoon to be complete.

The more silk there is on a cocoon the harder will it feel to the touch. The silk of the cocoon will be one continuous thread, unless, of course, the worm is disturbed during the spinning process. When the spinning of the cocoon is finished the worm rests inside it, and eventually again throws off its skin, but this time it becomes a chrysalis. In about three weeks' time this chrysalis, if undisturbed, will change to a moth; but before this it has made an exit from the cocoon by dissolving the gum between the silk fibres by means of an alkaline fluid which it excretes. If this takes place, the silk of the cocoon would be damaged where the escape took place, and would be useless for the purpose of reeling.

Hence, means are taken to kill the chrysalis before it arrives at this stage. In hot countries it is sufficient to place the cocoons in the direct rays of the sun for some days, but in European countries the heat is obtained artificially by means of an oven.

After this, of course, the cocoon may be kept for years without injury, or it may be sent from one country to another, and the silk can be readily reeled from these cocoons at any time by first placing them in hot water.

It can, then, be seen that the silkworm-rearing industry can only be carried out with success by those familiar with it. Also, it is evident that a good deal of labour is necessary, and the industry is not likely to be established on a commercial basis in those countries where labour is dear.

There are *various species of the silkworm*, all of which are known to naturalists by the family name of Bombyx.

The domesticated worm, from which the very great bulk of the silk of commerce is obtained, belongs entirely to one species, viz., Bombyx mori, or the mulberry worm.

In North China a species known as Bombyx pernyi produces a light-brown cocoon, the silk of which is reeled in China, as is also the silk of the Bombyx cynthia. The best-known wild silk producer is the Tussur moth. The worm of this species produces a large, rather dirty-looking cocoon, the silk of which differs considerably from that produced by the ordinary silk-worm.

In Japan there is an oak-feeding variety, which produces a greenish-coloured cocoon, the silk of which is much prized by the Japanese.

Silk is obtained from other sources also. Some interesting experiments have been made with the *silk spider* of Madagascar, or the Halabe, as it is called locally.

These spiders are very difficult to rear, so it is not to be expected that much material will get on the market. The spiders are carried up to the town (Antananarivo) by native women, in baskets, and it is of great importance that they do not remain long shut up, as they have a great tendency to eat one another. After the silk has been reeled from the spiders they are set at liberty, and if they have not been devoured by their mates they are ready for reeling again in a few days.

The silk of the halabe has a fine colour of a golden-yellow hue, and its elasticity and strength are considerable.

There is also a peculiar kind of fibre known as the *Sea Silk*, or *Byssus*, which is obtained from certain molluscs found principally on the shores of Corsica and Sardinia. The fibres are excreted by these molluscs for the purpose of attaching themselves to the rocks. They are of a golden-brown colour, soft, elastic, durable, and glossy. The diameter of the fibre varies from ·015 to ·055 mm. It is not so readily affected by acids or alkalies as ordinary silk.

Where the Bombyx mori are reared there should be healthy mulberry plantations, to supply the food suitable for them. In the northern plains of Italy, which are perhaps the most suitable regions of the globe for such a purpose, practically the only trees met with now in any number are the mulberry-trees, although in early times the whole of the Po basin was covered with forests of other kinds of trees.

It is a very important thing to obtain eggs free from disease, as it is only by so doing that good silk-producing worms can be obtained. The disease of silkworms has been responsible for considerable variations in the production of raw silk. Over forty years ago its ravages among the silkworms of the valley of the Rhone had become so considerable that in 1876 Pasteur was appointed to investigate the matter, and by careful observation he came to the conclusion that it was possible to detect healthy from poor eggs by means of the microscope. The disease is not confined to France. Some years ago it had extended to China, and several of the Chinese provinces have already considered the situation, and agreed that those who rear silk-worms should be taught how to distinguish the healthy eggs.

In the body of the silkworm are two small glands, in which the substance which becomes silk exists as two jelly-like masses. This jelly is excreted from these glands through ducts in the head of the worm, and the threads unite and also harden on exposure to the air.

Individual threads of the cocoon would be much too fine to use in the weaving process, so in *reeling the silk* the threads from several cocoons are united to form one single thread. The threads being of a sticky nature this is not a difficult matter, but it is not quite so easy to obtain a thread of uniform thickness throughout, and this is one of the greatest difficulties the silk reeler has to contend with.

Threads from fresh cocoons must be introduced sometimes in order to keep the thread being reeled of a uniform diameter. This reeled silk is the *raw silk* of commerce.

Two other names are usually met with in connection with the silk before being woven into cloth. These are *Tram* and *Organzine.*

Tram is formed by the union of two or more threads which have not been twisted. They are first doubled, and then slightly twisted together so as to make the thread more compact. Tram is usually used as the weft thread in silk cloth.

Organzine is formed by the union of two or more threads which have been separately twisted in one direction, then doubled, as in the case of tram. Afterwards they are re-twisted in the reverse direction. Such doubled threads are used for the warp.

There are, of course, certain portions of the cocoon which cannot be reeled, and these are known by the names of *husks, knubs*, and *waste.* The term husks is usually applied to the outside part of the cocoon, knubs to the inside, while waste is the name given to the many small fragments of thread.

It is this waste silk which is largely used in England, for our industry is mainly that in *spun silks.*

The actual weight of silk obtained from the cocoons is only about 10 per cent. of the total weight.

The chief regions of production are China, Japan, Italy, Turkish Empire, France, India, and the Caucasus. The order given is, roughly, a comparative one, although Italy and Japan may change places occasionally. About twice as much is produced in Asia as in Europe, that in China alone being more than the total produced in all the countries of Europe.

Of the Chinese silk, more than two-thirds is available for export. In connection with this it must be remembered that a good deal of silk obtained from wild silkworms is exported from China. Roughly speaking, about 10 per cent. of the total export of silk from China is classed as "wild and coarse silk."

A great change has taken place in the silk industry in China and Japan during the last few years. Modern appliances and methods of dealing with the raw silk were introduced by Japan, and the Chinese began to find themselves gradually being displaced in the silk markets. This continued until 1893, when the Chinese gave up the unequal contest, and began to fight on more equal terms; that is, they began also to introduce modern methods and to regain lost trade.

Large quantities of *wild* (*Tussur*) *silk* are annually exported from Manchuria, the value of this exported silk reaching over £250,000 in 1905–6.

Japan produces on the average only about one-third to one-half that produced by China.

India comes a very long way behind Japan, as it only produces about one-tenth as much silk. The mulberry-trees are cultivated chiefly in Bengal. Wild silkworms are found in India, and much silk is obtained from them, this silk, as before stated, being known by the general name of Tussur (Tussore or Tussah). The Indian tussur silk is reeled by the natives, but the process is such a slow and tedious one that it is almost hopeless to expect large quantities to come on the market.

The Far East (China) was the original home of the silkworm, and for many centuries no worms were reared elsewhere, for the Chinese guarded their secret so well. It was not until about the middle of the sixth century, when some eggs were smuggled out of China by a monk, that the silk-rearing industry spread westward.

Italy now produces about one-half the quantity produced in China, and between one-half and three-fourths the total produced in European countries. The industry is carried on chiefly in the great northern plains, but it has also been extended to the south to some degree.

In *France* it is chiefly in the sheltered valley of the Rhone that the silkworms are reared, and it is this region that has been so devastated by the disease before mentioned. In the years 1885–1905 the yearly production of raw silk of the world has nearly doubled in quantity. During that time the silk produced by Italy has increased 7 per cent., while in France it has increased by 30 per cent. Japan's increase, however, is even more remarkable, being over 300 per cent.

Several attempts have been made to establish the silk-rearing industry in the *United States*, but they have met with practically very little success. In California some years ago the offer was made by a large silk manufacturing firm that they were willing to pay 25 cents per pound more for a workable quantity of reeled raw silk produced in California than the market price of imported silk from China and Japan. Further, they undertook to take all that could be produced for one year on the same basis. Yet, although this offer was widely advertised in the State, less than 100 lbs. of silk were offered as the result.

In *Austria-Hungary* the industry has made very rapid strides during the last twenty-five years, and it now produces almost half as much as France. A great proportion of the raw silk which is exported from this country finds its way to America. The industry is largely in the hands of the Government, and is carried out principally by the poorer classes, who obtain employment by this means in the slackest period of the year.

About ten years ago silkworm culture was introduced into *Kashmir.* At that time many of the people were dying of starvation. The industry has made such rapid progress that a great increase in the export of raw silk from that country is looked for in the near future.

Experiments have also been recently tried in the *Island of Java.* The climate of that country is admirably suited for the rearing of silkworms, and quite a prosperous industry exists in the neighbourhood of Batavia, from which raw silk has already found its way to Europe. The silkworms were introduced from Japan.

Other experiments have been carried out in Lyons and other places to ascertain if possible the reason why some silkworms produce white, some grey, and some greenish-coloured cocoons. It was found that the natural colouring matter of the silk was identical with that of the food of the worms. When dyes were added to the food materials, *i.e.*, the leaves were dipped in a liquid to colour them, the colour of the cocoon produced partook of the colour with which the leaf was dyed.

It was, however, found that experiments succeeded better with some varieties of worms than others. On the other hand some American scientists declare that the colouring matter of the food has little to do with the colour of the cocoon, but that the colour of the cocoon depends entirely upon the breed of the silkworm producing it.

Be this as it may, there is not likely to be any change owing to it in the great silk-dyeing industries of the world.

The silk fibre, being a continuous thread, does not need to be spun in order to make it so, as is the case with all other fibres used in the textile industries. The true silk yarn undergoes a process which goes by the rather vague name of "throwing," which mainly consists in giving the fibres a slight twist so as to combine better with each other, but it may be taken as embodying all the processes after reeling which the raw silk undergoes preparatory to being woven into cloth.

In the case of the waste silk, the various processes by which it is converted into yarn are practically the same as in spinning cotton or wool, the yarn so made being distinguished by the name of spun silk, the other yarn being "thrown."

In the *reeling* and *throwing* of silk *Italy* stands first among all European countries, the great centre being Milan, which has of recent years outrun Lyons in this respect. Several reasons may be assigned why the balance of trade between these places has changed. The Lyons dealers have attributed it to the duty which France imposes on the raw silk imported, and on the new means of transportation. Some years ago, before Milan began to forge ahead of Lyons, the great bulk of the carrying trade from the East was in the hands of English and French shipping companies, who made Marseilles their port of call. The silk was landed there, and then forwarded to Lyons for manufacture or redistribution. Now, however, German lines of shipping have entered into competition for the trade of the East, and these have made Genoa their port of call. The silk brought by these vessels is landed at Genoa, then forwarded to Milan, where it is thrown, and then redistributed by means of the railway through the

St. Gothard Tunnel to Switzerland, Germany, and elsewhere.

France produces more silk goods than any other country in Europe, and, in fact, it produces two or three times as much as Germany, which is second in importance.

The great centre of manufacture is *Lyons*, where all branches of the industry are carried on. Here there are good technical schools, where young men can learn all the various processes in connection with silkworm rearing, throwing, spinning, and weaving.

Each student must keep note-books, in which the subject-matter of the lectures attended by him is entered, and these notes are signed by the lecturers. Again, in the practical work, samples are kept, so that when a lad has finished his course at the school he can produce the result of his own work as a recommendation, or otherwise, when applying for posts in the silk-manufacturing industries.

These schools are not only open to natives of Lyons and other Frenchmen, but foreigners are at liberty to attend, although the fee demanded from them is somewhat higher. For Frenchmen the fees amount to just over £30 per annum, but for foreigners to about £50 per annum. Then there is a municipal school, to which boys of fifteen years of age, with residence qualifications, can go, and in which the silk industry can be learned. Here the fees are very low (about 7s. 6d.), and the course extends over ten months for day students and three years for those who are only able to attend in the evenings.

Thus the industry in Lyons and neighbourhood is supplied with skilled labour, and although fluctuations occur, this is likely to remain as one of the most important of the world's silk-manufacturing centres.

It is worthy of remark, too, that the people of France excel in the production of good designs, and this is a great aid in the silk industry.

Of course, silk of an inferior quality, and mixed fabrics having the general appearance of silks, have risen largely in favour, and for these the looms of the mills in Switzerland and Germany were more suited, or were more easily adapted, but the French have risen to the occasion, and can now compete with those countries in these articles.

In *Germany* the chief centre for the silk industry, especially the dyeing of silk goods, is Crefeld, in the Prussian province of the Rhine.

In *Switzerland*, Zurich is noted for its silk cloths, while Basle is noted chiefly for its ribbons.

There are conditioning houses for silk at the following towns: Milan, Lyons, Zurich, Crefeld, Basle, Turin, and Elberfeld; the first two, however, condition four times more than all the others put together.

The silk-manufacturing industry in *America* is next in importance to that of France, and, of course, the very great bulk of the raw silk has to be imported, of which about 25 per cent. is obtained from Italy.

In 1904–5 nearly 40 per cent. of the raw silk on the market was taken by the United States.

The *manufacture in England*, carried on chiefly in Yorkshire and Lancashire, is almost entirely in connection with the spun-silk branch, and it is somewhat interesting to compare the state of the silk industry at the end of last century with the condition at about 1830.

At the earlier date we imported some 4,000,000 lbs. of raw and thrown silks, and 180,000 men, women, and children were employed in the trade. The sale of the silk goods produced amounted to £10,500,000, of which about £1,000,000 worth was exported, while goods to about the same value were imported. The population of the country at the same time being about 25,000,000, the average consumption of silk goods in this country worked out at about 8s. 6d. per head.

In 1898 we imported from France, &c., about £20,000,000 worth of silk goods, but only about £1,000,000 worth of raw material. The population, by this time, had risen to about 38 millions, so that the average yearly value of foreign goods consumed in this country per head amounted to 10s. 6d., but those of home manufacture had dwindled to 1s. 6d. per head. The following reasons may somewhat account for the change:—

We are unable to produce the raw material, and so find it more profitable to continue with cottons and woollens, for which we hold good markets, and—

Since the opening of the Suez Canal, England has become less and less a market for the goods of the East, therefore less raw silk has been imported.

Other reasons may be given, some of which are of a very debatable nature, *e.g.*, in 1860, the duty on imported silk goods was abolished, and this gave an impetus to the introduction of French manufactured goods.

Then the Continental manufacturers are well versed in the weighting of silk goods—for example, the introduction during the dyeing processes of salts of tin, &c., for which silk has a remarkable attraction.

So great does the amount of impurity sometimes become, that although it may be very difficult to detect its presence by merely handling the goods, yet the silk has become really something other than real silk, and the purchaser is paying silk prices for a fabric which is, perhaps, only half silk, although containing no other fibre.

However, speaking in February, 1908, Sir T. Wardle stated as his opinion, "That the silk industry was reviving, and the lost ground was being gradually made up. In the spun-silk industry very considerable strides had been made. . . . In the past they had been subjected to very severe and unfair competition from the cheap labour districts of the Continent. As wages increased on the Continent, the English manufacturers would have a better chance of successfully competing with their foreign rivals."

CHAPTER IV

ARTIFICIAL SILK AND MERCERISATION OF COTTON

THE chemical treatment of fibres, so as to improve their appearance, and also, if possible, their strength at the same time, has employed the attention of many workers during the last sixty years. The one which has, perhaps, been ultimately the most successful of these experiments is that known by the name of "mercerising cotton."

There is, perhaps, no better method of understanding the meaning of this, than briefly sketching its development from the time of John Mercer's first patent in the year 1850. John Mercer was chiefly interested in calico printing, and it was during experiments in this connection that he observed the fact that vegetable fibres have the power to absorb strong solutions of caustic alkalies, and at the same time acquire much greater attraction for dyes. He also noticed that the fibres swelled out, and shrunk in length. This shrinking has been, for the matter of a quarter of a century, the cause of an almost endless variety of patents appearing, all promising to lessen, and some to remove it altogether. The first among these was that of Lowe, who obtained two patents—one in 1889, which practically covered the same grounds as Mercer's original patent, and a second in 1890, in which Lowe showed that the shrinkage could be avoided by keeping the material stretched, either while it was in the caustic alkaline solution or during the subsequent washing processes.

At the same time, Lowe, for some reason or other, missed one of the most important and distinguishing features of mercerised cotton, that is, the fine silky appearance which the process imparts to the fibre. In 1895, however, Thomas and Prevost obtained a patent in which this also was embodied. Dr. Liebmann, in 1896, was the first to make the very important discovery that it was only in the case of the Egyptian, Sea Island, and the longer stapled variety of American Uplands that the full advantages could be obtained: little or no silky appearance took place except when these cottons were used. The shrinkage, which is brought about by the treatment with caustic alkalies, has been made use of to produce crepon effects on cotton and linen cloths.

Single yarn is seldom mercerised, as it will not stand the strain sufficient to produce a good lustre. All yarns that are intended for mercerisation should be specially spun and doubled with the smallest amount of twist that will answer the purpose, since the less twist the greater lustre. The yarn is gassed so as to remove the loose fibres, and should be well cleaned before the beginning of the mercerising process.

The material is printed with a strong solution of caustic soda, thickened with gum, and, in some cases, containing dyes which are not altered by the caustic solution. The printed cloths are dried and then washed; the parts which have been printed then shrink, and the required effects are produced. Should the material be dyed as a whole, subsequent to this, two distinct colours, or at least shades of the same colour, will be produced, for the mercerised part of the material will be dyed to a deeper shade than the remainder of the cloth.

In cases where it is necessary to test the strength of solutions from time to time a very common practice is to determine their specific gravity by means of some kind of float. The one in common use is known as Twaddell's hydrometer. This system is not altogether a satisfactory one, because it gives no absolute indication of the strength of the solution, as other soluble materials tend to alter the density of the solution, and it is the density which this instrument indicates. However, a few words explanatory of this instrument are necessary because of its widespread use. The graduation marks are degrees, and the method of finding the specific gravity of the solution by means of this instrument is as follows:—

The hydrometer is floated in the solution, and the degree to which it sinks is noted. Suppose the mark is 125°, this would be represented as 125° Tw. Now by specific gravity is meant the density of a substance as compared with the density of water, so if water is taken as of density 1,000 instead of as unity, the density of a solution can be ascertained with a Twaddell hydrometer true to the third place of decimals, for all that is necessary is to multiply the number of degrees by 5 and add the product so obtained to 1,000. Thus 125° Tw. will indicate a specific gravity of 1·625.

Now, by practice it has been found that solutions of caustic soda of strength 50°–60° Tw.

are the best to employ for mercerising. Stronger solutions are, it is true, quicker in their action, and may produce a slightly greater degree of mercerisation, but very little, if any, increased advantage results.

No mercerisation effect can take place if the solution is less than 45° Tw., and the weaker solutions, 10° Tw. or so, have no effect on the fibre at all. Mercerisation apparently begins with solutions 20° Tw. strength.

One curious fact worthy of notice is that warm solutions are far less effective than cold. This is very important, because it is much more convenient to work at ordinary temperatures. Again, strong solutions of the caustic alkalies have very injurious effects upon animal tissues, and in some of the processes it is necessary for the material to be handled, although in many of the patents which have been obtained for the prevention of shrinkage this has been reduced as far as possible. When it is necessary to handle the material while in the strong solution, indiarubber gloves must be worn.

Of course the strength of the solution is lessened by the process, and it becomes essential, if uniform results are to be obtained, to keep the solution of a constant strength by the addition of stronger solution from time to time.

It is advisable to remove all traces of the caustic soda by thoroughly washing the material many times. The first water that is used will, of course, contain a good quantity of alkali, and can be made use of in the formation of other baths. Sometimes a bath of a very dilute solution of sulphuric acid is made use of, so as to be quite sure that all the alkali has been removed from the material. This process is resorted to when most of the alkali has been extracted from the cloth or yarn, and it is subjected to a thorough washing after this steeping in acid solution.

Cellulose, which is the essential and chief constituent of vegetable fibres, is a compound consisting of carbon, hydrogen, and oxygen in the proportions 6 to 10 to 5, so that we may write its formula $C_6H_{10}O_5$. Now, when this compound is acted upon by the caustic soda, which is itself a compound of sodium (Na), hydrogen, and oxygen (NaHO), the caustic soda splits up into sodium oxide (Na_2O) and water (H_2O), and the sodium oxide unites temporarily with the cellulose. When thoroughly washed with water the sodium oxide is removed, and water takes its place, so that the final constitution of the cellulose of the cotton fibres may be looked upon as $C_6H_{10}O_5H_2O$.

Put briefly, the process then may be stated as follows: The material, either yarn or piece goods, is steeped in a solution of caustic soda of strength about 55° Tw. for about two minutes. It may be kept stretched or not, as desired, during this part of the process. While the material is in the caustic alkali it should be kept in motion, so that all parts of it may be subjected uniformly to the action of the solution. It is then thoroughly washed many times, and in some cases subjected to the action of dilute sulphuric acid before the final washing. During these washings it is absolutely essential that the material should be stretched, otherwise the fine silky lustre of the finished article will be wanting. Of course, one can readily understand, therefore, that much more satisfactory results can be obtained with cotton yarns than with woven fabrics, since it is only necessary to stretch the former in one direction, while the other must be stretched in two directions. Also the yarn is subjected to singeing before being mercerised, and this is not nearly so satisfactory a process on the cloth as on the yarn, hence less uniform results occur. If the warp and weft were singed previous to weaving, it is possible better results might be obtained on cotton cloth.

Caustic potash may be used instead of caustic soda, but since no better results are obtained by this means, and it is much more costly, there is no reason for using it. Other ingredients have also been tried with the caustic soda, but since all the advantages can be obtained by the use of the alkali alone, there appears no practical need for the manufacture of much more intricate solutions, especially as it would be more difficult in such cases to obtain uniform results.

By this treatment cotton yarn and material is found to increase enormously in strength, in some cases as much as 50 per cent. increase having been noted. Should increase in strength alone be desired, there is no necessity for stretching during any of the processes; in fact, the increase is more marked without than with stretching.

An increase in weight must also take place since $C_6H_{10}O_5$ has been changed to $C_6H_{10}O_5H_2O$, and a compensating reduction does not occur at the same time. Taken in this way, the change would theoretically result in an increase of $11\frac{1}{9}$ per cent. in weight. The actual increase in practice is about 5 or 6 per cent. Not only does the cotton become more or less silky in appearance when viewed in the bulk, but when looked at under the microscope it will be seen to have almost entirely lost its characteristic appearance, and to consist of a more or less uniform rod-like structure. All these various advantages accrue from this process without any great disadvantages, so we may expect that mercerised cotton has now come to stay with us.

Artificial Silks.—Many attempts have been made during recent years to imitate the silk produced by the silkworm, and a brief account of some of these should be of interest. Our forefathers had very peculiar notions with respect to ordinary silk, attributing properties to it of a somewhat fantastical nature. In old authors we find such passages as "In grinding silk care should be taken to remove the worm which is within, sometimes fresh, sometimes rotten," and "Silk has the virtue of making the heart pleasant, and the spirits brisk, and to cleanse the blood," which point to the fact that it was then used medicinally. The following extract, which appeared in the American *Silk Journal* as from an eighteenth century work, is also interesting as indicating the ideas which were then current as to the origin of the silk-producing worms:—

"The silkworms are little insects whose origin is altogether surprising as well as the various shapes and changes they undergo. Several authors have writ of them, and amongst others Mr. Isard, in a little Treatise of his, on the 254th page accounts for their origin thus: At the time when the mulberry leaves are ready to gather, which should be five days after their budding, in the beginning of spring they take a cow which is almost at calving and feed her wholly with mulberry leaves without giving her anything else to eat of herbs, hay, or the like, till she has calved. After which they let the cow and calf both feed upon this some days together, without any mixture as before. They kill the calf after it has been filled or satiated with the mulberry leaves and the cow's milk, then chop it to pieces to the very feet, and without throwing anything away put all together, the flesh, blood, bones, skin, and guts into a wooden trough, and set it on the top of the house in a granary or garret till it is corrupted, and from this will proceed little worms, which they lay together on a heap with mulberry leaves, to leave 'em afterwards just as they do those which are produced from the eggs, and these silkworms are abundantly more fruitful than those from the eggs, so that those who deal considerably in them, never fail every 10 or 12 years to raise them this way."

Our knowledge of natural history has increased since those days; still, it was through meditating on the possibility of being able to do in the chemical laboratory what the silkworm does in its body that led to the successful experiments of Count Chardonnet and the possibility of producing an artificial imitation of silk.

As the process known as Chardonnet has been one of the most successful, this will be dealt with first. Specimens of this kind of artificial silk were exhibited as far back as the Paris Exhibition of 1889, and most brilliant effects can be produced by its employment, for the artificial variety has a brighter lustre than even good silk which has been subjected to stretching.

The first thing to make clear is that all artificial silk that has become well known commercially has been produced from vegetable fibres. In some cases cotton waste is used, in others wood pulp. The Chardonnet silk is made only from cotton waste. The cotton waste, which must contain good, long, strong fibres free from grease, is thoroughly cleaned and bleached, then most of the moisture contained by the cotton is removed by drying it in hot air. Only 4 per cent. of moisture is allowed to remain. It is then ready to undergo the first of the processes by means of which it will ultimately become changed into artificial silk. It passes through many operations, but the whole of the first set may be looked upon as being performed with one object in view, viz., the production of a nitro-cellulose which can be readily dissolved. It is steeped in a mixture of sulphuric acid of strength 167° Tw. and of nitric acid of strength 80° Tw. and pure water. The quantity of each of the acids and water depends very much on the quality of the cotton, and has, of course, to be determined by experiments made upon samples of the cotton which is to be used. It is, therefore, of the utmost importance for manufacturing purposes that the quality of the cotton should vary as little as possible, sufficient of one grade being on hand for several batches of silk. It is not such a difficult matter as appears at first sight, for if some nitrated cotton which readily dissolves is examined by the polariscope and microscope certain characteristic colourations will be noted. The actual process of nitration is done by first filling large pans with about seven gallons of the mixed acid. Then about 2 lbs. of cotton, which should be warm, are put into each of these pans, and the cotton is thoroughly mixed in the solution. The cotton is left in these pots, exposed to the action of the mixed acids for a time varying from three to seven hours. It is then taken out and the excess of acid is pressed out by passing the cotton through a strong press. Then it is thoroughly washed for about four hours in order to remove, as far as possible, all traces of free acid. The acid which is thus obtained is made use of in the preparation of other baths, sufficient sulphuric and nitric acid being added to bring it up to the required strength.

After washing, the nitrated cotton is dried by means of a hydraulic extractor or centrifugal machine. The amount of moisture allowed to remain in the cotton must not exceed 28 per cent., for it is found that the dissolved nitrated cotton does not spin well if more than this amount be left in.

On the other hand, it is found advisable to leave from 27 to 32 per cent. moisture in the material, as it dissolves much more readily when this water is present. Also it can be handled with much greater safety than if perfectly dry, for under those circumstances it is highly inflammable. This may be more easily understood if it be remembered that the nitrocellulose used in the preparation of artificial silk is only one stage removed from guncotton, which is also a nitro-cellulose.

The nitrated cotton is then dissolved by using a mixture of ether and alcohol made up of sixty parts of the former to forty of the latter. It is then put into a large cylindrical iron vessel called a "mixer," with sufficient of the above mixture to ultimately form a very stiff solution, which is often known by the name of "collodion." The "mixer" is next closed and kept revolving at a low speed for between twelve and twenty-four hours. If on opening the mixer it is found that part of the nitrated cotton has not dissolved, more of the solvent is added, and the mixer is again revolved for some hours. It will, however, always be found that some of the cotton will in the end remain undissolved, but this is because it has either been too highly or not sufficiently nitrated, and no extra solvent or time spent on this will be of any use, as it will not dissolve in this manner. The collodion is then forced out of the mixer by atmospheric pressure into a kind of hydraulic press, which in turn forces it through a system of filters under the enormous pressure of between 1,400 and 1,500 lbs. on a square inch. The filter itself consists of two filter cloths, between which there is a layer of wadding.

The object of this filtering is to remove from the collodion all the undissolved cotton, and also to remove all the impurities that have been brought into it by the water, &c., during the washing processes. This, however, is not the only reason for filtering, for in this manner the collodion can be even more thoroughly mixed than during the process in the mixer, and so it is rendered much more suitable for spinning a continuous, even thread.

For this reason the filtering process is repeated twice before subjecting the collodion to any further operations.

The filtered collodion is received in a reservoir, in which it is advisable to leave it for some time in order that any air-bubbles which may have formed can rise to the surface. If this is not done such bubbles are likely in the spinning process to cause a break in the continuity of the thread.

From these reservoirs the collodion is forced, under great pressure, through small capillary tubes, and so forms very fine filaments, some twelve to fifteen of which, according to the count of silk required, are collected into one thread and wound on a bobbin.

The average speed with which the thread is drawn from one of the capillary tubes is 500 yards per minute, and the quantity in weight spurted out of each capillary is 1½ ounces per hour.

It should be noticed that the collodion solidifies as soon as it escapes into the air from the capillary tubes, thus enabling the operator to handle it and convey it to the bobbins as previously noted. In fact, the collodion has to be kept moist by means of damp cloths, in order that the process of throwing and twisting may be effectively carried out, for this artificial silk is twisted on the twisting machines, and then reeled into hanks just like ordinary silk.

It has now all the appearance of the artificial silk of commerce, but it would be impossible to put it to any practical use, for its great inflammability would render this far too dangerous. Further, it would be useless in this state, for it cannot be dyed. Now comes the extraordinary part of the process. The collodion may be looked upon as a solution of nitrated cellulose, so that the filament produced is also of that composition. The nitro-cellulose is now denitrated, and so changed once again to cellulose.

This is done by means of a sulphide of one of the alkalies. This process gives the silk a rather dirty colour, and, in order to improve this, it is necessary for it to undergo a bleaching process, after which it is thoroughly washed and dried, and then it is ready for use.

The advantages claimed for this silk are :—

(*a*) Cheapness, as compared with real silk of the highest class.

(*b*) Considerable lustre and brilliancy.

(*c*) Greater resistance to chemical influences, and—

(*d*) Greater stiffness than the best China silk, on which account it is more suitable for fringes, tassels, and braids.

With respect to the first of these advantages, it seems hardly fair to compare an artificial silk with the real article, since it cannot replace the real silk in the processes of manufacture. Again, with regard to (*c*), since the Chardonnet silk is so much more deteriorated by pure water, especially if in the stretched condition, it matters little, so far as its extended use in textiles is concerned, whether it is or is not resistive to chemical treatment.

Those who are familiar with the Chardonnet silk will readily grant the truth of (*b*) and (*d*), as its lustre is even greater than the best real silk.

Among the recognised disadvantages of this variety are :—

1. The lack of strength whilst wet. This is

not so marked in some of the other varieties of artificial silk, and even in this case it seems that the silk regains a great proportion of its original strength if allowed to dry before putting on the testing strain.

2. A very real disadvantage, however, is its much greater density than ordinary silk. According to Herzog, the Chardonnet silk has a specific gravity 13 per cent. greater than China silk. Since silk is bought by weight, it necessarily follows that as 100 yards of artificial silk thread of any diameter would weigh as much as 113 yards of real silk thread of the same diameter, the artificial variety is proportionately more expensive.

There are many purposes, however, for which this silk appears to be specially adapted. What for one purpose might be looked upon as an advantage, for another might turn out to be a very distinct disadvantage and *vice versâ*. Its disadvantage of greater specific gravity hampers its adaptability to all manufactures where a maximum of covering is desired with a minimum of bulk, such as covering cords, furniture tassels, electric wires, &c. Besides this, the artificial silk does not adapt itself to covering, on account of its greater stiffness, so that a very much greater weight would be required in order to cover the same amount.

Thus, although its brilliancy would lead one to suppose that it would be highly suitable for these purposes when so employed, it is brought into direct competition, as far as price is concerned, with natural silk of the highest class. To bring such a state of affairs about is not the aim of the producers, their object being rather to open up new fields for the artificial silk.

On the other hand, the very harshness and greater bulk of this artificial silk render it more suitable for use on braiding machines, as, while being dealt with on these machines, it does not pull out so thin as other yarns, but keeps a more embossed appearance. Hence it has most thoroughly succeeded in establishing itself in the braid and trimmings manufacture, in which all its advantages are of great value, and, as stated above, even some of its disadvantages are in its favour.

There is no doubt that its very great brilliancy makes the articles thus made from it much more effective than if made from the very best China silk.

On account of its greater specific gravity the Chardonnet silk is not suitable for the manufacture of sewing or embroidery silks. Owing to its lesser power of resistance to strain than real silk, and also the roughening effect which the movement of the shuttle would have upon it, the artificial variety is not suited for being used as the warp in woven material.

It is when used in finer counts very suitable for producing raised and brilliant effects, either in the form of stripes or figures, on a dull background. For this purpose it is often introduced into the weft of high-class fancy dress materials. Its lustre, when so used, can give a costly and taking appearance to very second-rate or coarse material. For like reasons it is often employed in the manufacture of neckties and fancy waistcoats. Its largest opening in tissues, however, is high-class furniture coverings, tapestries, and curtains—materials where, of course, its brilliant nature lends itself most readily for the production of damask effects.

This silk is, even in the dry state, not nearly so strong as China silk; according to one authority its comparative breaking strain is 45 per cent. less than that of the latter.

The dyeing of the silk is much simpler than that of most yarns, but attention must be paid to the treatment of the silk when wet, as it will not stand the twisting so commonly used. It should be dyed at a temperature not exceeding

43° C., and the dyes can be made fast just as in the other yarns.

The Chardonnet collodion fibre has been made use of to produce the so-called single threads, or *Monofil*, intended to take the place of horsehair in braids, and for other millinery purposes. This has, further, led to the production of that filament of varying widths and great brilliancy called *Lame*, which is used for millinery trimmings.

The single thread is produced in a similar manner to ordinary silk, but is squirted out of wider capillaries and is not subjected to twisting.

The chief place of manufacture under this patent is Besançon, in France, a factory of great importance, and able, as far back as 1901, to produce 2,500 lbs. of silk per day. In England attempts have been made to produce this article, first by the Artificial Silk Spinning Company and then the New Artificial Silk Company. These companies did not flourish, but others have arisen, having special guidance and assistance from the Besançon factory.

There are several other well-known varieties of silk on the market, and these may be divided into two groups: (*a*) those in which the cellulose is dissolved by caustic soda, and (*b*) those in which Schweitzer's solution is used as the solvent.

The article known as *Viscose* silk belongs to the first, and that known as *Pauly* belongs to the second group. Viscose silk is manufactured chiefly from white wood-pulp, which is imported to this country from Norway in bales consisting of sheets four feet square. There are, of course, many differences in detail in the process of manufacture, but the main outlines are briefly as follows:—

The wood-pulp is steeped in a strong solution of caustic soda for twenty-four hours, then removed from this solution without extracting the excess of alkali from the pulp. In this condition its weight is about three times that of the dry pulp which was introduced. In this wet state it is stored for forty-eight hours, so as to give the alkali a good chance of thoroughly impregnating the material. Then it is often cut up into small pieces, placed in a drum, and exposed for about five hours to the action of carbon disulphide; next, it is taken from the drum and exposed to the air, so as to allow the excess of carbon disulphide, which readily evaporates, to do so. It is then placed in an excess of a strong solution of caustic soda, in which it dissolves, and in this solution it is left for about a week, for it has been found that even after the solution has been completed a series of changes take place in the viscose which is produced, and these changes have an important effect upon the nature of the fibre ultimately produced.

For example, when first dissolved, the viscose which is formed is readily soluble in water, while that ultimately produced is insoluble in water.

The viscose solution is rendered of the right consistency by the addition of further alkali, and it is then squirted through holes in a platinum plate. The holes are $\frac{1}{250}$ inch in diameter, and the pressure can be arranged so that it is possible to obtain filaments of various thickness from one and the same hole. (Before spinning care is taken to remove air-bubbles.)

Immediately after escaping from the holes the filaments pass quickly through solutions for the neutralisation of the alkali and the consequent deposition of the gelatinous fibre. Those often used are solutions of ammonium sulphate and ferrous sulphate, the materials passing through the solutions in the order named.

The filaments, sixteen to thirty-two in number, are twisted together to form one thread or "singles."

The viscose is now, however, subjected to a process of steaming at ordinary atmospheric pressure, and this decomposes it, getting rid of the sulphide and alkaline matter. It is then thoroughly washed in water, and if, as is usually the case, great brilliancy is required, it is dried under strain.

The viscose silk has some advantages over the Chardonnet variety, such as: it is much less dangerous to manipulate; its price is much less, as it is much less costly to produce; and it is by some also regarded as being even more brilliant and supple than the latter. There is no doubt that it can be exposed to the prolonged action of water without being seriously damaged. This kind of artificial silk, like the Chardonnet, is suitable only for stripes and figures on other materials, and not for the sole fibre in a material. Its price is greater than that of mercerised cotton, and less than that of silk.

This variety is made in England, and also on the Continent. Many of the Continental factories have banded together, so as to avoid overlapping in the sales. Each factory has certain districts allotted to it; also, any improvements which are invented in any one of the factories are communicated to all others connected with it.

The artificial silk which is obtained by dissolving cotton or cellulose in Schweitzer's solution (see "Chemical Tests") is different from the other varieties in that no chemical compound is formed with the cellulose, which has ultimately to be decomposed before the fibre is fit for use. Of course, many patents have appeared dealing with this, as well as with the other varieties. Brennert obtained a patent in 1900, and a French patent was obtained in 1906. By this patent process the cellulose is dissolved in Schweitzer's solution, and this solution is forced through capillary tubes into a bath composed of one part glycerine and two parts concentrated sulphuric acid. (Alkalies may be used instead of the acid.) In this bath the cellulose is precipitated, and the action is extremely rapid. Then it is passed quickly through a solution of common salt in order to arrest the action of the glycerine and acid left on the fibre, and is finally rinsed in water.

Pauly silk, or, as its inventor calls it, Aachener Glanzstoff, is formed by dissolving silk in Schweitzer's solution, and differs from the above simply in the method adopted for throwing the cellulose out of solution, dilute acetic acid being, in this case, used for that purpose.

This silk is easily broken when wet, and has somewhat less lustre than the Chardonnet variety.

These silks can be dyed to various shades; and in this respect it might be mentioned that Chardonnet silk acts more like the animal fibres where dyes are concerned, and the Pauly silk like vegetable fibres.

So far we have been dealing with silk manufactured from vegetable matter. There is one case, however, in which animal matter has been successfully dealt with for a similar purpose.

Vandura silk is a thread made from gelatine. The manufacture was brought about by a Mr. Millar. The process is, briefly, as follows:—

The best gelatine is broken up into pieces about one-quarter inch each way, then placed in a melting-pot with about half its weight in water, stirred well, covered, and then left for about an hour. The melting-pot is then placed in a can of hot water, and kept heated to a temperature of 49° C. (about). In this hot water it is kept for one hour, being stirred once or twice during this time. At the end of the second hour the gelatine is forced through capillaries, on issuing from which it is laid on an endless band, which carries it some distance to allow it to dry.

The filaments are collected into groups, twisted together, and then spread out in a thin layer on an open metal reel about 1 foot in diameter.

A number of these reels of gelatine thread are next exposed to formalin vapour in a special room. This process quite changes the nature of the gelatine, for after it comes from this room it is no longer soluble even in boiling water, and it has, besides, a fine lustre. The gelatine is given access to plenty of air, so as to remove the smell due to the formalin, then it is wound in bobbins suitable for the manufacturer's use.

The capillaries used by Mr. Millar were $\frac{1}{100}$ inch in diameter, but by varying the speed of the travelling band, and by regulating the pressure upon the liquid, threads of very varying diameters can be produced, some as fine as $\frac{1}{1000}$ inch in diameter.

There have been successful attempts made in Germany to use the very fine filaments which can be produced from glass. This spun-glass, as it is called, produces a very flexible thread, which can be produced in a great variety of colours and has a very brilliant appearance. It can be produced very cheaply, and is used for covering electric wires.

As might be expected, attempts have also been made to cover ordinary cotton with a glossy surface, by treating it with a solution of the cellulose (collodion). Although good effects can be produced in this way, the collodion is very easily rubbed off, and so the result is not altogether satisfactory.

The large number of patents which have been obtained for one branch or other of this important industry have not closed the field to those who wish to try to bring about some of the various improvements for which there is still ample room. The strength of the fibres when in the moist condition still leaves much to be desired, and it is to be expected that many other improvements in detail will be brought about as the industry increases.

CHAPTER V

LINEN

THE flax plant belongs to the natural order Linaceæ. It has a smooth stem, fibrous roots, and is an annual. In temperate climates it grows to about 2–3 feet in height, and being a plant which thrives in widely different climates, is grown in temperate, sub-tropical, and even tropical countries. In hot countries the plant grows so coarse that it is produced not so much for the sake of its fibre as for the seed (linseed) which is obtained from it.

The plants must be carefully cultivated if good fibre is wanted. They must be grown close together, as if too much room is allowed the plants grow much larger and the fibres are coarse, and are then only of use for making sailcloth, tent covers, and other heavy materials.

In every field of flax there is sure to be plenty of plants which will only produce coarse fibres, so that it is never necessary to set land apart for their cultivation. The land must be kept free from weeds, and thorough weeding ought to take place three or four times during the growth of the flax plant.

When the plants have produced flowers they are pulled up by their roots (not cut), and then allowed to dry in the sun. Next comes the separation of the useful fibres from the more woody and useless part of the stem. This is done by a process known as *retting*, a word which is obtained from our English word " rotting." The general method in use at the present day is almost precisely that which was very probably in use in the very earliest times. One can very readily imagine that in countries like Egypt, where the flax grew, how the flax plants would fall into the river and become retted by natural means. Then a native picking up some of these plants would observe how readily the fibres separated one from another and from the harder parts of the stem. Also their great strength would become apparent, and so, step by step, the usefulness of the fibres would be found out, and its manufacture into material was then only a matter of time and experience. However this may be, the knowledge of the linen manufacture dates back to the time when the Egyptian mummies were first of all placed in their shrouds, for linen of excellent quality is found with the mummies.

The flax plants are laid in the water and allowed to soak until they have been in sufficiently long for the green outer bark to be destroyed and the fibres to be more easily separated one from another.

The water of some streams is much more suitable for this purpose than others. That in the neighbourhood of Belfast is good, but probably the best-known stream is a small river in Belgium known as the *Lys*. The flax retted in this water always fetches best prices on the market, and it is no uncommon thing for 90,000 to 100,000 tons of flax to be retted there in a year. The water of the stream is not used throughout its entire length, but it is between Menin and Vine St. Elvy that the retting is principally carried on. The best-known town in connection with the industry is Courtrai. In this district, after the retting, the flax is stored in barns until the winter, then the cleaning and separating of the fibre from the woody parts is done. For this it is often passed through a machine containing fluted rollers, and then beaten by the scutching knife. This process is therefore known as the *Scutching*.

As it takes about fourteen days, if the weather is favourable, to ret the flax, many efforts have been made to supplant the old system by one which can be carried out irrespective of climatic changes. Two Frenchmen of Lille introduced such a process in 1895, and their method was tested between 1895–8, and reported on as follows: "The inventors and patentees have found a process for retting and drying flax in one and the same apparatus without any manipulation, and only using water, air, and heat for the purpose."

The retting is performed by the action of a microbe in the water, which is kept in a closed vessel. When the flax has been sufficiently steeped it is washed thoroughly to take away the scum and dirt. The drying is then done by the uniform introduction of warm air blown into the vessel by a fan, without disturbing the flax in any way. The retting can be regulated *ad lib.*, and is entirely homogeneous. The whole operation of steeping, washing, and drying takes only four days to complete, and is thus much shorter than the old method.

Flax treated by the new process was scutched in forty minutes, whereas a similar quantity and quality scutched by the old method took sixty minutes. This can be accounted for by the more uniform action of the new process, and of course the fibres are less knocked about by it. The flax prepared by the patent method also gave very satisfactory results, both in the bleaching and spinning processes, and the cost of production was less than by the old system. Practically all the flax used is still retted by the old method, and the retting is mostly performed in the countries where the flax is grown.

Flax is grown in *Ireland*, chiefly in the north-east, in Ulster, but there are large tracts of land in other parts of the country eminently suited for the cultivation of this plant.

Experiments have been tried in Connaught, and the yield per acre has exceeded even that of the Ulster farms. Yet outside the province of Ulster there are only about ten scutching mills.

It is quite certain that the absence of large flax-growing industries in the other parts of Ireland is not due to climatic conditions or the soil. There is also a market at hand for large quantities of the raw material, and the large rivers in other parts, such as the Shannon and Lee, are quite as good, if not better, for retting purposes than the Bann and Lagan of the north-east.

Enormous quantities of flax are imported from Belgium yearly, a good deal of which might easily be produced at home.

Perhaps the truth is, it is easier for the farmer to grow crops such as the potato, which, on the whole, are not so profitable, yet do not call for the same care and expenditure of money.

Great quantities of flax are produced in *Russia*, and this is exported to many different countries. Some finds its way to Belgium, to be there used in the factories. Scotland also takes a good quantity of Russian flax.

The flax plants of *Belgium* have suffered somewhat from a disease known as *flax burn*, which arises from a microscopic fungus growth living in the cells of the roots and the root hairs of the young flax plant. Since this parasite is beneath the ground, and is also an internal one, there is no direct method of treating it without injury to the plant. Hence it has been found that the use of different classes of manure brings no satisfactory result. To remedy the disease the plants must be uprooted and destroyed so as to prevent the germs spreading, and no more flax ought to be cultivated on the same land for some years. It is also necessary to notice whether the parasite attacks other plants, and if so, to avoid planting these in the place of flax.

The *linen manufacture* is carried on in the north-east of *Ireland*, at Belfast and the neighbouring towns. This district is a suitable one for such an industry, as the raw material is grown in the immediate vicinity, there is water for retting the flax, coal can be easily obtained from either Scotch or English mines and imported through Belfast, and Belfast itself is a large port having sufficient foreign trade to become a good distributing centre for the manufactured goods; and lastly, the natural facilities for good bleaching of the linen form also a very important factor.

A large quantity of raw flax is obtained from Belgium for use in the better class of fabrics.

The linen industry in Ireland is probably the most important in the world, yet in the reign of George III. the staple manufacturing industry there was woollens. This latter industry has now almost entirely disappeared.

In *Scotland*, at Dunfermline, Kirkcaldy, Aberdeen, and many other places on the east coast between the Firth of Forth and the River Dee, linen is made. This district does not produce much flax, a great proportion of that used being imported from Russia. A glance at the map will make the reason for this apparent. The ports here are just opposite the entrance to the Baltic, and are hence the nearest in the

British Isles to the ports of Russia. Then, again, the kind of linen produced in Scotland is quite different from that produced in Ireland. In the former the coarse linens are the chief kind produced, while in the latter they are mainly of the finer grades. There are, of course, some fine linens produced in Scotland, Dunfermline having been noted for its fine table linen for a very long time.

In *England* the only town noted for the linen manufacture is Barnsley, in Yorkshire. Although such an enormous quantity of raw flax is obtained from *Courtrai* and the surrounding district, yet the linen manufactures here are carried on only to a very small extent.

On the other hand, in *Russia* the industry has grown during recent years, and it is only the finer varieties of goods which are now imported to that country in any quantity, and these are obtained almost exclusively from Ireland.

The coarse and waste fibres obtained during the manufacture of linen are not destroyed, but are made use of in the making of twine.

A good deal of *hand-loom weaving* is still carried on in Ireland, but yet this industry is rapidly declining. Various reasons may be given to account in some measure for this, such as the lower price at which goods, especially coarser grades, are now placed upon the market, owing to the increasing number of power looms. Power-loom weaving produces better wages and less responsibility. Changing fashions, too, have no doubt also had some influence on the decrease in the hand looms, for the linens now in use for shirt-fronts, &c., are not so heavy as they once were. Again, the decrease in the rural population owing to agricultural depression has caused an influx to the large industrial centres.

Fine linens, lawns, and extra heavy damasks are still woven by hand loom in parts of Down and Armagh, but even here the industry is on the decrease.

Much material has found its way on the market in the last few years which, although said to be linen, is a mixed fabric.

Cotton has been largely used mixed with the flax, and there is no doubt that by this means the actual cost of the finished material is not more than two-thirds that of all linen.

One very simple way to distinguish linen from linen mixed with cotton is to steep the material in water. Linen absorbs much more water than cotton, and the former will easily be distinguished if the materials are left to dry.

Of course, the most reliable way is to examine the material with the microscope, when the presence of any other fibres than flax would be at once apparent. Some pure cotton dress fabrics have actually been sold as Antrim linen or Donegal linen, while other fine cotton cloths have been sold as Belfast lawn.

CHAPTER VI

OTHER FIBRES WHICH ARE USED IN THE TEXTILE INDUSTRIES

WITH the growth of the textile manufacturing industries at home, but more especially abroad, has also grown the desire to obtain other fibres to supplant or supplement the more common ones. This is easily understood when it is remembered that the production is limited in some cases to a few countries, *e.g.*, the raw cotton is mainly obtained from the United States of America. Of the fibres which have been of late years introduced, there are one or two which are of sufficient importance to merit a somewhat detailed consideration.

Ramie, or *China Grass*, belongs to the vegetable fibres, and is the product of a kind of stingless nettle which apparently can be most easily grown, producing several crops per year, and in some climates even as many as five or six. It is also very readily propagated from seeds, cuttings, or even division of the roots. This same fibre is also known by the name of *Rhea* and *Nettle fibre*, the latter name being principally used in the United States.

The value of the fibre has long been appreciated in the East, for it has been used both by the Chinese and Japanese for some time. The individual fibres are somewhat difficult to separate, on account of the large amount of gum contained in them. In China the stripping is often done by using the fingers as a scraper. It can now, however, be prepared by improved methods, and so one of the chief difficulties to its more extensive use has been removed.

Those who know most about the value of ramie are of opinion that this fibre should not be looked upon as a substitute for any of the other fibres, such as flax, silk, &c., in common use, but rather as a rival to these fibres. Like the promoters of the artificial silk industry, those who try to push ramie before the public find that a good deal of energy is wasted in trying to use the article to imitate effects produced by other fibres, rather than in keeping it exclusively for purposes for which it is most adapted. There is no doubt that ramie is a very strong fibre, and produces a much stronger yarn, when tested count for count, than either flax or cotton; hence it would be suitable for the manufacture of material where a large amount of hard wear is required.

Ramie is being dealt with in large quantities in Europe now, several spinning and weaving mills being constantly at work. The kinds of goods produced are very various, including dress goods of great variety of pattern, and colour of yarn, underclothing, hosiery, curtains, fishing lines and nets, and incandescent gas mantles, in the case of which the great length of the fibre tends to keep the mantle in good shape. Ramie is also used in conjunction with various other fibres, *e.g.*, wool, mohair, &c., and is found, not only to blend well with these, but to add greatly to the strength of the yarn produced. There are two chief varieties of the plant producing ramie fibre. One is known as the "green-leaved" (Boehmeria nivea, variety Tenacissima) and the other as the "white-leaved" (Boehmeria nivea). The product of the former is usually known as "rhea," while that of the latter is called "ramie." The name "China grass" is used indiscriminately for both varieties. Rhea is, generally speaking, not quite so fine a fibre as ramie, and cannot be spun up into so fine a yarn, but it has the advantage of being somewhat stronger. The length of these fibres are both very great, and they both possess considerable lustre.

There is, apparently, a plentiful supply of China grass to be obtained from China, and there is no doubt that India could supply large quantities if the planters are willing to cultivate it. Some of the Australian colonies (New South Wales and Queensland) also produce small quantities. Certainly, now that the fibre can be readily decorticated and degummed, more progress will be made in its use; since its great strength and lustre, combined with its power of taking certain dyes, will more than compensate for the lack of elasticity which the fibre exhibits. This want of elasticity would, of course, be a distinct advantage if used for such articles as machine belts, ropes, measuring tapes, &c.

Jute.—Another fibre which has come greatly to the front during the last eighty years or so is *Jute.* This fibre is not mentioned commercially until the year 1828, although, of course, it had been grown for centuries previous to this in Eastern Bengal, and had also been made into fabrics for various purposes. The jute fibre is obtained from two species of plants of the genus *Corchorus;* the fibre from the two species being so very similar that practically no distinction is drawn between them. The area in which the plant is cultivated in India is almost entirely confined to Bengal.

Although the plant is not difficult to cultivate, yet, as in other things, it is found that the best crops are obtained where the greatest amount of care has been taken with respect to the preparation and weeding of the land. The sowing of crops takes place any time from March to June, and, as a rule, the crops require three or four months in which to mature. When the crops are fit the plants are cut down at the roots, and in order to obtain the right sort of fibre it is necessary to watch the crops carefully, cutting them down just at the right time. If a fine fibre is required the plants must be cut down when they begin to flower, but if the plants are allowed to remain until seeding has taken place then the fibre obtained is of a very coarse variety. In experiments with jute at one of the Indian Government farms it has been found that when the plants are cut in flower the fibres are of a heavier kind, and fetch the next best prices to fibres obtained from plants cut in the bud and from those cut when the fruit had set. The fibres obtained from plants cut before budding were of the best colour, but were priced the lowest.

The growth of the jute plant is not only inexpensive, but, when compared with other fibres, the preparation of the fibre itself is comparatively a cheap process. Of course it will vary considerably in detail, according to the district in which it is grown, but in its main features the process of retting is the same as that used in the preparation of flax. The crops are usually first stacked in heaps for three or four days, in order that the leaves may decay. During this time the plants will still be somewhat active, and, although the colour of the fibre is not likely to be improved by this process, there is no doubt that the fibres are strengthened. The bundles of plants are then placed in tanks or pools. The time which must elapse before the fibres can be removed from these tanks will, of course, largely depend upon the nature of the fibre, but will also be subject to change on account of atmospheric conditions.

The fibres must be carefully watched and tested during this time, as if immersed too long the strength of the jute will be very much impaired; so that the market value therefore is largely influenced by successful retting. When the fibres have been sufficiently long in the tank a native stands in the water and strips off the bark, repeatedly dashing the bundle of fibres which he holds in his hand against the surface of the water, so as to remove any impurities which may still adhere to them. When this has been done the excess water is removed by wringing and the fibres are hung up to dry. The jute fibre is very sensitive to the action of water, so that it is absolutely essential that it should be dry before being baled, otherwise it will almost certainly heat and then rot extremely quickly. Although this is a very primitive method of dealing with the plant, yet the fibre so produced is considered much finer than that prepared by machinery.

The very best part of the jute is exported and sold as "jute proper"; the lower classes of the fibres are sold as "rejections"; and the woody and hard ends of the roots form what are called "cuttings." These three classes are put up into separate bales, the weight of the bale being usually 400 lbs. The best jute is employed for the making of various articles, such as shirtings, sheetings, carpets, gunny bags, &c. The cuttings and rejections are made use of in paper-making, and the coarser fibres are used in the manufacture of cords, &c.

The various processes of jute manufacture are practically identical with those employed in the manufacture of heavy flax goods. Although Dundee is now almost the only place in the British Isles at which the jute manufacture flourishes, it was at Abingdon, in Berkshire, that the first experiments in our country were made. It was owing to some yarns which were obtained from that place, in 1833, that the Dundee manufacturers were led to turn their attention to jute. Now, although Dundee was then a centre of manufacture of the heavy flax goods, it was not until many years after that the jute industry grew to any considerable extent. The use of the whale oil for making the jute softer, and more easily worked, probably tended to help Dundee to keep and develop the industry, since that port is one which has sent out whale-fishing vessels for many years.

The growth of jute in India received an enormous stimulus in 1854–6, when, owing to the war, Russia ceased to supply the necessary flax to the Scotch mills. Since about 1863 India has not only been supplying the raw material, but has also been building up a very important jute-manufacturing industry. At first the mills were situated in the neighbourhood of Calcutta, but as time went on they were established in other places, although, even now, they are almost exclusively confined to the Province of Bengal; the only one outside the Province being at Cawnpore. Here, then, has arisen a very serious rival in trade to Dundee, more especially in the case of coarser manufactured goods. Of the total quantity of jute exported the United Kingdom usually takes over 40 per cent., or about one-fifth the total crop; the other chief buyers being Germany, the United States, and France. Quite one-third of the total Indian product is reserved for the home manufacture.

Attempts have been made to cultivate the jute plant in Egypt, and at first they met with some success, although the fibre produced there was of a somewhat harsher nature than that obtained from India; but that country has long since fallen out of the competition, and now, when Indian jute prices are high, the minds of those especially concerned in the trade are troubled about finding other suitable lands for supplementing the supply. Perhaps the latest of these is Rhodesia, where vast regions are lying fallow, which might be suitable either for the cultivation of the jute plant or of some other plants which would produce valuable fibres.

Hemp is a fibre obtained from a plant belonging to the nettle family (genus *Cannabis*). The plant grows to a height varying from 5 to 15 feet. The stem of the plant is hollow and slender, and, when cultivated for the fibre, only a few small branches are produced near the top. The fibre is made up of a series of long cells, and the length of the fibre may be nearly as long as the plant itself. It is especially suitable for the manufacture of twines, thread, sailcloth, &c.

The hemp plant had its home originally in Central Asia, but is now grown over widely extended regions in the temperate zone of the Northern Hemisphere, the countries where it is chiefly grown being Russia, China and Japan, Italy, Austria, and France. In the United States the cultivation of the hemp fibre is almost entirely confined to the State of Kentucky, although attempts have been made to establish the industry in California. Such enormous quantities are used in the States annually that considerably more than one-half has to be imported.

In some countries, *e.g.*, France and Italy, the hemp is retted in the usual manner by immersing the plants in water. Another method, in common use in the United States, is that known as *dew-retting*. In this process the plants are spread in long rows upon the ground during autumn and the early winter, thus exposing them fully to the action of the weather. When this has been done the bark and the useful fibre can be readily stripped from the inner and more woody portion. This process does not produce such a fine fibre as does the water-retting process, nor are the fibres of such a light colour. On the other hand, it is a much cheaper process, less labour being necessary, and there are no retting tanks to construct.

A process known as "*Breaking*" is begun as soon as the retted hemp is ready. By this process the fibre is separated from the stalk and partly cleaned. This is performed by the grower before the hemp is put on the market. A good deal of the hemp is still treated by hand, for although several machines have been invented for breaking purposes few of these are used in a commercial way.

Sisal.—The name hemp is now sometimes applied to fibres obtained from plants of quite different orders. There is the "sisal hemp," or "henequen," which is a leaf fibre obtained from a species of Agave, and the "manila" hemp fibre, obtained from the leaf of a kind of banana plant. This latter plant grows almost exclusively in the Philippine Islands, and there is little doubt but that the cultivation of the plant will largely increase as machines are constructed to more easily prepare it for the market.

Tropical plants of the lily order include three or four species producing fibres which are often known as "*bowstring*" *hemp;* these are cultivated chiefly in the Bahamas; and, lastly, there is an East Indian plant, from which is obtained the so-called "*Sunn*" *hemp.*

Of these, perhaps the most widely known is the sisal hemp, which has from very early times been in use in the countries of Central America. Yucutan is the chief centre of production, and most of the sisal exported from that country goes to the United States. The name "sisal" has been adopted in this connection since that is the name of the port from which the fibre was first exported. The fibre has been known in Europe, for well over one hundred years, as suitable for the manufacture of ship's ropes, &c., but for some reason or other, although it was used in the middle and some part of the latter half of the eighteenth century for that purpose, it was comparatively forgotten for many years at the beginning of last century, and it was not until near the middle that it again became prominent.

Once planted and properly treated, the plants will last a great many years, and when they are no longer any good as fibre producers the old plants send up a flowering shoot. They should, of course, then be cut down, and place thus given to younger plants, which should have already been planted between them. The leaves when ready for cutting are about 5 feet long. The thorns are cut from the edges and the hard point is removed. The leaf is then passed through a machine, and the fibre which is so obtained from them is bleached and dried in the sun.

The plant, or one closely allied to it, is cultivated extensively in the Bahamas, and factories for the extraction and cleaning of the fibre are established on the small estates. The Colony of Queensland has taken up the production of this fibre since about 1890, and it is found to be a very profitable crop, especially where the lands are poor, for the plants from which the hemp is produced are a kind of cacti, so that when grown on deep soil, and with access to plenty of moisture, they become pulpy, and do not produce a good fibre. Because of the nature of the plant there is practically no risk attached to its growth, as in the case of other fibre producers. It recently appears (1907) that New South Wales is meditating upon entering the field also, for a large number of plants have been imported there from Queensland. In passing it may be mentioned that bales of henequen weigh only about 160 lbs.

Another plant, belonging to the aloe order, yields a fibre which is known commercially as *Mauritius* hemp—which fibre is used for much the same purposes as manila hemp. It grows in Ceylon and Queensland.

A great many other fibres belonging to the vegetable kingdom have been from time to time exploited during the last few years, although so far they have not succeeded in occupying a very prominent place on the textile market. Among these the following may be briefly noted:—

The *arimina* fibre. This is produced from a plant (Guaxima) which grows in Brazil, and the fibre has been made use of locally in the manufacture of sacks, with somewhat poor success, although the Brazilian Government attempted to help on the new industry by means of a preferential export duty in its favour. Quite recently another fibre has been cultivated in Brazil. This fibre has qualities similar to those of flax and hemp, and is known locally by the name of *lin Perini*. A Mexican fibre known as *Zapupe* was at one time looked upon as being a species of henequen, but this is not quite correct, although it belongs to an allied family of plants. It is used by the natives for the manufacture of ropes, for which purpose it is considered to be equally as good as the best hemp. There is a wild *pineapple plant*, known also by the names of *chocohurstle* and *guamero*, which grows on the Pacific Ocean side of Mexico, which produces a fine silky fibre. This fibre has been worked locally by hand, and quite satisfactory cloths made from it. A silky fibre has also been prepared in Queensland from the leaves of a pineapple plant.

Among the palm-trees of Mexico the *Coquito* furnishes a coarse fibre which is suitable for the manufacture of bags and ropes. There is also a plant known as *Escobillo*, grown in the same neighbourhood as the wild pineapple, which produces a very fine fibre similar in some respects to ramie.

From Algeria, in North Africa, comes a fibre known as *crin vegetal*, or vegetable hair. This fibre is obtained from the leaves of small palms which grow in the coastal regions. It is used as a substitute for horsehair, especially in the manufacture of cheaper classes of goods. The largest market for the fibre is at present Antwerp, from whence it is distributed to German manufacturing centres. England takes practically no share in this trade.

As might be expected, there are several fibre-producing plants grown in India which are at times put forward as substitutes or auxiliaries to jute. The *helicteres* fibre, which is produced from a plant found in most forests of the Indian plains, is such an one. It can withstand great changes of moisture and warmth, does not readily rot, and is suitable for the manufacture of such articles as are produced from jute.

There are one or two fibres which have been found particularly suitable for pillows and cushions. Such are the *Kapok* and *Pochete*. The former is produced in South America, and exported from Quayaquil. The tree which produces it is often called the silk cotton tree. Kapok is also grown in the Island of Java. An acre of kapok-trees yields, generally, under 500 lbs. of clean kapok yearly, even when the trees are at their best, although small trees which are well grown have been known to yield over 100 lbs. annually. The kapok bales are only 80 lbs. weight, as a rule, since the fibre must not be compressed too much for fear of destroying its natural elasticity, which gives it value for the purpose for which it is used. The latter, obtained from the pochete-tree, grows in

Mexico. Both fibres are obtained from the pods produced by the plants. The quantity exported is very small.

Lastly, there is the *rafia* fibre, which grows in Madagascar. This fibre is woven into various kinds of articles by the natives. It is also used to some extent in the manufacture of Panama hats.

Yucca ricurvifolia, a plant of the palm family, has been subjected to experiments in Italy (Naples), with a view to introducing commercially the fibre obtained from it. The fibre is obtained from the leaves, and is suitable for making canvas and cordage, so that it would become a substitute for hemp.

This plant apparently grows easily in the malarious districts of Italy, where, of course, labour is scarce; but the only labour really required is for the annual cutting of the leaves. These leaves yield over 20 per cent. of fibre, and the refuse is then made use of for the manufacture of paper.

CHAPTER VII

THE MICROSCOPIC STRUCTURE OF TEXTILE FIBRES

THE identification of the constituent fibres in a piece of material is a very important and often a necessary accomplishment of those engaged in both wholesale and retail houses; and as this book is especially designed for the use of such as these, this part of the subject will be dealt with at some length, yet, it is hoped, in such a manner that the reader with little or no previous knowledge will be able to profit from its perusal.

In the first place it need hardly be stated that at the present time, when so many new fibres, natural and artificial, find their way into the manufacture of piece goods, it is by no means easy to ascertain by a casual glance, or even careful handling, the true nature of the fibre which constitutes a piece of material. Again, fibres are often so treated in the processes of manufacture that their appearance is changed; *e.g.*, material is often made with a cotton warp dyed to a natural shade so as to resemble flax yarn, and then the cotton yarn is woven up with a flax weft, and the article so produced has the general appearance of linen.

Something more than a careful scrutiny with the naked eye is therefore necessary, and for this purpose we call in the aid of the microscope. To those readers who have no acquaintance with this instrument a few words on its nature and use may be of service.

The essential parts of the microscope are (*a*) stand, (*b*) reflector, (*c*) objectives, and (*d*) eye-piece.

In the stand it is preferable to have one which can be adjusted to any angle required, as those which are fixed in an upright position are troublesome, unless a good source of light is always at hand. It is also advisable to have a coarse rack adjustment (1), as well as the fine adjustment (2), as there is always the liability of the sliding tube working either too loosely or *vice versâ.* The stand should at the same time be of a substantial make, as this is a great advantage where rapidity of working is essential.

The reflector should have two mirrors, one plane, the other concave, and a little practice

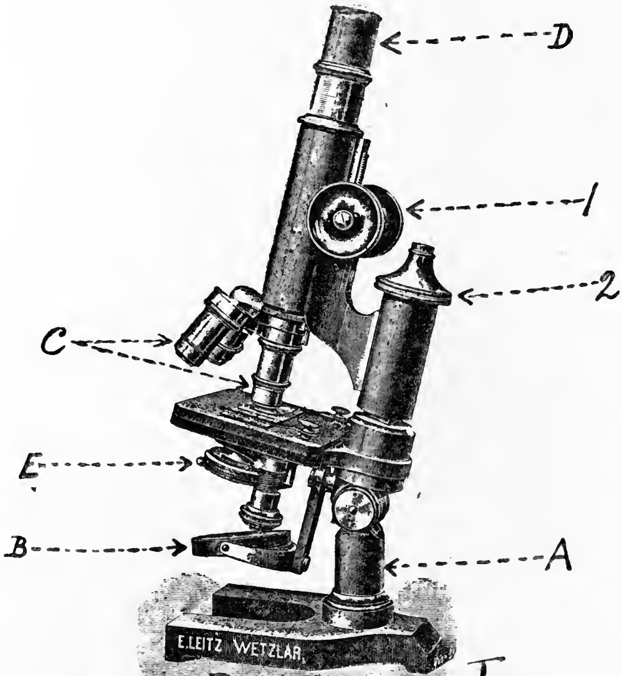


DIAGRAM I

will soon determine the circumstances under which each should be used. It need hardly be said that the object of this reflector is to throw the light from the lamp or other source of light up the tube of the instrument.

The most important part of the apparatus is the objective, as on this depends very largely the amount of magnification produced. Great care must be taken not to scratch the lens at the lower end of the objective; any dusting necessary must be performed with a very fine piece of wash-leather or an old silk handkerchief. The most useful objectives (for it is advisable and almost necessary to have two at least) for use in this work are $\frac{1}{4}$-inch or $\frac{1}{6}$-inch, and $\frac{1}{2}$-inch or $\frac{2}{3}$-inch. The smaller the fraction which designates the objective the greater the magnifying power. The eyepiece also helps to increase the magnifying power of the instrument, and it is usual to supply two or more eyepieces of different magnifying powers with each instrument.

Care should always be taken to raise the tube by means of the coarse rack adjustment when the slide is placed on or removed from the stage, so as to avoid touching the objective with the slide. When getting the object in focus the tube should be lowered by means of the coarse adjustment until specks, which are nearly always present on the top of the slide, can be clearly seen; then continue the process with the fine adjustment. A little practice will soon enable one to adjust the instrument for use in a few seconds.

Although the above parts are all that is really essential, an earnest student would find it very useful to obtain in addition (*e*) a sub-stage condenser, and (*f*) a polarising apparatus for attachment to the microscope. The sub-stage condenser, as its name implies, is for fixing beneath the stage and for increasing the illumination of the slide. In general, it will be found that with a good reflector sufficient light can be obtained without the use of this appliance, but occasions often arise where the condenser is not only an advantage but also an essential addition.

The polarising apparatus consists of two parts, one the polariser, for fixing beneath the stage, and the other the analyser, for fixing usually over the eyepiece of the instrument. The object of polarising the light is to limit the vibrations producing the light to one particular plane; this is done by the polariser placed beneath the stage. The analyser is really a second polariser, and if the prism which it contains is placed in a position parallel to that of the polariser the light comes through both to the eye of the observer; if, however, one is placed at right angles to the other, the field of vision appears quite dark. In order to understand this better the student should imagine a long piece of rope, with one end fastened to a wall and the other end held in the hand. If the hand is now moved up and down in an oblique direction the rope will appear as a series of waves, also in an oblique direction. A grating with vertical bars is now placed between the hand and the wall, the rope passing between two bars; then, on the rope being moved as before, it will be noticed that the waves formed by the rope between the grating and the wall are in a vertical plane. If a second grating, with bars horizontal, *i.e.*, at right angles to the first, is now placed between the first and the wall, the rope being placed between two of its horizontal bars, when the rope is moved as at first, it will be seen that no waves now appear between the second grating and the wall.

Hence, since light is produced by waves of ether, the polariser and analyser, when crossed, prevent those waves from reaching the eye, and a dark field is the result. For further information on this the reader is referred to books on Light, where, under the heading of "Polarisation of Light," details may be found.

Now, if a substance which has any power to alter the plane of vibration of the ether waves is placed between the analyser and polariser, the field will not appear dark when the prisms are crossed. The simplest way of doing this is to cross the prisms and then place the slide on the stage. Many textile fibres have this power, some to a much greater extent than others, and of this power details will be given when the microscopic structure of the fibres is dealt with.

An important point with many young men will be the price of an instrument suitable for examining fibres. No definite information can be given in this direction unless the exact specification be given, but an instrument having necessary eyepieces and objectives can be obtained for about £3, and one having all the accessories mentioned from £3 to £8. A great deal depends upon the nature of the stand, the usual prices of the other parts being as follows :—

(1) Abbe condenser with iris diaphragm, 15s. to £1.

(2) Polarising apparatus, £1.

(3) $\frac{1}{4}$-in. objectives, £1 1s. to £1 15s.;
$\frac{1}{6}$-in. objective, £1 10s. to £2 2s.;
$\frac{1}{2}$-in. objective, about £1;
$\frac{2}{3}$-in. objective, about 12s.;
according to quality of lenses and angular aperture.

One final word of advice is necessary to those who may be inclined to add to the usefulness of the microscope by purchasing, from time to time, other accessories, viz., be sure that the instrument is of a standard size.

To examine the fibres they must be mounted on glass.

For rough work all that is necessary is to have two pieces of good thin glass (such as is used for photographic negatives), some clean water, and a piece of narrow glass tubing.

Dip the glass tube to a depth of about one inch in the water, cover the open top end of the tube with the finger, and remove the tube from the water. It will be seen that the lower part of the tube is filled with water; hold this over the middle of one of the clean glass plates; remove the finger from the top of the tube so as to allow the water to drop on to the plate. If the raw fibre is to be examined, place it in the water; if a piece of cloth, take first either the warp yarn or weft yarn, hold one end of the yarn by means of a mounted needle (these can be bought for a few pence), while the other end is teased out by means of another needle. When sufficient has been teased out, hold that part over the water on the glass plate and cut about half an inch from off the end for the purpose of examination; cover this with the other piece of glass. It is now ready to be examined by the microscope. This should be done, using a low power first, and afterwards (without moving the slide) substituting a high power. Unless the glass is very thin it will not be found possible to obtain sharp definition with the $\frac{1}{6}$-in. objective. Keep the stage of the condenser in a nearly or quite horizontal position for this rough work, and take care not to wet the stage.

For those who wish to make a systematic study of the fibres, it is much better to mount them permanently. For this purpose slides must be obtained of size 3 in. by 1 in., and cover-slips, or, as they are sometimes called, microscopic circles. The slides are sold in gross, and are of different prices, according to quality of glass and finish of slides. The circles are sold in varying degrees of thickness and of different diameters. Those of $\frac{3}{4}$-in. diameter will be found a useful size.

As no very high power objective is to be used, the thicker cover-glasses will be found to be sufficiently fine and much easier to manipulate; those $\frac{1}{70}$ in. in thickness will do admirably. Before using slides or circles they should be carefully dusted, care being taken to use no material likely to leave small particles on the glass.

Canada balsam will be found the most useful mountant. This can be bought dissolved in zylol, but as this is made up into a very thin solution it is often difficult to place just the right quantity on the slide. When this is the case obtain some Canada balsam, and add some to the solution until the right consistency is reached. A piece of solid glass rod will make an excellent dropper. Care should be taken to avoid air-bubbles in the drop of balsam, and it will be easier to do this if one drop only is allowed to fall on the slide. The fibre, which should be well teased out, is now held over the drop of balsam, and sufficient for the purpose in view is cut off the end with a pair of scissors. The next, and by no means the easiest, step is to place the cover-slip over the fibre. Two ways of doing this will recommend themselves; the first is, to drop the slip horizontally, and, by gentle pressure, force it down until the liquid is in contact with all parts of the under surface of the slip. The second is to hold the slip in an oblique position, place its lower edge in contact with the edge of the balsam, and, with a mounting needle under the upper edge, gradually lower it into the liquid ; this will the better enable any air present to escape. Should it be found that a few small air-bubbles remain, they may sometimes be removed by gentle pressure, or they may probably, if left, work their way out by the weight of the slip alone.

Each slide should be carefully labelled in such a manner as to indicate (*a*) the source from which the fibre was obtained, *i.e.*, material ; (*b*) whether warp or weft ; (*c*) nature and quality of the fibre. An arbitrary scale of quality might be constructed for the observer's use, depending on the various characteristics of the fibre.

Successful permanent mounting is by no means easy, but it will be quite essential to have some slides which can be kept as standards of reference, as it will soon be found that the differences to be noted are in many cases extremely minute, and that nothing but continual practice can enable one to be even moderately sure in some cases. One word of caution is necessary. Do not carry this too far.

The author has met with cases in his practical class in which a student would have condemned a piece of material as not being what it was specified, simply because a stray fibre of another kind was found on the slide. A moment's thought would make it clear that one ought, at least in certain materials, to expect this sort of thing to happen. Take wool, for instance; the sheep are sure to get a good deal of vegetable fibres mixed up with their wool. Great care is taken to extract as much of this as possible, but some may be left. Then, again, in the course of manufacture it would not be surprising if, from one source or another, a few stray fibres are picked up.

If, now, slide after slide is prepared, and each is found to contain stray fibres, then one may begin to doubt the truth of the "all wool," &c., material. With a very little trouble a rough estimate of the quantity of other fibres present could be obtained, *i.e.*, by counting the numbers of different fibres on several slides and then striking an average for the whole.

Each fibre will now be described in turn, sufficient detail being given in each case to enable the reader to distinguish not only the fibres, but in some cases those of poor quality from those of good quality.

The *Cotton Fibre.*—This fibre, as seen under the microscope, differs entirely from any of the other fibres. In the first place, it consists of one elongated cell only; hence there are no transverse markings to be found, such as those of flax, which, of course, indicate the fact that the flax fibre is built up of a long string of cells. The cotton fibre is hollow, and at first its transverse section is as (*a*) in diagram. As more cellulose is deposited in the walls of the cell, the cell-sap gradually dries up, and its cross-section ultimately becomes as in (*b*) in diagram. Should any cause, such as frost, present the complete development of the fibre the part (A) does not appear, or perhaps is only just beginning to form. Again, as the cell-sap dries up and the fibre becomes mature, it gradually assumes a twisted form. The number of these twists varies with the variety of fibre, but may easily exceed 100 to an inch in length. If the growth of the fibre has been arrested these twists will, of course, not appear, so that an immature cotton is like a fine, flat ribbon as the walls of (*a*) ultimately collapse. The presence of these fibres in any large quantity means that the commercial value of the bale is small, as the absence of the part (A) and the twists (*c*) render the fibre of little value for spinning purposes.

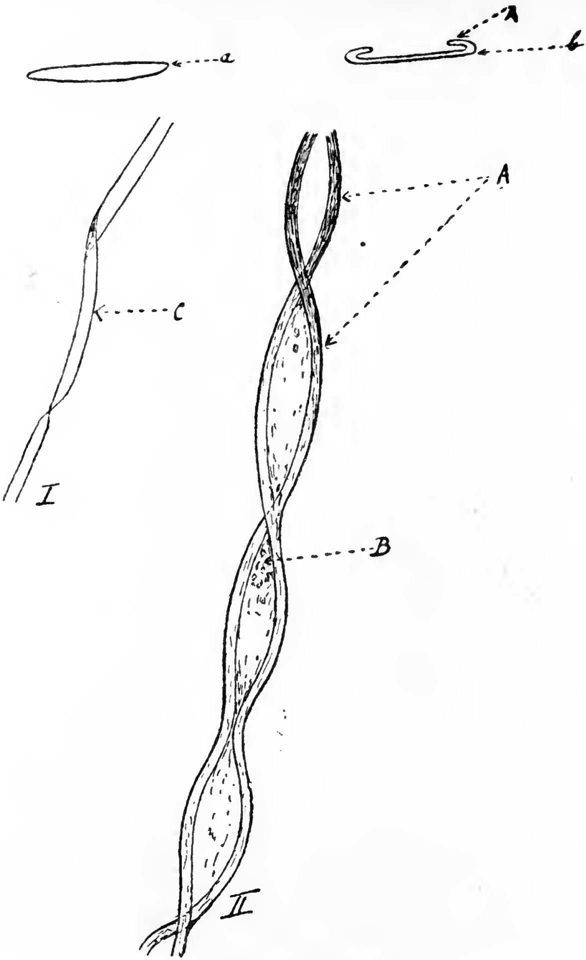


Diagram II.

Diagram to illustrate Cotton Fibre: (*a*) Transverse section (unripe). (*b*) Transverse section (ripe). I. General appearance of unripe fibre. II. General appearance of ripe fibre.

If such fibres are present in any part of a bale in large quantity they can be often distinguished with the naked eye, as they present a general sheeny appearance, quite unlike good ordinary fibres in bulk. Often some cell sap remains in the fibre, and it can be seen under the microscope as a series of small dots, as (B) in diagram.

No other fibre except Tussah silk has natural twists, so that the twists of the cotton fibre make it easy for the observer to distinguish cotton from other fibres, while the presence of the cell sap and the unicellular nature of the fibre is confirmatory evidence. The twists can be readily distinguished with the $\frac{1}{2}$-inch objective, but the edges (*A*) require a $\frac{1}{4}$ or $\frac{1}{6}$-inch objective to make them quite clear. Cotton fibres can therefore be easily recognised with the aid of the low power of the microscope, but to be quite certain as to whether the fibres are good or bad requires the aid of the higher power. The cotton fibre maintains a uniform diameter throughout the greater part of its length, and then tapers very rapidly. The finest of all cotton fibres is that of the Sea Island variety, although the West African and other American varieties are of greater diameter than the Sea Island; but it must be understood that it is an impossible task for one to be absolutely certain to what variety a cotton fibre belongs.

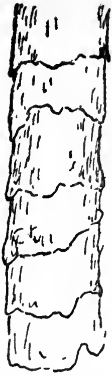
The polariscope with crossed prisms shows a many-coloured fibre on a black ground, and may be a help for those who wish to see the developed edges of the cotton.

For the student who wishes to examine cottons, slides of the following should be prepared:—

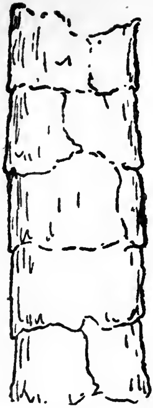
(1) Sea Island cotton (American).
(2) Sea Island cotton (Egyptian).
(3) Sea Island cotton (Queensland).
(4) Ordinary Orleans or American.
(5) Indian.
(6) Egyptian.
(7) Brazilian.
(8) West Indian.
(9) East African.
(10) West African.

The *Wool Fibre.*—Wool is essentially a kind of hair, and, as such, originates from a series of active cells covering a papilla (*P*) embedded in the skin.

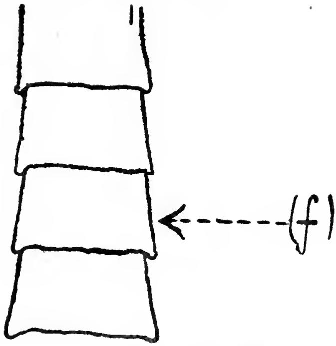
These cells form the root of the hair, and also its growing-point. As these multiply, the hair is pushed out of the skin, and therefore becomes longer. At first the hair has a very fine tip, as can be seen in wools of the first clip, but, of



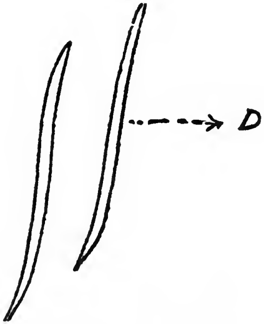
1. Wool (fine).



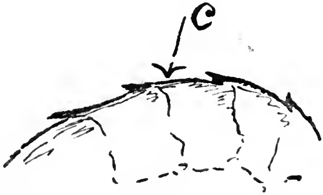
2. Wool (coarse).



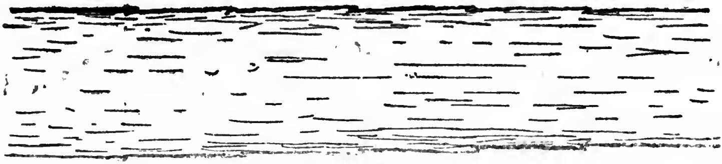
3. To illustrate scales of Merino.



4. Spindle-shaped cells of cortical substance.



5. Bent wool fibre.

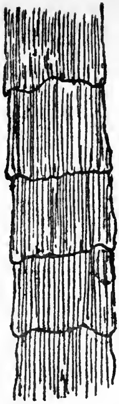


6. Mohair.

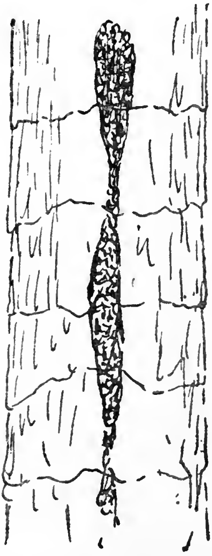
DIAGRAM III.

Diagram to illustrate Wool Fibre.

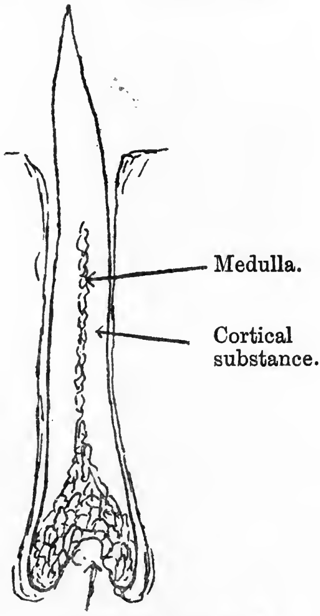
7. Wool showing distribution of colouring matter (natural).



8. Wool showing uniform effect of dyes.



9. Kemps wool showing medulla.



10. Growing part of hair.

DIAGRAM III.

Diagram to illustrate Wool Fibre.

course, when the tip has once been removed, the hair always keeps its blunt end.

The wool fibre itself, as seen under the microscope, will be found to consist of three distinct parts.

1. The outside covering, or *scales*. These can be made apparent to the senses without the aid of the miscroscope, by grasping a single wool fibre between the finger and thumb of each hand, and then drawing it gently. The end of the fibre nearest the root end remains fixed, but the other end slips. In order to see the scales satisfactorily, however, the $\frac{1}{4}$-in. or $\frac{1}{6}$-in. objective must be used, and even then in some cases they are by no means easy to distinguish.

If the wool be steeped in dilute sulphuric acid, and then examined, the scales will be much more evident.

The projecting parts of the scales (*a*) gives the edge of the wool a serrated appearance, and that part as seen over the fibre itself is a more or less broken line (*b*). If a fibre is seen bent, as at (*c*), the scales will be seen attached at their bases only.

2. The *cortical substance* which constitutes nearly, and sometimes all, the internal portion of the fibre. This part of the wool is made up of narrow spindle-shaped cells, which have taken

upon themselves a more or less horny nature. This part of the fibre can be examined by heating the wool in dilute sulphuric acid, and then gently teasing with mounted needles. This separates the cells, and their shape can then be seen (*d*).

This part of the wool has a much greater attraction for colouring matter than the scales.

3. The middle portion, known as the *central medullary portion*, consists of several layers of cubical or rhombic cells, which form a sort of pith to the fibre. These may traverse the whole length of the fibre, or may only appear in parts. In the merino wools this part appears to be absent. In colourless wool, under the microscope, it appears as a dull hazy stripe up the centre of the fibre (Diagram III.).

This appearance is caused by the air enclosed in the cells. This fact can be proved by boiling wool, showing the medullary part in glycerine or in turpentine. When such wool is again examined, the hazy stripe will be no longer visible. When the medullary portion is most marked the fibres are very brittle and stiff, and in fact, may be looked upon as approximating more to ordinary hair. Such extremely poor wool goes often by the name of *kemps*. In these more advanced types which are to be found even in good wools, for the wool from the lower part of limbs and also from the neck of all sheep tend to take on this nature, the scales are more or less indistinct, and sometimes even invisible. Sometimes the whole fibre appears opaque, and it always appears much denser than usual. Again, in some cases only the medullary part appears opaque; but these fibres are always deficient in strength, lustre, felting power, and are much more difficult to dye than ordinary wool. The general name *Wool* includes such a great variety of fibres that a little space must be allotted to the consideration of each individual fibre.

Of all wools the merinos hold the highest place as regards quality. These wools are of an especially fine diameter, and are peculiar in the enormous number of scales which they possess (4,000 or more to the inch in length). Another feature is the absence of the medullary portion, and the fact that each of the scales seems to envelop the fibre, so that the scales fit into one another like funnels (diag. *f*).

Wools from *cross-bred* varieties are, as a rule, of not so fine a diameter as merinos, but the most important difference is the far less number of scales per inch in length. Wools obtained from mountain breeds of sheep, such as the Scotch, are much coarser, and one has no difficulty in obtaining fine specimens showing the medullary portion.

Besides ordinary wools, such fibres as mohair, camel hair, cashmere, vicuna, llama, and alpaca, must be dealt with under the heading of "Wools." The *mohair* fibre is, often, of much larger diameter than the wool of the sheep. The scales are difficult to see, and the part on the fibre itself can only be made out with great difficulty. There is, however, a more general stiff appearance about these fibres than in the case of ordinary wool, and this ought to serve as the chief point of distinction. The *camel-hair* fibre is similar in appearance as far as stiffness goes and the difficulty of seeing the scales, but is of much smaller diameter.

With regard to the various kinds of *goat's hair* such as vicuna, llama, alpaca, and cashmere, one can only say that a fibre belongs to the class, and it would be rash indeed to class any such fibre absolutely. Cashmere and vicuna are fibres of very fine diameter; and the scales of cashmere are very easily seen, while those of vicuna are difficult to find. In vicuna, too, the pigment cells are much more numerous.

In the case of llama, the fibres are of a much greater diameter, being more akin in this respect to mohair. The pigment cells are very plentiful, and the scales even at the edges are by no means easy to find.

There is one further important question which can be readily settled with the aid of the microscope; that is, whether a fibre owes its colour to *natural colouring* matter or to colouring which has been introduced, *i.e.*, *dyes*. In natural coloured wools the colour is due to pigment cells which occur in very great numbers. These are, by means of the microscope, resolved into their constituent cells, and appear as dots scattered throughout the fibre (diag. *g*).

When a wool fibre owes its colour to dyes the appearance under the microscope is quite different. The colouring matter diffuses throughout the whole of the fibre, and gives it a general tint of a lighter shade than the material has in bulk: this can at once be ascertained by rough mounting, and ought to be a very useful method of testing natural coloured woollen underclothing, &c.

A list of slides should be made for the study of the wool fibre as follows:—

(1) Merino.

(2) Cross-bred sheep.

(3) Scotch mountain sheep, showing medullary part.

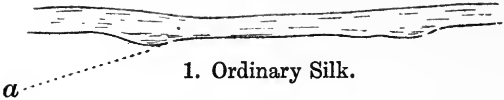
(4) Camel hair.
(5) Vicuna.
(6) Mohair.
(7) Llama.
(8) Alpaca.
(9) Wool natural colour.
(10) Dyed wool.

Slides to illustrate cortical cells should be prepared and mounted roughly only.

The *Silk Fibre* has very little to distinguish it as seen under the microscope. From the way in which it is formed this is to be expected. The general appearance of the silk is that of an elongated, solid, structureless cylinder. There is in places an uneven appearance, as at (*a*) in diagram, and this helps to distinguish real from artificial silk. The author has, however, seen specimens made from wood-pulp—so spun, that even in this particular it could not be distinguished from the real article.

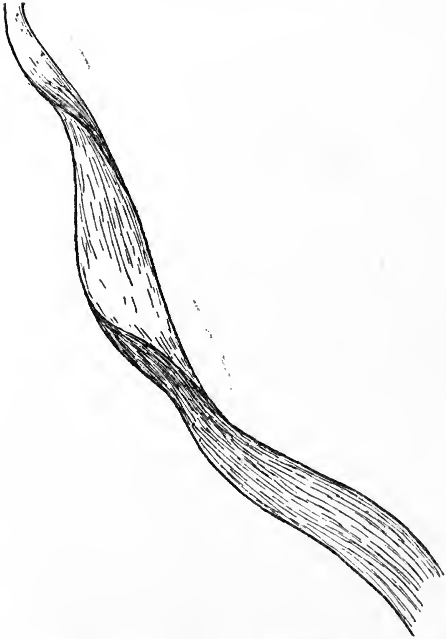
The artificial may, however, be generally recognised from real silk by its stiffer appearance, its much greater and more uniform diameter, and its more brilliant appearance when the polarising apparatus is attached to the microscope with the prisms crossed.

The silk obtained from wild silkworms, and known under the general name of *Tussah* or



1. Ordinary Silk.

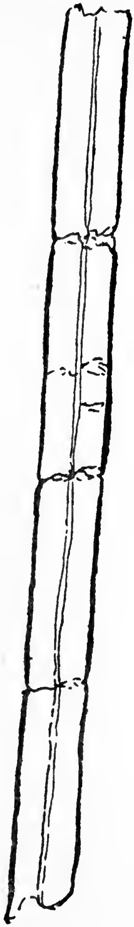
2. Artificial Silk.



3. Tussore Silk, showing twists and fibrils.

DIAGRAM IV.

Diagram to illustrate Silk Fibres.



FLAX

DIAGRAM V.

Tussur silk, is quite different in appearance to either real or artificial silk. It has a great number of longitudinal striations, which make it apparent that the fibre itself is composed of a large number of very small fibrils. Another distinguishing feature is the contraction which appears at intervals in the more or less flattened fibre. At these points the fibre is twisted, so that were it not for the striated appearance and the absence of the peculiar edges and cell sap, the wild silk might be mistaken for cotton.

As *mercerised cotton* cannot be looked upon as ordinary cotton, it can, from its general appearance, be included here. Not only does the mercerising process give the cotton a general silk appearance when seen in bulk, but each individual fibre as viewed under the microscope also, is found to have taken on somewhat of the appearance of silk: most of the twists have disappeared, and the cotton has assumed the structureless cylindrical form so characteristic of silk; here and there, however, twists can be seen and serve to point out its original nature. When the polarising apparatus is used it will be found that the general colour effect is the same as that produced by cotton, and the twists which still remain can be more readily seen by the different colouration of the fibre in their neighbourhood to that of the great bulk. For this branch the following slides should be prepared:—

(1) Ordinary silk.
(2) Artificial silk made from wood-pulp.
(3) Artificial silk made from cotton waste.
(4) Tussah silk.
(5) Mercerised cotton.

The other fibres of common use in textiles are: *Flax*, *Jute*, and *Ramie*. These all consist of a long series of vegetable cells placed end to end, and it is very difficult to distinguish one from the other. The following remarks may be of some assistance in this respect.

Flax fibre is the finest of these fibres, and the individual cells can be readily observed. The central canal of the tube can also be seen, but it will be noted that it has a very narrow bore. Beautiful effects are visible when the polarising apparatus is used, the many-coloured fibre showing up splendidly against the dark background.

The partitions between the individual cells and the central canal are also much easier seen under these circumstances.

The *Jute fibre* is not so fine as the flax, and the individual cells are by no means so easily picked out. The central canal in this fibre is relatively much larger than that of the flax. When the polarising apparatus is used the behaviour is similar to that of flax, but the partitions between the cells are now much more difficult to see than in the flax fibre.

Ramie fibre has a larger average diameter than flax, and its individual cells and the central canal can be very easily seen. With the polarising apparatus the colour effects are, perhaps, the most brilliant of all the vegetable fibres considered. The characteristics are also very apparent with this apparatus. The central canal is found to be of varying bore, even in the small field of the microscope, and the cell walls of the fibre are of correspondingly different sizes, *i.e.*, thicknesses, and a faintly striated appearance is also sometimes to be seen. Many interesting experiments can be done by staining these vegetable fibres with different reagents, but for these the reader is referred to works on practical botany.

The slides required for this part are—

(1) Flax. (2) Ramie. (3) Jute.

As previously stated, nothing but plenty of practice can make the student at all proficient, either in the use of the microscope or the identification of the fibres, and this chapter is designed to give a few hints to enable beginners to pursue the systematic study of textile fibres for themselves.

The various slides mentioned in the text, as illustrating the characteristic features of the fibres when examined by means of the microscope, can be obtained by post from the author, Central Y.M.C.A., 186, Aldersgate Street, E.C., at the rate of 3s. per half-dozen, or 5s. 6d. per dozen, carriage paid.

CHAPTER VIII

CHEMICAL TESTS FOR FIBRES

PRACTICALLY all the fibres used in the manufacture of piece goods belong either to the vegetable or to the animal world, hence it will not be difficult to realise that the chemical reagents used as solvents for the fibres can be arranged in two main divisions, viz., (*a*) those used as tests for vegetable fibres, (*b*) those as tests for animal fibres.

Perhaps no simple test for the presence of animal fibres is so widely known, so easy to perform, and so effective as that which depends upon the solution of those fibres by dilute solutions of the Caustic Alkalies, and it would be well to start with this.

In order not to confuse those whose knowledge of chemistry is limited, for the first few pages each reagent will be dealt with separately, and the arrangement will be that of reagent and its effect upon different classes of fabrics.

It has also been thought advisable to arrange this chapter as a series of experiments, so that each part is complete in itself.

Caustic Soda, or sodium hydrate, is a solid which is sold in the form of cylindrical sticks of about the same diameter as the ordinary pencil. It is not an expensive chemical; sufficient for carrying out these experiments can be bought for a few pence.

The solid should be kept in a bottle fitted with a ground glass stopper, as it very readily absorbs moisture from the air. Great care should be taken when handling the sticks, for, as its name implies, it has a caustic effect on any sensitive part of the flesh with which it comes in contact.

Two solutions of this solid will be required: (*a*) a saturated solution obtained by adding the solid to boiling distilled water until no more will dissolve. This can be done by means of the apparatus illustrated in the diagram. The other solution (*b*) should be made as follows: Balance a beaker on the left-hand pan of a pair of scales, using a beaker of same size as counterpoise. In the beaker on the left-hand pan place pieces of caustic soda until it just balances a 10-gram weight placed on the other pan; add distilled water to the caustic soda until the total weight of water and caustic soda is 100 grams.

These solutions should be made up and kept in bottles fitted with ground-glass stoppers.

Experiment 1.—Place some raw wool or

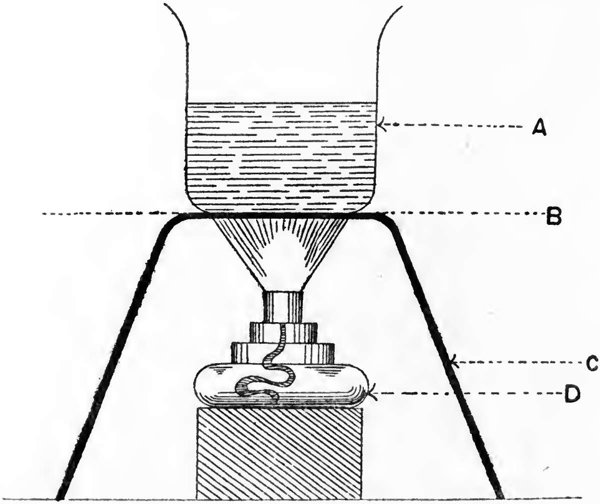


DIAGRAM VI.

A, a glass beaker. B, a piece of copper wire gauze. C, an iron tripod. D, a spirit lamp.

woollen fabric in a beaker and pour in solution (*b*) until the material is covered. Place the beaker on the wire gauze on tripod stand and boil gently. Carefully note the time taken for all the wool to dissolve. It will be noted that the liquid becomes coloured to a light brown tint even when undyed raw wool is used; when woollen materials are used the solution will often be found to be very muddy in appearance owing to the dressings, &c., contained in the fabric. Any fibres which remain undissolved at the end of 15 minutes' boiling should be carefully examined microscopically, as in all probability they are of vegetable origin.

Experiment 2.—Place some silk in the beaker in some fresh solution (*b*) and proceed as in Experiment 1. The silk does not dissolve quite so readily as wool.

Yet as both wool and silk dissolve in solution (*b*) it is essential that some test be made to ascertain which of the fibres is in solution.

Experiment 3.—Obtain some concentrated hydrochloric acid and make a solution containing one part acid and one part distilled water.

(All acids should be kept in bottles fitted with ground-glass stoppers.)

Into a solution of some wool obtained as in Experiment 1 and contained in a test-tube pour some of the dilute hydrochloric acid; note the very disagreeable smell which results.

Experiment 4.—Perform a similar experiment with the silk solution obtained in Experiment 2. No such smell will be recognised in this case.

The peculiar smell in the case of the wool solution is due to the action which the acid has upon the small amount of sulphur contained in the wool. A gas known as sulphuretted hydrogen is produced when the acid is added. It is this same gas which is so much in evidence when a very stale egg is smashed.

Experiment 5.—Another and less disagreeable test can be made as follows: Obtain some lead nitrate (or other soluble salt of lead), and make a strong solution of it by heating as much as will lie on a sixpence in a small quantity of distilled water contained in a test-tube.

Add a few drops of this solution to each of the solutions obtained in Experiments 1 and 2. (In this and all similar experiments the solution should be held in a small test-tube.)

In the case of wool a dense black substance forms when the lead nitrate solution comes into contact with the liquid in the test-tube, and the black colour does not disappear when the test-tube is well shaken. In the case of silk a milkiness is produced when the solution is first added, but this very quickly disappears when the test-tube is shaken.

The black colouration in the solution of wool is produced by the union of the sulphur contained in the wool with the lead of the lead nitrate to form an insoluble black compound, known as lead-sulphide.

Experiment 6.—Steep some silk in solution (*a*) caustic soda, then place the beaker in which the experiment is performed in a larger one, and pack ice between the beakers. The ice jacket may be prepared before the silk is placed in the solution, and then it will be found that the silk is not acted upon by the caustic soda.

Experiment 7.—Boil some tussore silk in solution (*b*) caustic soda. This silk is much more difficult to dissolve than ordinary silk.

Experiment 8.—Weighed quantities of cotton, flax, and any other vegetable fibres may be boiled for 15 minutes in solution (*b*) caustic soda, and the general effect of such procedure noted.

If the fabric is to be tested by weighing, it should be thoroughly washed in plenty of water before drying, then it will be found that very little if any of the fabric is dissolved by boiling in this solution.

Experiment 9.—Examine some cotton fibres under the microscope, using $\frac{1}{4}$-inch or $\frac{1}{6}$-inch objective. Steep some cotton in solution (*a*) caustic soda for about 5 minutes, again examine it under the microscope. The mercerising effect of this treatment will be apparent.

Experiment 10.—Place some bleached cotton fabric and some bleached linen fabric in a beaker, and pour in some solution (*a*) caustic soda. Allow them to be thoroughly soaked in the solution, then compare their appearance with that of similar material which has not been so treated. The cotton will be found to be only very slightly darker in tint, but the linen has become quite yellow in colour.

It might be observed in this connection that, generally speaking, linen is more liable to be damaged by such reagents as caustic soda, lime-water, and bleaching powder than cotton.

Experiments with Hydrochloric Acid.

Experiment 11.—Steep some cotton fabric in concentrated hydrochloric acid. When thoroughly saturated allow the material to dry slowly in contact with the open air, without having previously washed the acid out. It will then be found that the strength of the material has been much impaired by this procedure; in fact it has been to a large extent disintegrated.

Experiment 12.—Boil some cotton fabric in a solution containing one part hydrochloric acid and one part distilled water. After a time it is seen that the cotton has dissolved. If the fabric be examined before it has dissolved (say after boiling 5 or 10 minutes), it will be found that the fibres are destroyed, and the material can be rubbed into a kind of paste.

Experiment 13.—Steep a fabric known to be composed of cotton and wool in dilute hydrochloric acid. Remove it from the acid and allow it to dry slowly in the open air. The acid will cause the cotton to disintegrate, but will have very little effect upon the wool. If the material is rubbed between the hands the cotton will break up and crumble, leaving the wool behind.

Experiment 14.—Steep some silk in concentrated hydrochloric acid, and at the same time steep some tussore silk in a similar quantity of concentrated acid. The ordinary silk dissolves almost immediately, but the tussore will be only partially dissolved, even if left for two or three days.

Experiment 15.—To ascertain the relative amount of cotton and wool in a mixed fabric.

Cut three pieces of the material each 10 grams in weight, and label them *A*, *B*, and *C*, *i.e.*, have receptacles for them so labelled. *A* is kept for reference.

B and *C* are boiled for 15 minutes in a very dilute (2 or 3 per cent.) solution of hydrochloric acid. At the end of that time they are both taken out of the solution and thoroughly washed.

B is then thoroughly dried in a hot-air oven at a temperature of 100° C. to 110° C. (drying methods are described in detail later), allowed to hang 24 hours at least in the open air, so as to regain its natural amount of moisture, and then carefully weighed.

A is also weighed at the same time to ascertain if any allowance must be made for changes of atmospheric conditions.

C is boiled for 15 minutes in solution (*b*) caustic soda, then dried, weighed, and compared with *A*, just as in the case of *B*.

As even dilute caustic soda solutions may remove a small amount of cotton, 5 per cent. is added to the weight of *C* so obtained, and this is then taken as equivalent to the weight of cotton present. The weight of *B* less that of *C* is the weight of the wool; while the weight of *A* less that of *B* is the amount of matter other than fibres, such as dressings, &c., present.

To illustrate the method used in calculating the relative quantities present. Suppose $A =$ 10 grams, $B = 9{\cdot}7$ grams, $C = 4$ grams.

Then 4 grams + 5 per cent. of 4 grams = 4·2 grams is the weight of cotton present. 9·7 less 4·2 = 5·5 grams is the weight of wool present, and 10 less 9·7 = ·3 grams is the amount of impurities. From this we readily obtain the percentage composition, for 4·2 grams of cotton in 10 means 42 per cent., and 5·5 grams of wool in 10 means 55 per cent., leaving 3 per cent. for impurities.

Care must, of course, be taken not to remove any pieces of fabric during any of the washings. Any wringing-out in order to remove excess of water should be done by placing the material in the middle of a clean linen cloth, then twisting the ends of the cloth in opposite directions.

Experiment 16.—In such a fabric as the one described a counter experiment might be tried as follows: Remove the cotton from *B* by boiling it in dilute hydrochloric acid instead of dilute caustic soda, proceeding in every other respect as before, but remembering that *B* less *C* will now represent the weight of cotton present.

The removal of the cotton by this method will be found preferable in the case of any material in which cotton is present in very small quantities.

The material sold as Viyella is very suitable for Experiments 15 and 16. The fabric is made of a mixture of cotton and wool, these fibres being spun up together so as to form a yarn, and then this yarn is used for warp and weft of the cloth. When the wool is dissolved out as in 15, the material will be found to still retain considerable strength. When the cotton is removed, as in 16, the fabric readily breaks up into small pieces. It is also suitable since wool and cotton are present in proportion, 55 : 45 about.

Experiment 17.—Experiment 15 could be tried also to separate cotton from silk, and the relative amounts of each could be determined in a similar manner.

In the above experiments practically only two chemical reagents have been used. The hydrochloric acid as used is a solution of hydrochloric acid gas in water. When the concentrated, or even dilute, solution (if not too dilute) is heated this gas escapes into the surrounding air. If this gas is inhaled in any quantity its effect would be injurious, so some means of getting rid of the gas as given off is necessary. For those who have not a fume cupboard at their disposal it would be advisable to boil this acid only when absolutely necessary, and then only if plenty of fresh air is easily obtained.

In the following pages will be found a number of experiments which may be found useful, and in many cases simple to perform. These are arranged so as to indicate the fibres for which they are suitable.

Cotton.

Experiment 18.—Make a saturated solution of potassium iodide in distilled water, add crystals of iodine to this solution until no more will dissolve; or an excess of crystals may be added and the solution shaken up from time to time. Filter another day so as to remove the iodine which has not dissolved. The *solution of iodine* so obtained is of a dark brown colour. This should be diluted with distilled water until it has a deep sherry-brown colour, and the solution so made should be kept for future use in a well-stoppered bottle.

Mount a small quantity of cotton which has been well soaked in iodine solution in a single drop of concentrated sulphuric acid diluted with an equal quantity of water, taking great care not to allow any acid to touch the objective or stage of the microscope. [A little practice is required in order to get the acid of exactly the right strength. If too strong the fibres are disintegrated, and a diffuse blue colour results; if too weak the blue colour does not appear.] The low power of the microscope will show (*a*) the cell walls swell greatly, become irregular in form, and ultimately lose their sharp outline altogether; (*b*) they assume a blue colour which may be by no means uniform. This reaction forms a trustworthy evidence of the presence of cellulose, which is the chief constituent of cotton (forming about 85 per cent. of its total weight), but cellulose may be present without the colour appearing. If the cotton is examined after being soaked in iodine solution, but without the addition of the acid the fibres will be found to be stained yellow. This also occurs if the acid added is too weak.

Experiment 19.—Chlor-zinc-iodine (Schultze's Solution).—This solution can be obtained, already made up, at a chemist's or from dealers in microscopic materials, but for those who wish to make it for themselves the following instructions will be found useful:—

(*a*) Dissolve 20 grams of zinc in 60 cubic centimetres of concentrated hydrochloric acid;

boil this until it has been reduced one-half in volume. (*b*) Dissolve 2 grams of potassium iodide in as small a quantity of distilled water as possible, and add ·3 grams of iodine. (*c*) Mix the two solutions (*a*) and (*b*).

Mount roughly some cotton fibres in above solution (*c*), and observe the result through the microscope. The cell walls of the cotton are stained to a blue or violet tint, and should any protoplasm be present in the cells this will be stained to a yellow colour.

Experiment 20.—Make up the following solution (often known as Schweitzer's solution): Make a strong solution of copper sulphate crystals in distilled water. Make a dilute solution of caustic soda or potash by dissolving about 1 inch of one of the ordinary sticks in about 100 cubic centimetres of distilled water. Add the dilute caustic soda to the first solution until the light blue precipitate ceases to be formed. Filter so as to remove the light blue substance, which is copper hydrate.

Wash it thoroughly by blowing water on it from the wash-bottle while it is still on the filter-paper.

The light blue copper hydrate should be preserved in a bottle of distilled water, and the

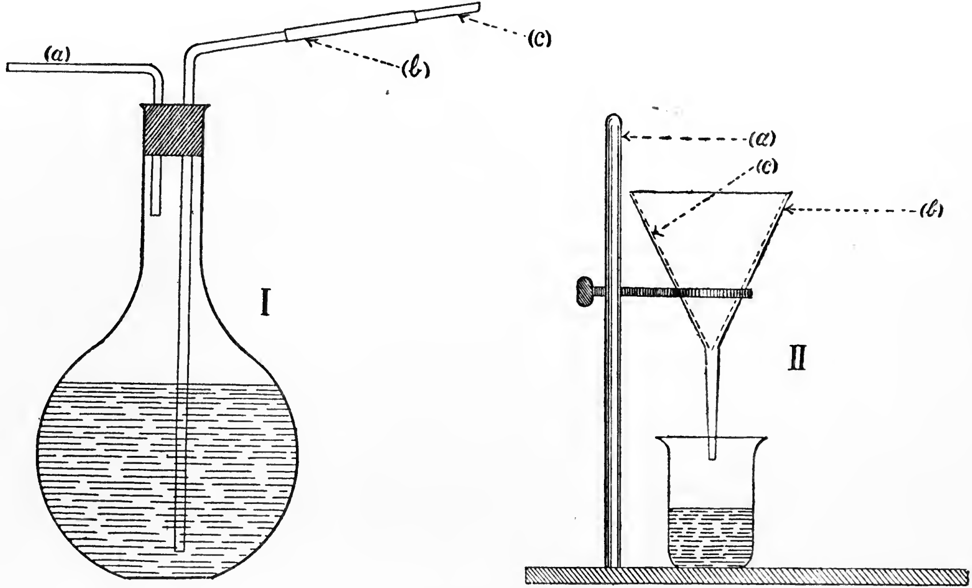


DIAGRAM VII.

(Filter and Wash-bottle.)

I. Flask fitted as *wash-bottle*. (*a*) Tube for blowing air into bottle, (*b*) Rubber tube, (*c*) Tube for escape of water.

II. *Filter stand*, &c. (*a*) Stand, (*b*) Glass funnel, (*c*) Filter-paper.

solution of it should only be prepared when required.

Dissolve some of the copper hydrate in a small quantity of concentrated ammonium hydrate. The solution so formed has a dark blue colour. Mount some cotton-wool in this solution, and observe by means of the microscope the changes which take place in the appearances of the fibres.

The cotton fibre will be seen to become

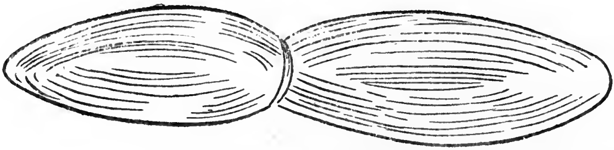


DIAGRAM VIII.

(Cotton acted upon by Schweitzer's Solution.)

constricted in places and to swell out in others, as in the diagram (VIII.).

Ultimately the fibres dissolve. Other interesting changes can also be noted if a little care be taken and the substance is observed continuously for some time. This had better be tried with raw unbleached cotton, as the cuticle of the cotton fibre is often destroyed in the process of bleaching, and then the peculiar appearances cannot be seen.

Experiment 21.—Place some cotton-wool or fabric in a beaker and pour some concentrated sulphuric acid on it. The cotton swells up and becomes a more or less gelatinous mass. Quickly pour this into another beaker containing distilled water, and note the precipitate formed. To this add some iodine solution, and note the blue colour produced.

Experiment 22.—Allow some cotton to remain for a long time in concentrated sulphuric acid. The cotton will be dissolved, for it is converted into dextrin (a kind of sugar). Dilute the solution so obtained by adding distilled water, and then boil it gently for some time. By this means the dextrin is converted into glucose, or grape sugar. If iodine solution is added to the dextrin solution, the colour obtained will be reddish brown, not blue.

It may be noted that dilute mineral acids—*i.e.*, nitric, hydrochloric, and sulphuric—have little or no immediate action on cotton if applied in the cold—*i.e.*, at ordinary temperature. Strong nitric acid entirely decomposes cotton.

The organic acids—oxalic, tartaric, and citric—have no injurious effects upon cotton under ordinary circumstances, but cotton exposed to the vapour of these acids, especially under increased pressure, is liable to lose in strength.

Acetic acid also has no injurious effects.

The alkaline carbonates and milder forms of alkalies, such as soap, borax, &c., have no injurious effects on cotton.

Ammonium hydrate can also be used upon the fibre without fear of injuring it. In the case of the caustic alkalies and lime the effect is somewhat different. These compounds do not injure the fibre at ordinary temperature if free access of air is prevented. In the presence of air and at high temperatures the cellulose of the fibres tends to change to oxidised cellulose, and by so doing its strength is considerably lessened. As there is a tendency for cellulose to be converted into oxycellulose, it can be easily understood that active oxidising agents, such as permanganate of potash, chlorine, and bleaching powder, may, when their action is of a prolonged nature, have a most injurious effect on cotton materials.

Experiment 22.—Make a strong solution of zinc chloride in distilled water, add to the solution a quantity of crystals of iodine.

Place in the cold solution so obtained some ordinary cotton, and also some which has been mercerised. Both will be coloured blue, but if they are well washed the ordinary cotton will soon lose its colour while the mercerised cotton will retain it. This test, combined with the microscopic appearance, can be used as a test for mercerised cottons.

Wool.

While wool can be so easily dissolved by the caustic alkalies, ammonium hydrate and the carbonate of ammonia have practically no injurious effect on the wool fibres.

Experiment 23.—Steep some wool in concentrated sulphuric acid, and note the result. The concentrated mineral acids will completely destroy the wool and ultimately dissolve it.

Should any dilute mineral acids be dropped by accident on woollen clothing, well soak the spot at once with concentrated solution of ammonia and the injurious effects may be annulled, but if concentrated nitric or sulphuric acid is dropped on woollen fabric its action is so very rapid that it is of little use to hope for any success by the above treatment. Still, it is just as well to apply it in order to neutralise the acid and so prevent further damage.

As very incorrect ideas are often met with as to the action of these acids, a word or two here will not be out of place.

Sulphuric acid has a very peculiar affinity for water; which can be proved either by pouring a small quantity of concentrated acid into an equal quantity of distilled water, and noting the great rise in temperature which results, or by leaving some concentrated acid in a marked vessel, exposed to the air, and noting the increase in its volume after a few days' exposure.

Now, substances containing cellulose are mainly composed of carbon, hydrogen, and oxygen, the latter in the same proportion as they occur in the water. When sulphuric acid acts on such substances, it removes the hydrogen and oxygen, and, if the action is complete, will leave just a black mass of carbon, hence the black stain when such acid is dropped on white wood.

Nitric acid, on the other hand, owes its action to its very powerful oxidising powers. As this is the case when concentrated nitric acid acts on material, the fabric is really burned, and so can never be restored; on the other hand, it is not correct to say that sulphuric acid burns the material.

Linen, Flax.

Experiment 24.—Steep some bleached linen in iodine solution. Mount some of its teased-out fibres in one part sulphuric acid and one part distilled water, and examine with the microscope. The thick cell walls of the flax fibre will be coloured blue. If there are any secondary deposits on the insides of the walls of the fibre immediately enclosing the central canal, they will assume a yellow colour. The blue colour proves that the fibre consists mainly of cellulose.

Experiment 25.—Place some linen in Schweitzer's solution, and examine it from time to time. It will take much longer to dissolve the flax than was found to be the case with cotton.

Jute.

Experiment 26.—Steep some bleached jute in a solution of iodine and then mount in sulphuric acid and distilled water, as in 24. The jute fibre will be coloured yellow to brown. This proves that it does not consist of cellulose like the cotton and flax fibres. It is a substance derived from cellulose, which is often known by the name of bastose.

Experiment 27.—Make a solution of bleaching powder in distilled water (containing about 2 per cent. of bleaching powder). Place some jute in this solution. Next steep this jute in a dilute solution of sulphuric acid. After a time wash it in plenty of water, and then in a solution of sodium sulphite. Wash again in plenty of water. The jute has assumed a fine magenta colour, owing to the formation of a coloured compound, by union with the chlorine of the bleaching powder. This makes clear the fact that jute cannot be bleached by using chlorine.

Experiment 28.—Make a strong solution of sulphate of aniline in distilled water. Add a drop or two of sulphuric acid, and test with litmus-paper to see that the solution has an acid reaction (turns neutral litmus red). Place some bleached jute fibres in this, then mount roughly in water, and examine with the microscope. A dark golden-yellow colour will mark the cell walls of the fibre, no other parts will be coloured. This shows the presence of what is known to botanists as lignified tissue.

Some cotton, ramie, and linen might also be steeped in this solution and examined. As these do not contain lignified tissue, no coloration is produced.

Experiment 29.—Place a drop of nitric acid on some jute fibres and wash in water. Note the red stain produced. If this experiment is tried with hemp instead of jute no such reaction occurs, hence this gives a rough method of distinguishing jute from hemp.

Ramie.

This fibre, like flax and cotton, consists mainly of cellulose.

Experiment 30.—Treat fibres of ramie with iodine solution and sulphuric acid, and examine with the microscope. With careful observation the colour of the fibre may be seen to have a reddish tint, but this very quickly gives place to the ordinary blue colour.

Hemp.

Experiment 31.—Try the iodine solution with this fibre. The colour produced will be found to vary from green to shades of yellow.

Experiment 32.—Place some of this fibre in Schweitzer's solution. The hemp swells up but does not dissolve and its colour becomes a tint of blue.

Silk.

Experiment 33.—Make a solution of nickel hydrate in ammonium hydrate. Place some ordinary silk in this solution and boil. The silk will be dissolved.

Experiment 34.—To distinguish silk from wool and cotton. Dissolve 16 grams of copper sulphate (blue vitriol) in 50 cubic centimetres (grams) of distilled water, and then add 10 grams of glycerine. To this solution add a concentrated solution of caustic soda, and continue to add to this until the precipitate which is formed has all dissolved. The solution so formed dissolves silk very readily, but does not affect either wool or cotton.

Experiment 35.—To illustrate the weighting of silks. Make a strong solution of basic ferric sulphate in distilled water. Place some white silk material in this solution and allow it to steep in it for 12–15 hours. Take the silk from the solution, wash it well in water, and wring it so as to remove the excess of iron sulphate. The colour of the silk is now brown. The silk might be weighed before the experiment, then after the experiment dry it and reweigh so as to note the amount of increase in weight.

A piece of silk might be steeped in this solution and allowed to dry without being previously washed. If kept for some time exposed to air and light and then examined, it will be found to be quite rotten. Hence the necessity for thorough washing when ferric salts are used for weighting silks.

Other substances, such as stannic salts, sugar, &c., are also absorbed by the silk fibre, and so can be used for weighting it.

Experiment 36.—Dissolve some zinc chloride in as small an amount of distilled water as possible. Place some silk in this solution. The silk rapidly disappears and a thick, sticky fluid is produced. This fluid can be diluted with water to which a small quantity of hydrochloric acid has been added, without any precipitate forming. (Try this in a small quantity contained in a test-tube.) To the main bulk of the solution add some distilled water; a precipitate is at once formed. When no more precipitate forms filter and well wash the precipitate by blowing water from the wash-bottle on to the filter-paper, while the precipitate is still on it. Place some of the well-washed precipitate in a beaker, add a concentrated solution of ammonium hydrate until it is all dissolved. In the solution so formed steep some cotton or linen fabric and then allow it to dry without washing. A silky covering will appear on the material, for as the ammonium hydrate evaporates the solid silk is deposited on the cloth.

Experiment 37.—Materials of a pale tint can sometimes be tested by their varying affinities for colouring matter. To illustrate this, perform the following experiment on some white or pale mixed fabric:—

First thoroughly wash and rinse in clear water, so as to remove the starch and other similar dressings. Then boil for 10 minutes in a solution of 2 grams of sodium carbonate (washing soda) and a little soap in 100 grams of water. Rinse well after this in hot water. Make a solution containing 2 grams of concentrated sulphuric acid to 98 grams of water, and raise its temperature to just below 60° C. Steep the material in this solution for about 10 minutes, and then wash well in plenty of water.

While this has been proceeding the colour-bath should be prepared by dissolving about half a gram of magenta in about 50 grams of water, heating the solution so formed until it boils. While it is still boiling add caustic soda solution, drop by drop, until the liquid has a pale rose colour.

Stop heating, and place in the prepared sample; after some minutes, take it out and allow it to dry. Silk and wool are dyed, while the cotton present remains almost without colour. The shade of the silk will be slightly deeper than that of the wool.

Experiment 38.—Make a solution of plumbate of soda, and steep in it for a few minutes a piece of material containing both wool and silk and pale in colour. The wool is coloured black, but the silk remains unchanged. This experiment depends, of course, on the sulphur contained by the wool.

Experiment 39.—Dissolve some silk in boiling Schweitzer's solution (boil 10 to 15 minutes). Quickly neutralise the solution by adding nitric acid until a litmus-paper, when in the solution, just turns red. No precipitate will be formed if silk alone is present. If the experiment is repeated, using cotton instead of silk, a precipitate will be formed when the solution is rendered neutral.

Experiment 40.—To illustrate the separation of silk, wool, and vegetable fibres in a mixed fabric. Cut four pieces, *A*, *B*, *C*, and *D*, each 2 grams in weight.

Place *A* on one side for future reference. Boil *B*, *C*, and *D* for 15 minutes in a 3 per cent. solution of hydrochloric acid. If the solution at the end of this time is deeply coloured, repeat with a fresh solution. *B*, *C*, and *D* are then well washed in plenty of water and wrung out.

In this process most of the dye, and practically all the dressings, &c., have been removed. *B* is then placed on one side.

C and *D* are next immersed for one or two minutes in a strong solution of zinc chloride (see Experiment 36), and the material is allowed to drain. They are then well washed in water containing a very small quantity of hydrochloric acid, and afterwards in pure water. After each operation the material is carefully wrung out in linen, as previously described. By this means the silk is completely removed. *C* is then placed on one side. *D* is next gently boiled for 15 minutes in a dilute solution (*b*) of caustic soda, and then well washed. By this means all the wool has been removed, so that *D* now contains only vegetable fibres.

A, *B*, *C*, and *D* are then all immersed in distilled water for a few minutes, dried in the hot-air oven, and then left exposed to the open air for 12 to 24 hours.

A should then weigh 2 grams (any increase or decrease up to 5 or 6 milligrams may be neglected).

A less *B* is the weight of dressings, dyes, &c.

B less *C* is the weight of the silk.

C less [$D+5$ per cent. of *D*] is the weight of the wool.

While *D* plus 5 per cent. of *D* is the weight of the vegetable fibres.

Other Useful Experiments.

To Ascertain the Amount of Moisture which a Fabric contains.—In order to do this an oven of some kind is necessary. For quick work an ordinary hot-air oven will be found very useful, and a means should be found of keeping its temperature between 100° C. and 110° C. As the metal bottom of the oven is almost sure to be at a higher temperature than the contained air, the beaker or other vessel containing the material to be dried should be placed on a small stand made of a material which is a bad conductor of heat (another beaker inverted will do), the height being arranged as in diagram, so that the material to be dried is in the centre of the oven, and the thermometer, which should register up to 200° C., should be placed as shown. A very useful oven can be made out of a good-sized biscuit-tin; a hole as large as a halfpenny can be cut in the lid, and a cork for thermometer fitted to this hole. A second hole may be cut in the lid to allow the vapours to escape. The above arrangement will then be found useful. In ordinary

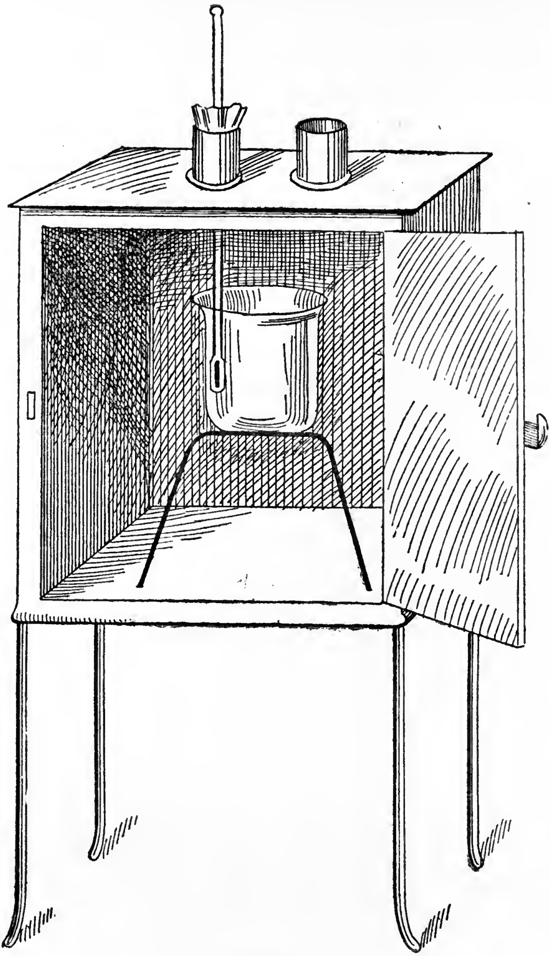


Diagram IX.

Hot-air Drying Oven, showing arrangement of beaker and thermometer.

drying ovens a shelf on which to stand the material is usually provided.

Weigh carefully two pieces of the material to be tested; let each be 10 grams. Place one piece on the right-hand pan of the balance in a beaker, and place the other piece in the oven in a beaker of exactly the same size as the first.

It is difficult to obtain two beakers of exactly the same weight, but a counterpoise can easily be effected.

Raise the temperature of the oven to 100° to 110° C., and allow the material to remain in the oven at that temperature for 3 or 4 hours. Place the beaker and material on the left-hand pan of the balance, and add weights to this pan until the balance is again restored.

Heat in the oven again for 15 minutes, again weigh and add more weights if necessary. Again heat for 15 minutes. Continue this process until two consecutive weighings give the same result; it may then be taken that no more moisture can be driven out of the material at that temperature.

Suppose at the end of the experiment the dried material requires 1·7 grams in order to make it balance with the other piece, then clearly, since 10 grams contained 1·7 grams of water, there must be $10 \times 1{\cdot}7 = 17$ per cent. of moisture present in the material.

Since dry material very readily absorbs moisture from the surrounding air, all weighings must be performed as quickly as possible. The method here given is, of course, only a very rough one, but with care very fair results may be so obtained.

In this connection it might be found of use to have a short account of the normal amount of moisture present in the various fibres.

Cotton usually contains about 8 per cent. of moisture, although normally it contains $6\frac{3}{4}$ per cent. The 1 or 2 per cent. in addition to the $6\frac{3}{4}$ can easily be got rid of by raising its temperature to about 25° C. The cotton will not absorb this extra moisture again under ordinary atmospheric conditions. Air-dried linen contains from 6 to 8 per cent. of moisture.

Wool contains a natural moisture amounting to as much as $18\frac{1}{4}$ per cent.

Silk, of all the fibres used in textiles, has the greatest capacity for absorbing moisture, this material being able to absorb from 25 to 30 per cent. of its weight of water without feeling damp. Normally, however, silk only contains from 11 to 13 per cent., and it is usually bought on a basis of 11 per cent. moisture.

One of the great uses of Conditioning Houses will be apparent if these facts are carefully considered.

It is usual to find the weight of the material in a state of absolute dryness, and then to allow a certain percentage of "regain," as it is called, in addition to this dry weight.

The following table contains the facts for the principal fibres.

Material.	Regain Allowed.	Loss of Weight from Normal Condition.	
Wool Scoured	16 per cent.	13·8 per cent.	These are approximate values, the second decimal being omitted.
,, Tops in Oil	19 ,,	16·0 ,,	
,, Dry Tops	18¼ ,,	15·4 ,,	
,, Noils	14 ,,	12·3 ,,	
,, Yarns	18¼ ,,	15·4 ,,	
Silk	11 ,,	9·9 ,,	
Cotton	8½ ,,	7·8 ,,	
Flax	12 ,,	10·7 ,,	
Jute	13¾ ,,	12·1 ,,	
Hemp	12 ,,	10·7 ,,	

Effect of Heat upon Fabrics.

These experiments can be tried by placing the material in a large-sized test-tube (boiling tube), and then placing the test-tube in a beaker containing concentrated sulphuric acid, which liquid has a very much higher boiling-point than water.

The bulb of a thermometer, made so as to register up to 300° C., can be placed either in the test-tube with the material or in the acid itself.

The temperature is gently raised by heating with a spirit lamp, the beaker and its contents being placed on some wire gauze over the flame.

When cotton is placed in the test-tube it will be seen that the fibres become somewhat plastic at temperature 110° C. If the temperature be very slowly raised, the cotton turns brown at about 230° C.

If wool be next tried, it will be found to be more plastic than cotton at 110° C., and as the temperature approaches 130° C. the wool quickly decomposes—a fact which may be readily recognised by the peculiar smell due to the ammonia gas which is given off.

At still higher temperatures (140°–150° C.) the vapours given off will contain sulphur also.

Silk will be found to be more or less plastic at 110° C.

The Amount of Ash which Pure Material should Yield.

This is a very important point, especially where silks are concerned, so a simple method of ascertaining the quantity of ash will be briefly described.

For this purpose a porcelain crucible with a lid will be required. The crucible is weighed, and a good quantity of material (20–25 grams) is placed in the crucible. It is then heated in a good Bunsen flame, and when most of the smoke due to the burning material has disappeared, place the lid on the crucible by means of a pair of crucible tongs. It may be necessary to direct the flame into the crucible, but great care must be taken that no small pieces are thus blown away. Continue the heating until it is found that the smoke, &c., cease to escape, or better still, until after cooling and weighing, then reheating and again weighing; it is found that two successive weights agree. It is advisable to use a blow-pipe for this work, as otherwise it is hardly possible in a reasonable time to get rid of all the combustible material. (The cooling should be performed in a desiccator if possible.) The ultimate weight of the crucible and its contents above that of the crucible is the amount of ash. Since this is produced from 25 grams of material, the quantity per cent. can be obtained simply by multiplying the difference by 4.

The following facts may be found useful :—

Good American and Egyptian cottons yield only about 1 per cent. ash.

Indian cottons may yield up to 3 or 4 per cent.

Clean wool yields only 1 per cent., and three-fourths of that is soluble in water. Ordinary pure silk yields 1 per cent. or even less, but Tussore silks may yield as much as 5 per cent.

From 1 to 5 per cent. may be taken to indicate in the case of silk the use of mordants in the dyeing process, while anything in excess of 5 per cent. may be looked upon as due to weightings.

Tests by Burning.

A very simple method of discriminating between cotton and animal fibres is by applying a match to the material.

Cotton will burn up very quickly with a flash, and will leave only a very small amount of ash, while the animal fibres, wools and silk, will give out a very disagreeable smell, and will not readily burn, but will form into little black knobs.

It must, however, be remembered that this only applies to those silks which are practically free from weighting material. When a heavily weighted silk is ignited, instead of forming itself into small black knobs, it burns, leaving a distinct ash, which retains somewhat the shape of the original silk.

In this it resembles artificial silk, which always leaves an ash of the same shape as the fibre.

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