TEXTILES

A · HANDBOOK · FOR THE · STUDENT · AND · THE · CONSUMER ·

WOOLMAN AND McGOWAN

TEXTILES

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TEXTILES

A HANDBOOK FOR THE STUDENT AND THE CONSUMER

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PREFACE

This book is the result of twenty years' experience in teaching textiles to college students. It is intended as a textbook for college classes or for study clubs and as a guide for the housekeeper or individual consumer of textiles and clothing, the teacher, the club woman, the saleswoman, and as an introductory survey of the subject for the student who contemplates professional work in the textile industries.

The growing emphasis upon textile study in college departments of home economics or household arts, and the increasing use of the textile industry as teaching material in other departments and other grades of schools, shows a recognition of the part that the textiles are playing in the development of civilization and in our everyday life. Interest in the subject is still further accentuated by the movements now on foot to regulate the social-economic conditions in the textile and clothing industries and to secure standardization and honest labeling of textile products, as is being done for food products by the "pure food laws."

To meet the existing need the authors have attempted to prepare a text suitable for use in college classes or by the public, shorter and more readable than the technical handbooks, yet sufficiently thorough and comprehensive to give a sound grasp of the subject as a whole with so much of the technology as is directly helpful to the consumer and as should be included in general courses in colleges and technical or vocational schools.

This has been a difficult task and could scarcely have been brought to a successful conclusion without the coöperation of the experts who have guided the authors, read the manuscript, and suggested ways of dealing with certain intricate and changing processes so as to make the book scientifically and technically accurate while non-technical in form.

With full appreciation of the time this service has taken in the busy lives of the experts, the authors express a debt of gratitude to Mr. William B. Sleeper, Mr. James Chittick, Mr. Theodor Quasebart, Mr. Gordon Donald, Mr. Franklin W. D'Olier, Mr. George F. Smith, and Professor H. T. Vulté of Columbia University, who have read the technical chapters of the book, and to Dr. Susan B. Kingsbury and Dr. Benjamin R. Andrews, who have read the social-economic parts. They also wish to thank the manufacturers who have allowed the use of photographs and cuts of machines and also the authors and publishers who were willing to allow the reproduction of pictures from their printed works.

June 10, 1913.

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TEXTILES: A HANDBOOK FOR THE STUDENT AND THE CONSUMER

CHAPTER I

BEGINNING OF THE TEXTILE INDUSTRY

The building up of the textile industries has been one of the greatest factors in civilization. The object of this chapter is to present the principles of textile manufacture as they existed in their simplest form, before they were obscured by the elaborate parts and adjustments of modern machinery. Modern woman owes a debt to primitive woman, for until machinery was invented she held, in truth, the textile industries in her hand. She was the original inventor and workman. In the earliest times she bent her whole mind to improving the conditions immediately around her. Her work had to do with shelter, clothing, food, and the growing of simple things. She had to gather as well as to manufacture. If she could not find what she wanted, she tried something else, using everything around her which her strong fingers, her sharp teeth, or her rude tools could render available.

Primitive Conditions. — To consider the development of industry in primitive communities is the best way to understand the reasons for some of the present industrial, social, and economic conditions. The need of food, clothing, and shelter caused the early inhabitants of the earth to use the materials spread about them by nature to supply their wants. They were at a great disadvantage in their struggle, for they had not the strength of the animals, nor had they weapons for defense or for obtaining food. They had to fight with nature for life itself, but the results show that they were able to think and act, for they made progress toward control of their environment, and their labors and inventions made the modern world. The sharp stones at their feet were fastened to handles of wood or bone by the aid of rushes or strips of skin, and used for weapons. Branches of trees were interlaced to form carriers, to cover the wet or rough floors of rocky caves, to make a shelter above the entrance, or a defense outside of it. The skins of slain animals were used for many purposes, being laid on top of interwoven branches to form a shelter, thrown on the floor, worn upon the body, or dried, cut into strips by sharp stones, and used for binders and for decorations. Thorns, bones, and twigs served for pins or fasteners of the rude skin cloaks. Sinews, rushes, barks, grasses, reeds, quills, rawhide, and vines were useful for twines, ropes, and handles. Birds' nests, spiders' webs, and other animal industries offered suggestions for using nature's materials at hand. The gourds, the covering of some varieties of palm buds, the cocoanut, and the barks of cedar and other trees were ready for immediate use. Adaptations and changes were made, which opened the way to greater inventions.

Mats for various purposes were made at an early period by tying, twining, twisting, knotting, and interlacing grasses, rushes, twigs, sinews, strips of skin, and fibers of plants when soft material was needed, or split canes, vines, willow, and other branches when rigid forms were desired. Two kinds of materials were often combined in such articles as carriers or baskets. Nets for fishing or for carrying burdens, and traps for catching fish or game, were made in a similar way. Crude attempts at decoration show the birth of design and the instinct for beauty. Mats were woven showing variations of color in design from the turning over of rushes. Fringes of rushes, grasses, and shells were common, and later were used for clothing. A network of knotted grasses added to the attraction as well as to the comfort of the garment. Such grass garments are still worn in the East.

The skins of animals were worn with the fur inside to make them comfortable. The felting of the wool of sheep as it touched the body led the way to the making of felt for clothing. The dried skin was later tanned to lessen its roughness. In some warm countries the soft, juicy inner bark of special trees was pounded into a flexible mass, soaked in water to ferment, and beaten again with mallets and rollers carved to give special effects. Patterns were made on these bark clothes in various ways, leaves and flowers wet with dye being sometimes laid on and pressed down. Bark material is still made. It is supposed to have been a forerunner of felted cloth. The cloth was beaten into large sheets, one being welded to the other, and was varnished with oil to render it waterproof.

Basketry was at first very simple, being made with splints, but it soon developed patterns in diagonals and diapers. The alternation of rigid with pliable materials gave a wide scope for design, and the twined and sewed basketry of some primitive people was an art (Fig. 1). Basketry and weaving have much in common, and improvements in one helped the other. Pottery soon developed, probably from the habit of lining baskets with clay in order to hold water. Some of the most primitive pottery shows the form of the weaving of the basket on the clay. (See Fig. 30.)

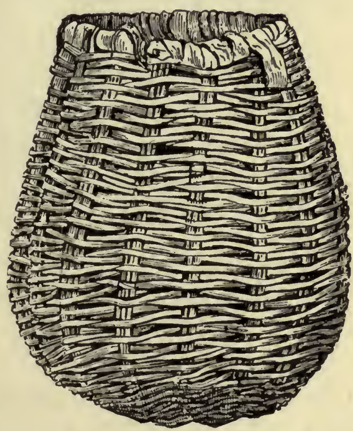


FIG. 1. — WICKERWORK BASKET.

The men were occupied in food getting, in fishing, hunting, and in war, while the women were working at the camp. The discovery of the use of fire tended toward further division of man's and woman's work, for she was the caretaker of the children, and naturally stayed by the fire. As the early people were wanderers, they needed carriers for transporting their young children and their household goods, and mats and baskets served many useful purposes in the life on the march, as well as in the tree, cave, or shelter homes. Inventions were adapted to numerous purposes; for example, a method of holding rigid material by softer fibers twined about it, now called wattling (Fig. 2), was used for shelters by fastening several heavy sticks together in a point, with their loose ends stuck into the earth, laying grass and rushes on top, and holding down this covering by laying sticks at intervals across the grass and rushes, and tying them down by intertwining pliable material around the sticks; for defenses, by holding together the great stakes used for stockades around primitive huts; for early weaving of soft materials, or for very coarse basketry, as well as the fine basket weaving of the Pacific Coast of the United States. Wattling is really a form of weaving. Such a principle once grasped by these awakening minds became a means of development as the environment offered new materials for use, and the many needs gave an impetus.

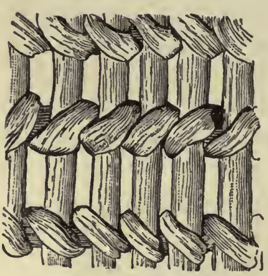


FIG. 2. — WATTLING.

The earliest beginning of the race has well been called the "Age of Fear," for man was afraid of his fellow, afraid of the animals, and afraid of nature. The individual was at first sufficient unto himself; there was little interdependence among the members of families. As family life increased, there arose a tendency to form into small groups. By degrees they entered into alliances with other nomads, thereby increasing their safety and bringing knowledge of new methods of fishing, hunting, and living. These social interrelations tended to decrease fear and to develop industries, for some families had made more progress in the crafts than others, and added comfort and beauty were found to come through new devices. Gradually those who excelled in textile work began to attain prominence, as did the great warrior or the great hunter.

Era of Hunting and Fishing. — During this time many crafts originated and devices to assist labor were invented. Work in metal had begun and was used to improve the textile tools. Although women did some planting, the homes were moved too

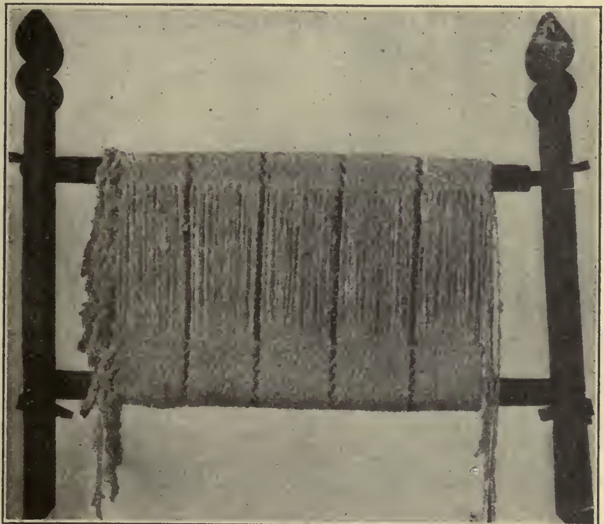


FIG. 3.—A PRIMITIVE TYPE OF LOOM.

frequently for the maintenance of a settled agriculture. There was little trade between people, and little providence for the future in storing food or in making covering, for all extras impeded travel.

During this wandering life the important industries passed their simplest form. Weaving was now done on looms, which were nothing more than two heavy sticks between which rushes were stretched so that the latter were held taut, while the weaver wove other rushes across these threads (Fig. 3). The value of fibers taken from the plants and the coats of animals had been discovered, and crude forms of spindles and distaffs aided in the spinning of yarn. At first, hair, hemp, leaf fibers, strips of fur and sinews were in use, but when it was found that short fibers, such as wool and cotton, could be prepared and twisted continuously around each other, a great step was taken toward weaving (Fig. 4). The first woven articles were more for floor or house covering than for clothing. The advantage of the softer materials for carriers and coverings was soon felt, consequently softer fibers were in demand. Coarse handlike wood contrivances (See Fig. 18) aided in the opening (carding) of the wool or other fibers, so that they could be twisted more easily into yarn. Weaving which combined pattern with color gave results of interest and even beauty, increased by knowledge of dyeing, staining, and painting by the use of crushed berries and roots. Climate, of necessity, had its effect. Tropical regions gave fine, soft fibers which made exquisite weaving possible, while cold countries offered skins and coats of animals to be used for similar purposes. The ease of life in the tropics tended to idleness, but colder climates made it necessary to struggle continually to obtain the necessaries of life. It is in temperate parts that we must look for the greatest industrial inventions and improvement in living.

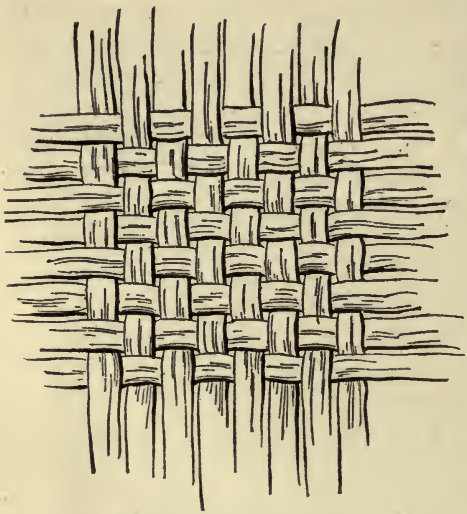


FIG. 4.—PLAIN WEAVING.

Some form of sewing was used in various developing industries, as in basketry. The thorns and bones used for fastening were now made into needles, with an eye to hold the twisted yarn. The bone needle, stiletto, and awl were treasured utensils (Fig. 5).

The increasing knowledge of animals and of means of trapping them led to domestication of the less savage species.

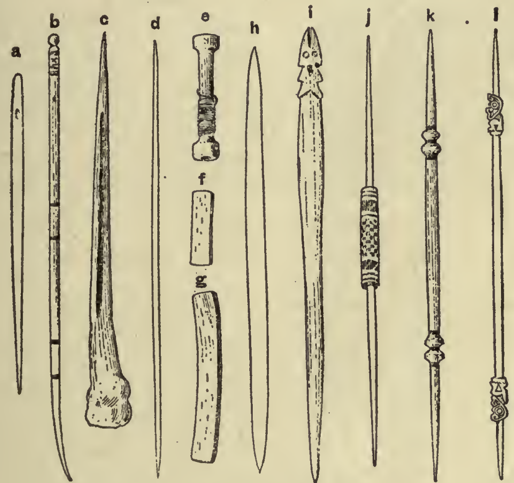


FIG. 5.—PRIMITIVE IMPLEMENTS.

a, *b*, needles; *c*, bone awl; *d*, needle pointed at both ends; *e*, wooden spool; *f*, netting mesh; *g*, weaving band; *h*, shuttle-like piece of wood; *i*, netting or weaving instrument; *j*, *k*, *l*, spindles.

The effect of the keeping of such domestic animals on problems of food, shelter, and clothing was very great. More permanent homes were established for the women, children, and the less able, while the strong men went out with the flocks and herds, returning at intervals. A pastoral life took the place of the wild and uncertain life of the chase. Care of animals developed a different and less savage temper. Warlike instincts were less constant. Peace between neighboring families increased, and ceremonies showing the pact between them were held around mounds of stone, which became the center of life and government.

The Navajo Indians are present examples of this pastoral life. They settle on land good for grazing, their property being chiefly flocks of sheep and goats, and herds of horses. The flocks give them food, and wool for their rugs, blankets, and lariats. They do some planting, but are not agriculturists.

During the Pastoral Age the industries developed rapidly in spite of the semi-nomadic life. The more stationary home life gave an incentive to the making of rugs, hangings, and clothing, which were often rich and beautiful. The uniting of many families under one leader stimulated the desire to excel, and specialization in some particular textile craft was not uncommon. The wish for social approval led to the adornment of the person, and clothing became more decorative in character. It had been adopted originally to show prowess or to frighten enemies, by displaying the skins of animals slain by the wearer, or by strings of teeth or scalps worn around the body. This custom led to the use of cloth for ornament. A feeling of shame for not wearing clothes came only after dress had become customary. Hats, which at first were inverted baskets, were now made especially for the head covering. The demand for material made from spun wool or cotton increased with the demand for clothing. Dress now became a means not only of comfort or of decoration, but to show the distinction of sex or of classes. Among the Navajo Indians the chief's blanket has its special design and colors, and the dress of the young unmarried women is different from that of the married ones. Special costume was used for the medicine men and warriors, and for ceremonials. The use of dress for social distinction has always characterized developing people. The Middle Ages perhaps saw its height, but although moderated, it is still a part of modern civilization, though now more practiced by women than by men. The demand for fabrics of rare design gave great impetus to the art of weaving (Fig. 6). Tribes began to look to each other for exchange of products, and so tended to assume more peaceful relations.

By the close of the pastoral and the beginning of the agricultural era, many textile industries had passed their primitive

FIG. 6.—PUEBLO WOMAN WEAVING.

From Watson's *Textiles and Clothing*, by courtesy of the American School of Home Economics.

stages. Devices and even rude machinery to assist the hand were common. Beauty of design and skillful handling are evident from examples preserved in the museums. The most common of the textile crafts in use were:—

Braiding and looping.
Tying, wattling, and thatching.
Netting for fish nets, carriers, and clothing.
Weaving for shelters, mats, rugs, hangings, and garments.
Basketry, both woven and sewed, made into carriers, hats, traps, and household articles.
Knitting and crocheting.
Carding and spinning.
Reeling.
Needlework in sewing, embroidery, appliqué, repairing, box making, and clothing.
Lace making, by sewing, weaving, and knitting.
Skin drying and curing.
Dyeing and staining.
Decoration in bead work, stenciling, block printing, and picture writing.
Felting and beating.
Making tools for use in the various crafts.
Loom building.

Agricultural Life. — The time when agriculture became the chief occupation marked an important stage in industrial life. The childhood of the race had passed, but was recalled in its emotional and recreational life. The people now lived in permanent homes and life had become duller on account of its round of constantly repeated occupations. Festivals, dramatic representations, folk tales, dances, songs, and religious ceremonies were instituted. Events in the former primitive life and the all-important industrial processes, such as spinning and weaving, became motives for these performances. Incantations and charms were used to assist young girls in learning to weave. Interest was taken in cultivating textile plants, such as flax and cotton. Sheep were raised in order to provide wool for spinning. Private ownership and a sedentary life increased the demand for household goods. Two classes of textile industries began to be developed, the extractive and the productive. The people gathered together in groups, moved by the impulse toward sociability and the need for mutual help. New social and political relations arose between them, which required the establishment of forms of government. Slaves taken in the frequent wars were made to perform domestic services, hence a new class of industrial worker was available, who did not belong in the home and was considered inferior. A feeling of caste was more apparent, and dress was used to indicate varying conditions of life. The people built their own homes and provided for their wants with occasional help from neighbors. The exchange of a few commodities was the only business relation. Industrial towns developed as trade centers, and additional workers had to be employed in the home workrooms to increase the output. The women were factors in this industrial change, for spinning, weaving, and bleaching were still home occupations.

The Household System. — Entire families soon began to devote themselves to special industries in order to sell to others or to exchange, and many households became economic centers.

This era was in progress in Bible times. In Proverbs 31, the mother of King Lemuel speaks of the work of women in the households as comprising both home use and sale: —

> "She seeketh wool and flax and worketh willingly with her hands."
> "She perceiveth that her merchandise is good."
> "She layeth her hands to the spindle and her hands hold the distaff."
> "She is not afraid of the snow for her household, for all her household are clothed in double garments."
> "She maketh fine linen and selleth it and delivereth fine girdles unto the merchant."

The employer and helpers worked together in the home factories, each owning his own tools. Apprentices learned the whole process and were therefore fair judges of the output as well as workers on it. Great fairs occurred at intervals at which the industrial products of the household were sold outright or exchanged for farm products. Trade difficulties soon made a middleman necessary to collect the goods, sell, and exchange. The demand for bedding, for blankets, heavy serge curtains, flannels, household linens, and homespun materials increased the number of textile workrooms where both men and women worked together. Wherever industries were numerous, great towns began to develop. It was customary for workers to gather around the home of some influential man, giving their services in return for his protection, but the downfall of the feudal system at the end of the fifteenth century cast them adrift and they increased the number of those working in the commerce or industry of the towns. Markets were opened for selling goods, and guilds for both the merchant and the craft worker were organized to help standardize the work, to better conditions, and to give good goods at honest prices. The textile guilds became very influential and did much to organize trade and to train the workers. However, the passing away of the guild system in the seventeenth century deprived the workers of a central body which was responsible for the coördination of capital and labor, and which understood the relation of laborers to each other. There was not at the time any clearly defined division between the capitalists and the working classes, and much of the textile work was still done in the home workroom.

America was colonized about the time of the decline of the guilds, and its industrial life was characteristic of this era of home workshops. The life of the colonists was on the farm. Each home was a self-sufficient unit, and consequently a center of varied occupations. The mother directed the work of her daughters and also paid for such additional help as she could obtain from the neighborhood. The farm occupations were numerous and were in the stage in which homemade machinery and devices were used by the worker. The textile activities

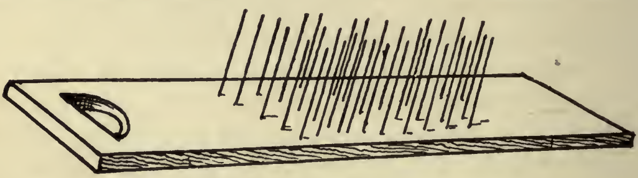


FIG. 7.— FLAX HETCHEL.

in each colonial household were principally carried on by the women. They consisted of carding of wool; breaking, hetcheling, and swingling of flax; wool and flax spinning; winding, reeling, and warping; the weaving of cloth, blankets, and rag carpets; the bleaching of cloth and yarns; sewing; quilting; dress and garment making; embroidery and lace making. The devices and machines used for this work were the cards, hetchels (Fig. 7), flax breaks, the great or wool wheel, the flax wheel, winders, reels (clock and hand), niddy noddy, quill winder, swifts (Fig. 8), warping bars or warping drum, skarne, bobbin frame or creel (Fig. 9), bobbins of many kinds, healds and shafts, the raddle, and the loom. The fathers and sons assisted in the textile work by growing and preparing the fibers and making the machinery and tools. Some small factories run by water power were established in the late eighteenth century.

The Industrial Revolution. — The inventions of Hargreaves, Arkwright, Crompton, and Cartwright brought the modern factory system and with it a new industrial era. Power was now needed to move the spinning frames and looms. Horse and water power were soon succeeded by steam. The markets were extended, for this same steam power made transportation

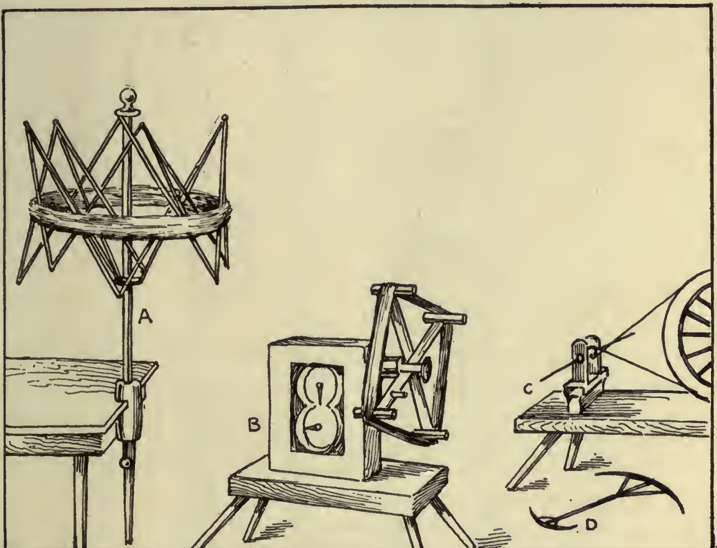


FIG. 8.—*A*, Swift; *B*, Clock Reel; *C*, Quill or Plug Winder; *D*, Niddy Noddy.

easier. An impetus toward increasing the output came as a result of the possibility of selling outside of the environment. Workers of both sexes turned toward the textile factories, for the expense of power had driven the work out of the home workshops into especially constructed and equipped buildings. The isolated workers could not compete with the machines. Capital for the industries was provided by men of means who, unlike the heads of the domestic workrooms, were not of necessity textile workers themselves. They controlled the situation, but often knew little of the condition of workers. Questions of the division of profit between capital and labor began to cause irritation. Competition arose between factories and the sub-

FIG. 9.—BOBBIN FRAME.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

division of industry followed as a means of increasing the output through rapidity of work. The worker, therefore, soon lost his individuality and likewise his interest in the perfection of the product. The capitalist increased in wealth, but low wages and poor living were prevalent among the lower class of workers.

A powerful mercantile class began to have voice in national affairs. The economic situation became acute, but gradually from it there developed a new social conscience in all classes, and laws were enacted which aimed to improve working conditions, to limit working hours, to regulate the work of women and children, to prevent industrial accidents or to compensate for them, to improve housing conditions and the sanitation of workrooms. Leagues and societies of workers and employers were organized and are still at work adjusting these conditions.

The industrial revolution is responsible for bringing about great changes for women; for as their home workrooms were taken away and the manufacture of textiles was conducted elsewhere, the women were no longer important economic producers. With this change their knowledge and ability to judge of the content and value of materials passed also. Those who had to labor became part of the huge subdivided activities in the factories and knew only the small part on which they worked. Those who remained at home were entirely removed from participation in the work of making cloth or even knowledge of the methods. The desire for cheap yet pretentious fabrics and the cost and difficulties in manufacturing reliable ones have brought into the market a large supply of untrustworthy and often adulterated materials to satisfy the demand.

CHAPTER II

SPINNING

Carding and Spinning by Hand. — Spinning is the twisting of a succession of fibers into a continuous cord, rope, or yarn. It was one of the earliest industries of the human race, and the necessary opening of the fibers, which were often matted and rough, to make them twist more smoothly, was the beginning of carding. It is supposed that both processes began about the same time. The need of some form of binding twine, and later of mats and shelters, led to the use of rushes, strips of skin, the hair and sinews of animals, the bark of trees, the fibers of the agave and of other plants. These fibers were limited in length, and had to be knotted or twisted together to serve the purpose required. They were not spun. It was later discovered that some fibers lent themselves to continuous twisting. Wool spinning may have been the earliest, for wool was accessible and easily twisted on account of its natural oil and crimp. Flax (linen), though difficult to prepare, was in use even before the age of metals, for the yarn has been found in hanks and also in cloth in the ruins of early dwellings now covered with the mud of some of the Swiss lakes. Pictures on Egyptian tombs show the processes of flax preparation as conducted there at an early age. Cotton was used in India, and the laws of Manu, 1000 B.C., give regulations concerning its manufacture, seriously objecting to the heavy sizing of the yarn, showing that spinning was an old industry at that time. In South America at a very early period cotton was spun into fine yarns and woven into cloths of great beauty. Silk, too, was taken from the cocoons, slightly twisted, and woven into cloth in China and Japan at the dawn of their history.

Early spinning was done by the fingers alone, the fibers being held in the left hand and twisted with the right (Fig. 10). It

FIG. 10.—SPINNING WITH DISTAFF AND SPINDLE.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

is a very simple process. Even a little twist greatly strengthens the fibers. The spinner drew from prepared (carded) fibers, such as cotton or wool, a number of parallel threads and twisted them as they came, making a continuous piece. It took a little practice to make a firm, even yarn. As the fibers thus spun untwist very quickly unless held by some artificial means, the discoverer probably wound the product on a stick, later fastening the end of the yarn in a natural or manufactured cleft, or holding it by a half hitch around the stick. It was seen that if the stick or spindle on which the spun fiber was wound and caught slipped from the hand while the spinner was twisting in another length, it would revolve rapidly in the other direction and untwist the length of yarn. Experiment would show that by giving the spindle a sharp twirl as it descended, carrying the length of yarn, a twist might be put in during the time the revolutions continued. A spindle on which a quantity of spun yarn was wound would be found to revolve more smoothly and draw out the fibers better than one which had no yarn on it; this suggested the placing of a weight on the spindle. A lump of mud or clay, a stone or a piece of wood were early added to the spindle to assist the revolutions. It also kept the yarn from slipping off the spindle. Such weights, called whorls (See Fig. 5, *j*.), were often molded, carved, or painted attractively.

Good spinning required careful carding of the fibers. Some means other than the hand of holding these opened-up fibers was necessary in order to keep them in good condition. At first a simple stick was used, at one end of which the carded mass was placed, lightly tied around with a piece of yarn to keep it smooth. This stick was called the distaff. It was held under the left arm or in the belt, or it was thrust into the ground beside the spinner. In Germany it was called the rock (Fig. 11), and was placed on a block to hold it erect, while the spinner stood or sat near by. In parts of the Continent spinning with the distaff and spindle can still be seen. The spinner draws out a number of fibers from the under side of the carded material next to the distaff, twists them, and fastens them to the end of the spindle. With the right hand she gives a sharp twist to the spindle; in the meanwhile, she continues to draw out a number of fibers with her left hand to supply the descending spindle. When the spindle reaches the ground, she picks it up, winds on it the length of thread just spun, and catches the end in the cleft (Fig. 12). Spindles were made of wood, bone, and metal. They were usually from ten to twelve inches in length, while the distaff was from twelve to thirty-six inches in length.

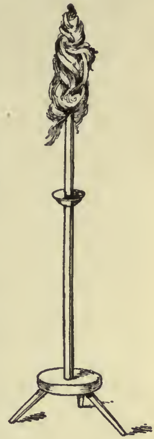


Fig. 11. — Rock.

Spinning is found among all primitive people, and although it differs in method, the underlying principles are the same, *i.e.*, drawing out the fibers, twisting them, and winding them up. Rope making was similar to spinning. The worker held the raw material, such as hemp or flax, in the hand or apron, and after attaching some of the fibers to a revolving device, walked backward, letting out the material. It was thus drawn and twisted. The required length of rope was made by extending the twisting for a hundred or more feet and then returning, to allow it to be wound. The single ropes thus made were united in threes, making a heavier rope. Ropewalks across fields are still found in Europe. In India we find a method of spinning the finest grades of cotton yarn by revolving a thin piece of bamboo in a cup of cocoanut shell. The fineness of the yarn to be used for Dacca muslin has never been surpassed by machinery. A simple method of spinning coarse yarn for hammocks

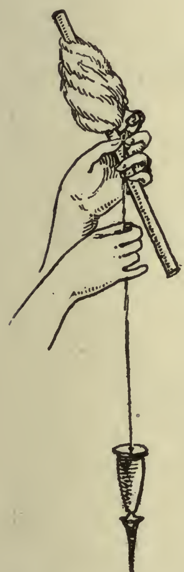


Fig. 12. — Hand in Action.

Fig. 13.— Navajo Woman Spinning.

or twine was found in New Guinea. The worker laid a bundle of fibers on the left knee, pulled some threads from it with the right hand, twisted them, and rolled them into a ball on the right knee. Another method of spinning was to tie fibers to a stone and revolve the stone. The Navajo Indian women of New Mexico and Arizona have for a spindle a slender stick of wood with a circular disk or whorl at the end of it. The woman sits on the ground with her slivers of carded wool beside her, holds the spindle with her right hand, and puts the point of the spindle on the ground with the whorl just above it. She lays the long end of the spindle against her knee, attaches the end of a sliver close to the disk, holds it out and draws it away so that it grows thinner and is twisted as she twirls the spindle. When a length of yarn is sufficiently attenuated and spun, she winds it on the spindle. This process is repeated until the spindle is full (Fig. 13). The first yarn spun is soft and only slightly twisted, consequently the process is repeated several times until it is strong enough, especially for the warp threads.

Spinning by Wheels. — Between the fourteenth and sixteenth centuries spinning wheels began to take the place of the distaff and spindle. The latter method had supplied the yarn from the dawn of history until the Middle Ages. Fabrics in museums testify to the skill, patience, and instinct for beauty in the women of the past. The process was, however, so slow that a more rapid method was necessary to increase the supply of yarn. India at a very early period invented a method of spinning by attaching a wheel to the spindle by means of a band, causing the latter to rotate. It was called the Gharka or teakwood wheel (Fig. 14).

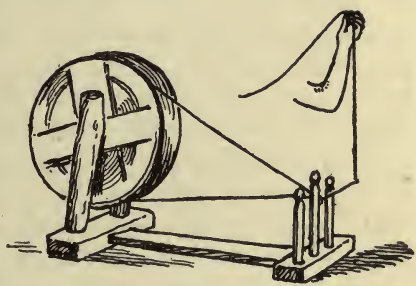


Fig. 14.—The Gharka Wheel.

The spinner sat on the ground beside the wheel and supplied the spindle with raw material. The India wheel was a very rude instrument, but could spin a coarse yarn; the fine spinning of India continued to be done by the revolving spindle propelled by the hand.

The Great Wheel. — In Europe early in the fourteenth century a single-thread wheel was used which was similar to the India wheel. The idea may have been brought from India, or it may have been original. In England this wheel was called the Jersey, the Great, or the Wool wheel, and in Scotland the Muckle wheel (Fig. 15). It was principally used for wool, as its slow, intermittent motion was well fitted for short staple fibers which easily pull apart after being carded into the roll or sliver form. The one-thread wool wheel differed slightly in various places. It was found in both the high and low form. At first the great wheel directly revolved the spindle, the latter being in a horizontal position, but later a large wheel drove a smaller one, which again turned the spindle by means of a wharve or small grooved pulley fastened on the end of the spindle. The wharve was a development of the whorl.

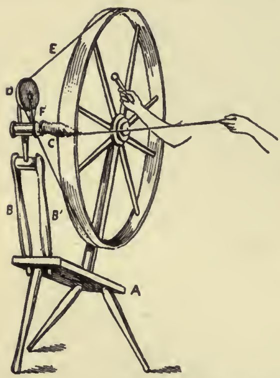


Fig. 15.—The Great Wheel.

The Parts of the Great Wheel were: I. The standard (A) on three legs, on which were the two upright posts (B, B) which held the spindle (C) in a horizontal position. A wharve or pulley was at one end of the spindle, and a small wheel (D) provided with a pulley or groove. At the other end of the standard (A) was a post which held a large wheel. II. A band or cord (E), which connected the large wheel with the small grooved wheel (D). III. A cord (F) which connected the small grooved wheel with the wharve or pulley on the spindle.

The Motion of the Great Wheel. — By revolving the great wheel by hand the small wheel turned very rapidly, communicating motion to the spindle through the wharve or pulley, consequently the spindle turned as long as the great wheel revolved.

The Method of Spinning on the Great Wheel. — The wool or cotton was first carded by hand combs into soft rolls a foot or more in length and a little less than two inches in width. (See Fig. 18.) The spinner stood beside the wheel. An end of spun yarn had been left on the spindle to which she attached a roll, or, if not, she drew and twisted by hand a short length of yarn from one of the rolls and fastened that to the spindle. She brought the end of the twisted yarn to the point of the spindle, and held the remainder of the roll in her left hand. In her right hand she usually held a wooden peg, with which she struck a spoke of the great wheel, causing it to revolve and the spindle to turn. She gently drew the roll away from the spindle almost on a line with it. As the roll became attenuated, the revolving spindle twisted it into yarn in the same way that the revolving vertical spindle had twisted the yarn when it was spun by the hand of the worker. When the roll was drawn and twisted almost to its end, she stopped the wheel. By turning the wheel slowly in the opposite direction the spun yarn, which extended to the end of the spindle, backed off to the center of the spindle or to any point that the spinner desired. The yarn was now at right angles with the spindle. The spinner again turned the wheel in the original direction, thereby winding the length of spun yarn up on the spindle. She was now ready to piece on another roll. She laid one end of it over the end of the one just spun, again drew the end of the twisted part of the yarn to the end of the spindle, and repeated the process as described. She thus repeated the three principles required in the earliest spinning, *i.e.*, (1) Drawing or attenuating the fiber, (2) Twisting it, and (3) Winding it up on the spindle. She did this in two parts or intermittently; the first division drew and twisted the yarn, the second wound it up. As has been said, the motion of the great wheel was intermittent. For soft yarn, made of easily separated fibers, this was a decided advantage, for it did not put too great a strain on the yarn by winding it while it was being drawn or twisted. The wheel was the progenitor of the modern mule, the motion of which is also intermittent. The yarn was respun several times before it was strong enough to be used for warp threads. When the spindle was full of yarn the thread was wound off on a reel. (See Fig. 8.) In general, the yarn from the great wheel was more satisfactory for the filling than for the warp threads. At the low wheel the spinner sat, but at the high one she stood, walking back and forth at her work. It is said that twenty miles a day were frequently covered by spinners on the wool wheel in our colonial times. The great wheel spun several times as much yarn in a given time as the distaff and spindle, and relieved the pressure for more yarn, but the cry for better warp thread still continued, and was met by the Saxony wheel.

The Flax, Saxony, or Leipsic Wheel was invented, it is said, by Jurgens in Germany about 1530. It is probable, however, that wheels of a like character had been made before that time. This wheel was an elaborate piece of mechanism as compared with the wool wheel. The foot was used as power, consequently the hands were free to draw out and guide the fiber to the spindle. The Saxony wheel was well adapted to the spinning of flax, for the principles of drawing, twisting, and winding were continuous, which made a strain on the yarn which flax could stand better than wool or cotton. The latter fibers were, however, spun upon it, not from the distaff, but from rolls of carded material fed by hand directly to the spindle, thus lessening the strain. There are several models of this wheel. A common one, though not the earliest form of it, is seen in Fig. 16.

The Parts of the Saxony Wheel were: I. The frame (12) which stood on three legs, the wheel end being lower than the distaff end. II. The wheel (1) had an iron bar through its hub by which it was supported in the deep grooves of two upright bars of wood (11*a*, 11*b*). III. The distaff (10) was supported on a high standard at the opposite end of the frame from the wheel. IV. At the distaff end of the framework two upright bars (3*a*, 3*b*) supported the spindle (6), which was made of polished steel, and had a pointed end protruding through a leather ring on the upright bar (3*b*) away from the spinner, and a needle end (4) (in which was an eye) through another ring in the bar (3*a*) toward the spinner. A flyer (2) was fastened about one inch from the needle's eye, and a large wharve or pulley one inch from the pointed end. A cord from the wheel caused the revolution of the spindle. The flyer had a series of hooks or guides over which the yarn was passed before it was delivered to the bobbin (7). The turning of the flyer twisted the fibers, which were threaded through the needle's eye, and wound them up on the bobbin. The spinner changed the yarn from one hook to the other of the flyer as she spun, and gradually filled the bobbin evenly with yarn from end to end. The flyer went round very rapidly, but the bobbin was kept back by the friction of the yarn which was

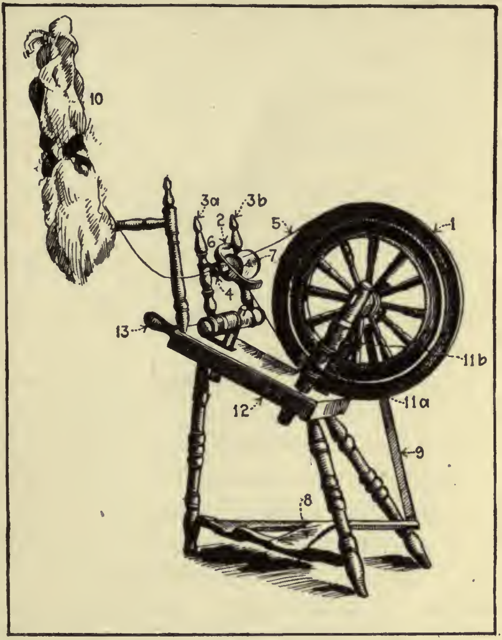


FIG. 16.—THE FLAX WHEEL.

let out as the spinner wished, according to her ability or her desire for fine yarn. The slower movement of the bobbin caused the yarn to wind upon it. The bobbin or reel fitted loosely on the spindle, and was slipped on it by removing the pulley at the end of the spindle. The bobbin had also a groove or pulley at one end of it, around which one of the cords from the wheel was placed. V. A band or soft cord (5) was passed twice around the wheel; one part went over the grooved pulley or wharve on the spindle, and the other over the pulley on the bobbin, causing them to revolve with the wheel. VI. A handle (13) regulated the tension by turning it either backward or forward, thus moving the standard on which the spindle and other parts revolved, and tightening or loosening the band. VII. Underneath the framework was the treadle (8), connected with the wheel by means of a rod (9), which was attached by a crank to the iron bar through the hub of the wheel, and was tied to the treadle.

The Motion of the Saxony Wheel was continuous, that is, the drawing, twisting, and winding occurred simultaneously, and not as in the great wheel in two divisions, requiring the stopping of the wheel and backing off of the thread on the spindle before winding began.

The Method of Spinning on the Saxony Wheel. — The flax was carefully prepared beforehand in order to have the fibers parallel and untangled. The spinner laid the flax carefully down on a flat surface, and turned the distaff in it until it was evenly covered. She then tied a ribbon loosely about it to keep it in good order, and placed the distaff on the standard. The fibers were now in good condition for drawing steadily down as many or as few as she desired. The spinner sat beside the wheel with her foot on the treadle, and by means of the connecting rod gave motion to the wheel. The double band caused the revolution of the spindle and flyer as well as the bobbin through the wharves on each. She drew the threads down from the distaff with her right forefinger and thumb until they reached the eye of the spindle. The flax passed smoothly under her second, third, and fourth fingers as she held it lightly between the first finger and thumb, which she slightly turned toward her as the thread was drawn down. She used her left hand to open up the mass of fibers next to the distaff, making them into a wedge shape with the narrow end running toward the right hand. She slightly twisted them, and threaded the yarn thus made through the needle's eye in the spindle, brought the thread over one of the hooks of the flyer and fastened it on the bobbin by means of a thread which had been left for this purpose. Beginners often found it difficult to keep the wheel revolving smoothly while drawing the flax evenly from the distaff to the spindle. It took time to become a good spinner. The threads of flax were kept moistened by the spinner in order to make a tighter and smoother twist. The spindle, the iron bar on the large wheel, and the crank connected with the treadle were kept well greased.

The Saxony wheel was more complex than the great wheel. The flyer (Fig. 17) on the spindle by which the thread was twisted (said to have been invented by Leonardo da Vinci) was a great step in advance of former spindles, and is utilized in power spinning even to the present day. The continuous motion of this wheel made it possible to spin more and stronger thread in a given time than had any previous invention. The bobbin revolved at a different speed from the spindle, consequently it was possible to wind up the yarn as it was being spun. The flax wheel was improved upon in various ways, and two spindles were later used on it at one time, enabling expert spinners to double the output.

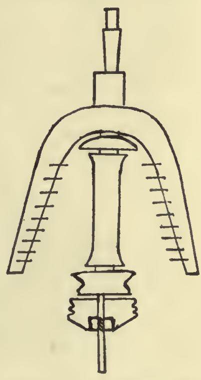


Fig. 17.—Detail of Flyer.

Hand and Machine Carding. — The opening up, combing, or carding of raw fiber is probably as ancient as the art of spinning. The first cards or combs were evidently the fingers, with which the matted mass was opened, dirt and knots were pulled out, and the fibers were laid in a soft, open lap. A device for aiding the hand was later made of wood or bone, the shape being like the outstretched fingers. This instrument was succeeded by two flat pieces of wood covered with skin (Fig. 18), through which teeth or thorns protruded. The fiber was laid between the teeth of the two combs, and combed or carded thoroughly. Such cards are still in use by primitive people, and also in some modern factories, where they are used for blending wools and trying out colors. The Navajo Indian woman of Arizona uses cards to comb her wool. They are made like the primitive ones, but the flat surfaces are now covered by card

FIG. 18.—HAND CARDS.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

clothing (bent wires closely set together in leather or rubber). After the Indian woman prepares her raw wool, — always a very necessary part of successful carding, — she sits down on the ground and spreads a small quantity of wool on one card, which she holds face up with the left hand. The other card she holds with the right hand, having the card clothing down. She firmly presses one card on the other, and draws toward her the one in the right hand, thus combing through the fibers on the other card. By repeating this process she finally has the wool in a clean, fluffy mass. When the wool is sufficiently open and free from dirt she lays the lap on the back of the left card, and makes it into a roll or sliver with the back of the other. With these rolls she spins her yarn.

When the demand for more rapid spinning came there was naturally an equal demand for better and more rapid carding, for good spinning depends upon it. The problems before the inventors of the eighteenth century were to accomplish the work of the hand cards by mechanical means at greater speed, and to make a continuous sliver instead of short pieces. They wished to do this with the minimum injury to the fiber and with the least possible waste. It cannot be said, however, that the modern carding engine, wonderful as it is, works with as little bad effect on the fibers as did the hand cards.

When Lewis Paul in 1748 discovered that carding could be satisfactorily done by the use of revolving cylinders covered with wire clothing, he gave the principle of modern carding. James Hargreaves invented an improved cotton carder in 1762, which had more than one cylinder rotating in contact with the cotton. Richard Arkwright also invented one which he used in his own mill at Cromford. Until 1772 the fiber was fed by hand into the carding machine, but John Lees or Leigh of Manchester invented an apron feed, which saved the labor of one worker and facilitated the process by making it continuous. At that time the slivers received from the carder were in short pieces like the rolls from the hand cards. Arkwright made an invention by which the cotton was fed in a wide lap to the machine, which carded it and passed the lap thus made to a funnel, which contracted it into a sliver. He also invented a doffer or stripper to remove the sliver from the machine. The doffer was a helpful invention; it is claimed by both Arkwright and Hargreaves.

These inventions led to great changes in methods of manufacture. By 1774 all of the principles of modern carding were in use, — the continuous carding surface, the continuous feed, and the continuous doffer. In the modern carding engine an enormous number of fine teeth come in contact with the fiber; the object sought — of cleaning, opening, and laying the fibers parallel — is accomplished, but the process is a severe strain on them. Good carding often requires many previous processes of cleaning and opening, all of which have an effect on the strength of the fibers. On account of differences in the characteristics of raw materials, the processes leading up to carding and the work itself differ. Silk and flax are not carded, although the latter undergoes a similar process called hackling.

The revolving flat card (Fig. 19) is used extensively in the United States for cotton. It has a cylinder about fifty inches in diameter and forty inches in width, called a swift, which is covered with card clothing, having about six or seven hundred steel wire teeth per square inch, amounting in all at times to three or four million. The teeth are turned in the direction of the movement of the cylinder. They are fastened in a leather, rubber, or cloth foundation, similar to the hand cards. In the process of carding, a large roll of partly cleaned cotton is placed in front of the machine. A revolving small roller takes the end of this sheet of cotton and delivers it to the "licker-in," which in its revolution brings the cotton in contact with the big cylinder or swift, and the teeth catch the cotton and carry it on. Flat bars on an endless lattice above the swift are covered with card clothing, and in rotation press their teeth into the cotton which is on the cylinder. The contact of these slowly moving flat bars with the revolving cylinder is like the contact of the two hand cards; the cotton is thus combed and cleaned, and the poor fiber is carried away by a stripper. This rough, broken fiber is used for cheaper classes of goods, having machinery especially adapted to it. The impurities drop through to a box under the machine. The revolution of the swift carries the good carded cotton to a point directly opposite the licker-in, where it is stripped off by another revolving cylinder, called the "doffer cylinder," the teeth of which are so set that they take the cotton from the big cylinder or swift. An oscillating knife or comb, the "doctor knife," strikes the cotton from the doffer cylinder, and the soft lap is then delivered to a funnel or to two rolls which contract it into a ribbon or sliver and deliver it to a can. The great cylinder or swift often moves at a rate of 150 to 200 revolutions a minute. The doffer comb strikes the cotton about a thousand times a minute. The

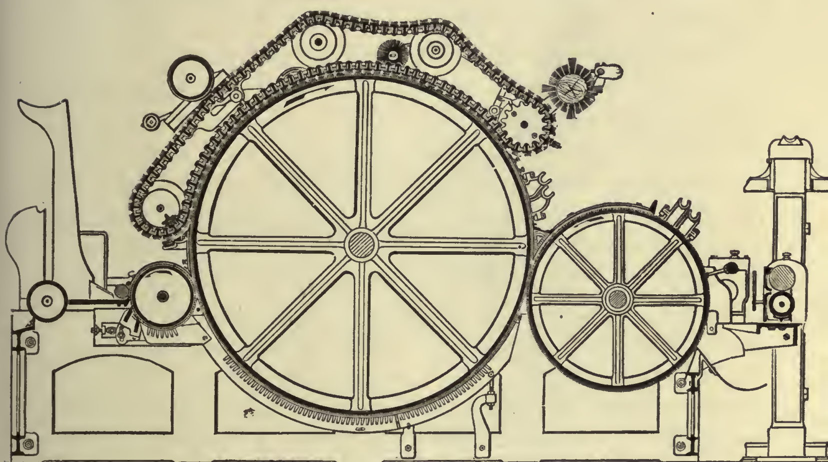


FIG. 19.—REVOLVING TOP FLAT CARD.

Courtesy of the Whitin Machine Works.

card for wool does not aim to lay the fibers parallel, but simply to open them into a soft mass. A series of small cylinders, covered with card clothing, working over the top of the swift, take the place of the flat bars in the cotton card. These rollers or cylinders are in pairs called workers and strippers and alternately press the wool on the teeth of the swift and remove it again, thus opening the fiber. Three cards in a train are in general use in the wool industry. (See Chap. VI.) The fiber passes from one card to another in a transverse direction, to overcome the inclination to parallelism. The card in use in the worsted industry differs from the train of cards required in the wool, but the principles remain the same. The rapidity of movement in the swift depends upon the length of staple of the fiber. In the wool card the final stripping roller is called the fancy. It is larger and has longer teeth than the others, in order to lift the carded wool from the teeth of the cylinder, that the doffer may carry it off. The speed of movement in the various cylinders depends on the requirements of the raw material.

Modern Spinning Machines Developed from the Principles of the Wheels. — In England about the middle of the eighteenth century pressure for more rapid production of cloth, especially of cotton cloth, began to be felt. Suffering from poverty had lessened and more comforts were demanded. The subdivision of industry had increased in the towns, and as women no longer spun and wove in every home the demand for textiles was insistent. There was scarcity of yarn for weaving, for many of the spinners were not capable of making warp yarn. Wool and flax heretofore had been the staples, but the introduction into England of cotton fabrics from India led to a demand for the spinning and weaving of that fiber. Some inventions were made, but little was thought of them at first, therefore the names of the first inventors and the dates of their inventions were not carefully preserved and are even now uncertain. The supply of yarn and the ability of the weavers to turn out cloth were about equal when John Kay of Bury invented his fly shuttle and picking stick (see Chap. IV), thereby increasing fourfold the output of the loom. This was followed by a patent of Robert Kay, son of John Kay, of the drop box (see Chap. IV), which also saved the weaver's time. These inventions brought the capacity for weaving far ahead of the supply of yarn. Pressure was brought to bear on the spinners to meet the situation, by (1) finding a mechanical way of spinning a number of threads at one time by keeping more spindles revolving, and (2) some automatic means of drawing out the fibers. John Wyatt of Birmingham is generally conceded to have been the first to suggest a way of spinning thread without the use of fingers. His patent was taken out in 1738 in the name of Lewis Paul, his partner. In his machine he uses the flyer of the Saxony wheel for spinning, but probably he had an entirely new and brilliant idea in the use of drawing rollers to attenuate the yarn. This latter principle is important in power spinning. Richard Arkwright later used this principle in his water frame, but gave no credit to either Wyatt or Paul, and is generally given credit for the invention.

In 1764 or 1767 James Hargreaves, a spinner and carder, living in Blackburn, Lancashire, invented a spinning frame

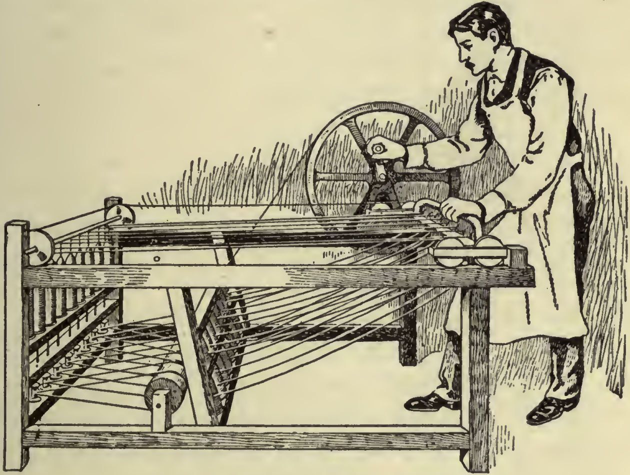


FIG. 20.—HARGREAVES' SPINNING JENNY.

From Robinson and Beard's *The Development of Modern Europe*, by courtesy of Ginn & Co.

(Fig. 20) which was the progenitor of the modern self-acting mule. (See Fig. 22.) His idea was evidently taken from the principle of the great wheel. For power he used one hand to control a traveling carriage, and the other to turn a wheel by means of a crank. The wheel was connected by a band with a cylinder under the framework, and bands went from the cylinder to the pulley or wharve of each spindle, thus setting them in motion as the wheel turned. This machine spun from eight to eleven threads at once. It was a great invention, but the fibers were not parallel, and the yarn was too softly twisted to be used for warp. The pictures now seen of the machine have improvements over the original invention. The important principles of Hargreaves' spinning jenny were (1) a number of bobbins of roving (the last step in the preparation of yarn previous to spinning) were placed vertically in a creel under the frame; (2) the yarn from these bobbins passed through a holder and across to the spindles. The holder was so made that it could keep the threads fast or let them slip, and (3) a carriage which could be moved back and forth on the framework so that the holder could be drawn away from or moved toward the spindles. When the carriage was near the spindles the roving was caught in the holder and fastened to the tip of the spindles, and was attenuated by drawing the carriage away from the spindles. In the meanwhile the stretch of roving was twisted by the revolution of the spindles by means of the wheel. When the carriage reached its farthest point on the track it was stopped, but the spindles were kept turning until the yarn was sufficiently twisted. The wheel was then stopped, and the carriage was backed slightly to allow guide or faller wires to back off the twisted thread from the end of the spindles, as was done in the great wheel. The carriage was now pushed back toward the spindles while the length of spun yarn was wound up. Thus Hargreaves' jenny repeated the intermittent motion of the great wheel, for the attenuating and twisting were done in one motion, and the winding in another. When one length of yarn had been spun, the bar on the holder was loosened, another length of roving was drawn from the bobbins into the holder, and the work of drawing and twisting was repeated. This machine was used widely, but Hargreaves had little use of his patent, which was taken out in 1770, for the hand spinners were infuriated, and persecuted the inventor for taking away their work. He was obliged to flee from his home on account of the tumult. He deserves to be remembered as one of the fathers of the modern industrial world, for he made cotton spinning possible, and thus brought a cheaper fabric to the poor of England. Credit for this invention is given by some to High of Leigh.

The spinning jenny was known to Richard Arkwright, a clever barber of Preston, who wandered about the towns of

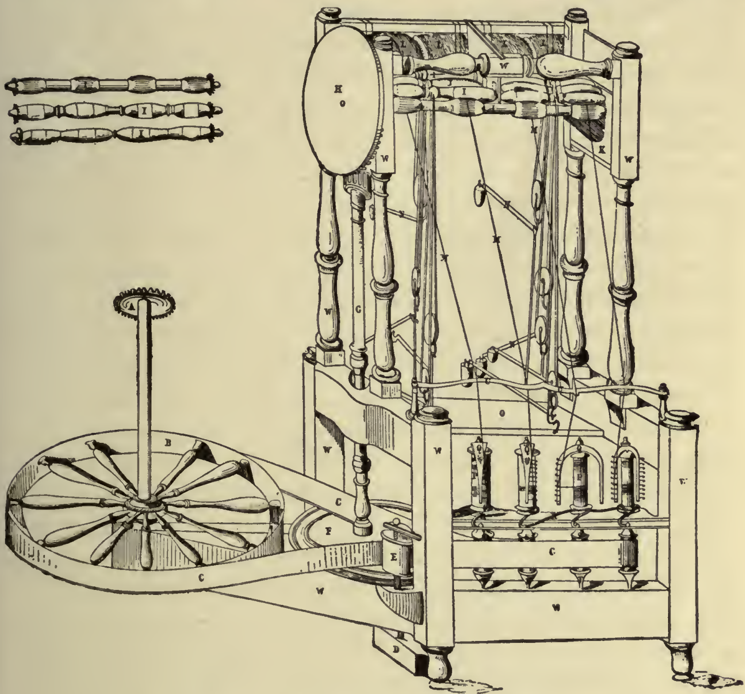


Fig. 21.—Arkwright's Water Frame.
From Barker's *Textiles,* by courtesy of Constable & Co., London.

England in pursuit of business. He continually heard of the need of yarn and cloth, and probably improvements in devices were talked over with him, and new appliances shown him. About 1768 he brought out a machine founded on the principle of the Saxony wheel. It had an upright frame, a continuous motion, and the spindle and flyer of the Saxony wheel placed vertically (Fig. 21). The roving passed through twin drawing rollers and was attenuated before being twisted. It is probable, though not proven, that he had seen this in the machines of Wyatt and Paul. He received much credit for his invention, but is thought to have been a greater business man in forwarding the ideas of others than original in inventions of his own. His ideas of factory organization are not yet obsolete. He is, in any case, worthy of honor for what he has given to us. The principle of his machine is as follows: The roving was attenuated by means of a couple of twin rollers placed one behind the other. The first two rollers which received the roving ran rather slowly, but the two rollers ahead moved more quickly. Hence the fiber was caught, drawn, and laid more nearly parallel. After the roving, now of the required thickness, left the rollers, it was twisted by the flyers of the spindles and wound on the bobbins. Arkwright probably gave us the reciprocal vertical movement of the spindle. His first mill was built at Cromford in 1771, where he installed his own carding and spinning machinery. So greatly was his work appreciated that he was knighted. His machine was too heavy to be driven by the human hand, hence horse or mule power was used, and later water power gave his invention the name of the water frame, or water twist frame. The homes of that time where most of the spinning had been previously done could not provide sufficient force, consequently small factories sprang up where the Arkwright spinning frame spun the yarn for those having private looms or for groups of manufacturing weavers. Steam power was applied to it in 1790. The use of drawing rollers is the great basis of modern spinning.

Another inventor of note of this period was Samuel Crompton of Bolton. He was a textile worker, and a capable man. He felt the need of a greater supply of warp yarn in his daily work. His invention in 1779 was a spinning frame which combined the good points of the machines of both Hargreaves and Arkwright. From Hargreaves he took the upright spindle frame, but placed it on the moveable carriage. (In Hargreaves' machine it had been attached to the back of the main framework.) From Arkwright he took the idea of drawing rollers and placed them where Hargreaves had his spindles. It is believed by many that Crompton invented the drawing rollers for his machine, and that he had never seen or heard of the Arkwright patent. Crompton placed the roving or slubbing in a creel behind the spindles. He patented his machine, calling it the mule spinning frame. It proved to be a wonderful machine, and has been the basis for one of the most useful spinning frames of the present day — the self-acting mule. Crompton was not only an inventor himself, but he knew how to take advantage of the inventions of others and use them in his own way. At that era before steam power was utilized, Crompton's mule was of more use than either Hargreaves' spinning jenny or Arkwright's water frame. Many other inventors made important additions to these inventions. The use of steam for power, and Whitney's cotton gin, both of which came at the end of the eighteenth century, gave a tremendous impetus to cotton spinning, and the inventions of Roberts in 1830 gave the world the modern self-acting mule, which was a triumph of skill and automatic action.

The following dates mark important eras in the development of modern textiles: —

1. Distaff and spindle, from the dawn of history to about the fourteenth century.

2. Spinning wheels, from the fourteenth to the eighteenth century.

3. The great eras of invention: (*a*) Improvements in spinning and weaving, (*b*) the use of power other than the hand, and (*c*) the modern factory system.

The beginning of modern spinning, carding, and weaving came principally from such men as the following: —

JOHN WYATT, Birmingham. First thread spun without fingers, and the use of drawing rollers, 1738.

LEWIS PAUL. In connection with Wyatt, carding, revolving cylinder, 1748. (Claimed by Hargreaves.)

JOHN KAY. Fly shuttle, 1738; improved in 1750.

ROBERT KAY, the son of John. The drop box, 1760.

Hargreaves. Spinning jenny; the spinning of a number of threads at once, 1764–1767.

Arkwright. Water frame (upright), 1768; the principle of rollers; doffer comb.

Crompton. Mule frame, combining Arkwright's and Hargreaves' ideas, 1779.

Lees or Leigh. Apron feed, 1772.

Cartwright. Power loom, 1789. Application of steam to Arkwright's frame, 1790.

Eli T. Whitney. Cotton gin, 1794.

Roberts. Self-acting mule with quadrant, 1830.

The half century from 1750 to 1800 was one of tremendous issues. On account of the inventions capital became more important than labor, factory towns took the place of farming villages, large numbers of women heretofore working in the homes had to work in the factories, markets were extended all over the world to make use of the larger output from machinery, and society to meet these conditions had to be almost entirely reorganized.

At first the industries of spinning and weaving were separate. Little factories began to spring up where water power was good. When steam power was used, spinning and weaving were often combined to save expense. But about the middle of the nineteenth century, so much capital was required to combine the two that they were again separated, except in very large plants.

Modern Spinning Frames. — The principles of modern power spinning follow closely the inventions of Hargreaves, Arkwright, and Crompton. These men in their effect on the development of our factory system may be said to have been among the principal instruments in bringing forward the industrial and social problems of the present day. One girl now probably spins twelve hundred times as much in a day as was done with the old wheel. The difference between the old and the new is not in the principles employed, but in the mechanism which is used to take the place of the hand, *i.e.*, the belts, pulleys, levers,

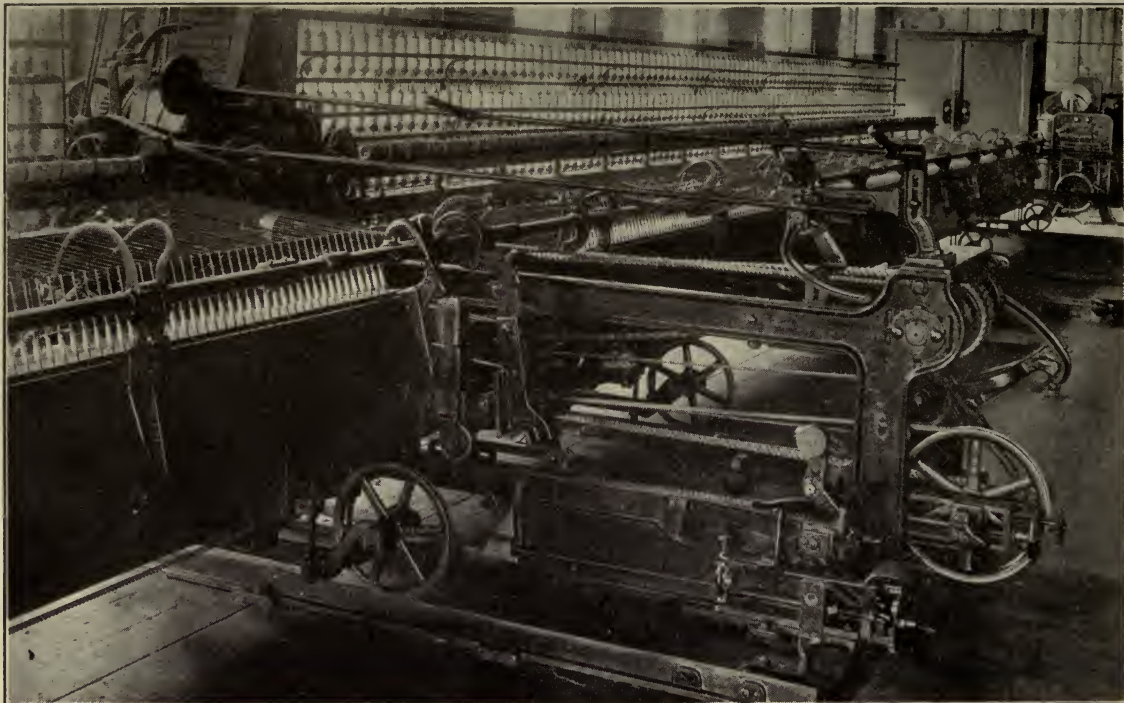


FIG. 22.— MULE SPINNING.
Courtesy of the Mason Machine Works.

wheels, gears, springs, chains, and cams, which automatically handle a thousand spindles at once, where the hand controlled one. True spinning is in reality the final process of twisting, but the term spinning is used to cover all of the preparatory steps as well. Before the final spinning the twisting is only sufficient to keep the attenuated fiber from breaking apart. The final process before true spinning is called the roving. The final spinning may be done by the mule (Crompton's patent), or by a ring spinning frame on the order of the upright spinning frame (Arkwright). Both machines may be used for tightly or loosely twisted yarns, but the mule is better adapted to the softer yarns, and the upright frame to the closer twisted yarns.

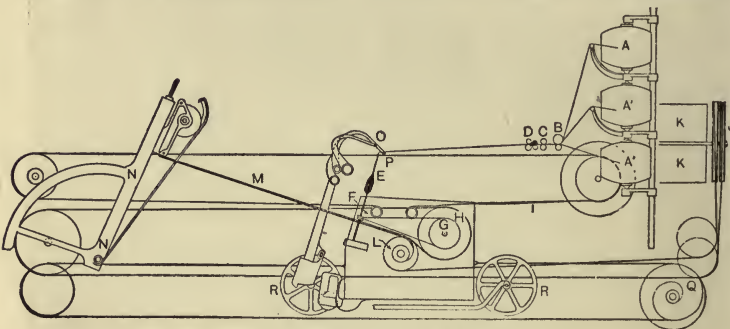


FIG. 23.—DETAIL OF MULE.

From Barker's *Textiles*, by courtesy of Constable & Co., London.

In the present day the true spinning machines are preceded by others which are more or less similar in method, but they only prepare for the final twist. The principle of rollers is used for drawing and attenuating the fiber, and the twisting is done not only by the flyer but by other methods. The modern mule spinning, which has developed from Crompton's mule, is more complicated than ring spinning, which followed Arkwright's upright frame.

Mule Spinning — Intermittent Motion (Fig. 22). — The essential features are as follows: The bobbins of roving are placed in a creel in the back of the machine. The roving is passed over bars through three separate twin drawing rollers, which attenuate and prepare the fiber. It is then carried between faller wires to spindles which are on a carriage which moves on a track. As it moves forward to its full extent the fiber is further attenuated while the spindle twists it. Probably five feet are covered by the movement of the carriage, the yarn being at the extreme end of the spindle for this purpose. When the carriage reaches its limit, it is stopped, the yarn is backed off the top of the spindle by the faller wires, one of which guides and the other holds taut, and the yarn is wound up on the spindles as the carriage returns to its place at the back of the mule. As a consequence the action is intermittent, as in the great wheel (Fig. 23). The spindles are placed at an

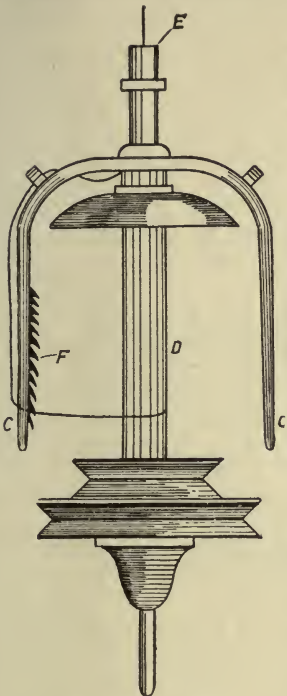


FIG. 24.—FLYER.

From Barker's *Textiles*, by courtesy of Constable & Co., London.

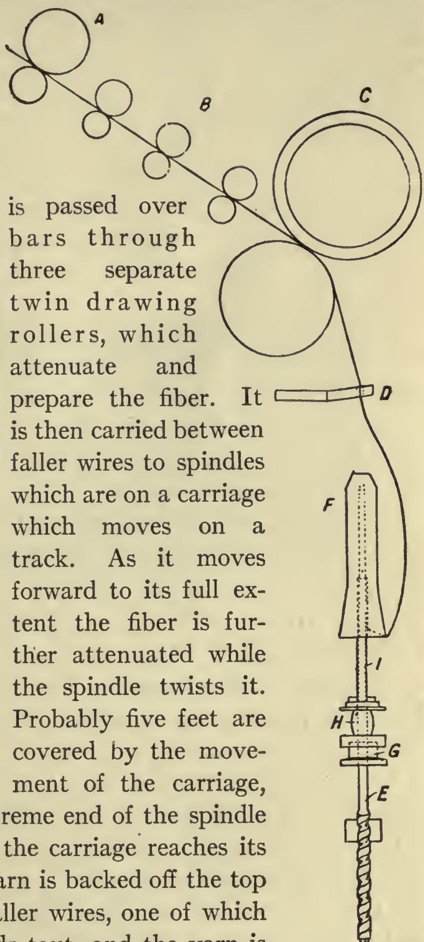


FIG. 25.—CAP SPINNING FRAME.

From Barker's *Textiles*, by courtesy of Constable & Co., London.

angle of fifteen degrees, and each is provided with a wharve, whorl, or pulley by which it is revolved, a band around it passing to a driving cylinder. The mule is a complicated machine, and requires skilled attention. Men are usually in attendance. The machine has to be adapted to differences in fiber, as between wool, worsted, and cotton. High counts of yarn may be spun on the mule.

Ring Spinning — Continuous Motion. — The principle of ring spinning has largely taken the place of the flyer spinning as found in Arkwright's patent. Following the Arkwright spinning frame came a series of inventions to improve the spindles. The upright frames look much alike. The drawing rollers were satisfactory and are found about the same, whether the flyer, ring, cap, or top principles are used for the spindles. A throstle frame (still used for making roving) followed Arkwright's patent, and combined some features of Hargreaves' jenny with Arkwright's water twist, giving a new spindle, but it is seldom seen now in true spinning. The flyer (Fig. 24) principle is seen in the bobbin and fly frames, used to prepare the rove (slubber, intermediate, and roving) in cotton spinning. The twist depends on the relative speeds of the bobbin and flyer. The spindle has gradually been made more free in its motion, and runs more loosely in its bearings, which makes it steadier. Cap spinning (Fig. 25), used much in cotton spin-

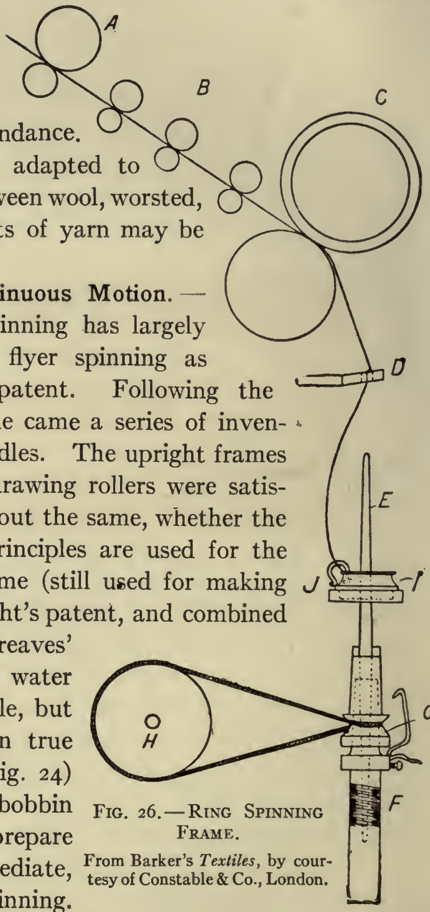


Fig. 26. — Ring Spinning Frame.

From Barker's *Textiles*, by courtesy of Constable & Co., London.

ning, utilizes this idea, and gives the spindle as much freedom as a spinning top, which running at full speed balances itself. Cap spinning is used in spinning worsted yarns, the principle at base being a stationary spindle with a stationary cap and a revolving bobbin. The latter has a whorl on it, and a band connected with the driving shaft makes it revolve. The yarn comes from the rollers above, the bobbin moves up and down, and the end of the cap keeps the yarn evenly winding on the bobbin.

In ring spinning (Fig. 26) the yarn is twisted immediately on leaving the rollers. In spinning frames there are usually

FIG. 27.—DETAIL OF RING.

two rails. In the lower the spindles rest, and through the higher, called a bolster rail, the tops of the spindles pass. In ring spinning there is a third rail. This rail moves up and down the spindle, causing the yarn to wind evenly. A series of rings (Fig. 27), each with a flange, are fixed on the rail, and move with it. The front of each spindle goes through a ring, but does not touch it. A traveler, which is a crooked piece of fine wire, is sprung on the flange. It can move easily, but cannot come off. The ends of the yarn come through the rollers and each passes through a traveler and is fastened on a bobbin which is on the spindle. The spindle and traveler revolve rapidly. The latter is held back slightly by the yarn and consequently winds the yarn on the bobbin. A traveler makes as many as 10,000 revolutions per minute. Separators of metal are often used between the spindles to keep the threads from interfering.

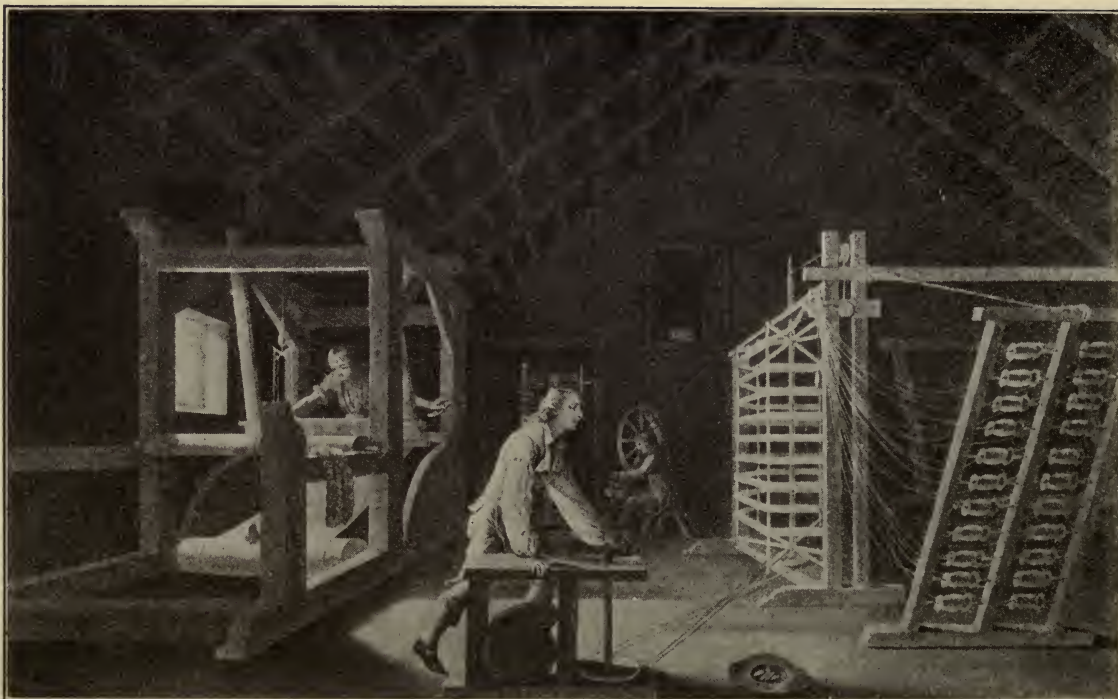


Fig. 28. — An Ancient Weave Room.

CHAPTER III

HAND WEAVING

WEAVING is the interlacing of two lines of threads crossing each other at right angles. (See Fig. 4.) Plain or pattern effects are made according to the manner in which the threads are interwoven. The threads running the length of the cloth are called warp, or ends, and are set up first in the loom. Those that intersect and run across the warp are called woof, weft, pick, or filling. The filling threads which bind in the warp threads at either side form the selvage (Fig. 29).

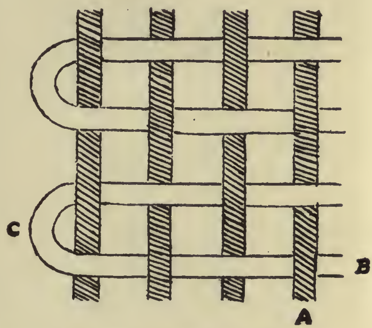


FIG. 29.—DETAIL OF WEAVE.

A, Warp or ends.
B, Filling, woof, weft, or picks.
C, Selvage.

Weaving is one of the most ancient of the arts. Its development has called forth and still requires a high order of mechanical ability. Marvelous results in fineness of cloth and beauty of design were attained in it even when it was in its infancy, with few devices to aid the hand, and when to make one rug required untold labor. Even modern machinery cannot outdo the handwoven materials from various parts of the world. At first women were the weavers, but since the industry has passed from the home they are no longer preëminent in it, though they still work in the textile factories. It is said that one fifth of the working world is now occupied with weaving, its allied arts, and the distribution of the products of the industry.

Our present knowledge of the beginnings of weaving comes (1) from the work of nations which are now in primitive conditions and whose work we can watch, such as the natives of the

Fig. 30.—Textile-Impressed Pottery.

A. Pottery. *B*. Weave used.

Philippine Islands, the American Indian, and African tribes; (2) from early pottery, which was frequently decorated with a textile design, and shows clearly that woven cloth was laid upon it when it was in a moist state (Fig. 30); (3) picture writing on tombs; (4) mats, rugs, and cloth which have been preserved in tombs. These ancient materials show the art from the coarsest mat weaving to the finest cotton and linen fabrics, with often the most intricate designs in various colors woven upon them.

Principles Underlying Weaving. — A knowledge of the principles of weaving is found among almost all primitive people, no matter how savage, and their first steps toward an adequate loom seem strangely similar, when it is remembered that there was often no communication between nations. There were three principles developed, and these same three are the important ones in modern power weaving: (1) *shedding*, or the raising of the warp threads as needed; (2) *picking*, or the throwing across of the filling; (3) *battening*, or the driving up of the filling. Various devices were invented to facilitate these motions. Weaving was done at first by the hand alone, rushes being laid lengthwise on the ground and lifted alternately, to allow the woof or filling to be inserted across them, and the fingers pushed the filling into place. One of the first inventions was a way of holding the warp stretched, that the threads of it might be raised more easily for the insertion of the filling. The early looms (see Fig. 3) were usually vertical, and had a heavy wooden bar or beam at the top to hold the upper ends of the warp, and stone weights tied to the lower end of each thread, thus keeping the warp taut. The beam was suspended in a framework, or between trees. Some nations placed bars at each end, which were forerunners of the warp and web beams of the modern loom. To accomplish a more rapid raising of the warp threads sticks were inserted alternately in the sheds, to indicate the path of the filling, a simple device which led finally to the harness of the modern loom. (See Fig. 47.) To take the place of the fingers for throwing the filling threads across the warp, a stick was used on which the filling was wound; this later became the shuttle containing its quill of yarn, and the shuttle race. (See Fig. 46.) As a means of widening the shed for the insertion of the filling, and later battening it up, a sword or batten (See Fig. 34) was used, which served both purposes. The lathe or sley of the modern loom, with its reed, has developed from the early sword.

Primitive Looms. — Many kinds of looms were invented: (1) the upright or vertical, such as the Navajo Indian loom or some forms of the tapestry loom; (2) the horizontal loom, like those of the Moros of the Philippine Islands, and of the Zuni and Pueblos of America, a form also seen in the hand loom of colonial days and in the power looms, and (3) slanting looms, such as

Fig. 31.—Chilcat Blanket.

are found among the rug makers of the East. A simple form of loom is found in British Guiana, in which the lower end of the warp is rounded by the use of a flexible reed, and the upper bar is straight. As the warp threads are put in they widen slightly. A rod laid across the warp is attached to alternate threads by a cord and is used as a simple means of drawing these threads out while leaving the others down, thus forming the shed. A slender stick on which some yarn was wound was used for a shuttle, and a wider stick with a flat edge beat the threads together. Color was introduced by hand, the design being thus a variety of tapestry weaving on stretched threads. The Navajo loom has similar devices. The beautiful Chilcat blanket (Fig. 31) used for ceremonial purposes and woven by the Tlinget Indians of northwest United States, is rounded, and heavy weights held the warp threads in place while the weaving was in progress. It was woven of goats' wool combined with bark, and had a marvelous conventionalized design of a whale. Few devices were used by the weaver.

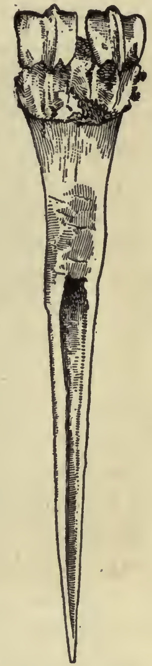


Fig. 32. — Bone Awl.

Tools of various kinds were invented by different peoples to assist in the making of cloth, such as knives to split material, which took the place of the teeth of the worker; gauges to measure distances, which replaced the finger nail; awls to assist the fingers in fine work, and act as needles (Fig. 32), and combs to help the fingers in driving home short sections of filling.

At the time of the discovery of America, the art of weaving was well advanced among the inhabitants. The Zuni Indians invented an interesting heald shaft or heddle for making the shed. It consisted of a series of small flat sticks held in a frame-work, with holes in the center of each stick, and spaces left between the sticks. (See Fig. 35.) The first warp thread was passed through a slit between sticks and the second through a hole in a stick, the third through a slit, the fourth through a hole, until all the warp threads were disposed of, every other one being through a slit and the alternate ones through the holes. The shed was formed by raising or depressing the heddle, thus threads were alternately brought up or down, through which the filling was passed and battened up. This form of heddle is on the order of those used in the modern power loom (Fig. 47). Heddles of similar construction are found in many parts of the world. The Esquimaux made one of bone, and the European carved one from wood. Our colonial women used a similar heddle in their tape weaving.

The Navajo women are still weavers. Beautiful rugs were once woven of the wool of the native sheep, dyed or undyed, and characteristic designs upon them had been in use for centuries. Unfortunately the demand for a cheap rug is injuring their art. Few buyers understand the value of these old rugs, and consequently are unwilling to give an adequate price for them. The better grade of rug took sometimes as long as a year to weave, but the present one is frequently made rapidly and poorly, with a cotton warp and commercial wools for filling. Cheap dyes and poor designs are used. In fact, these rugs are even copied on power looms and sold in large quantities. The real Navajo rug has the hand spun yarn prepared for the loom by winding it around two upright sticks which are set apart the length of the rug. The threads are wound on the sticks transversely or spirally to form a crossing, until there are sufficient for the width of the warp. A stick is then slipped through the warp at either end, which secures the lease or crossing — thus every other thread can be traced. The lease is vital in both hand loom and power weaving. The Navajo woman sat on the ground to do her work. The loom (Fig. 33) consisted of a framework made usually of two poles and two beams. The poles were forked at the top and stood upright; the beams were lashed across at the top and bottom. At each end the warp was wattled (see Fig. 2) in and out by special threads, which kept it from slipping. It was then stretched between two other poles the width of the rug. The poles were lashed to the beams. As the warp hung taut the lease or crossing of the threads could be clearly seen, for every other thread was slightly forward of the alternate ones. By slipping sticks into these sheds they were accented. A simple harness was made by laying a long rod across the warp threads, fastening a piece of strong yarn to the rod, and in succession catching the yarn around each back thread in the lease and then around the rod. When all the back threads were thus connected with the rod, they could be drawn forward at one time, making a distinct shed. Through this the sword was thrust and turned over to make a wider opening of the threads, while the filling was inserted. A stick had been placed in the

FIG. 33.—NAVAJO LOOM.

alternate shed, which preserved it. As the threads of this shed were forward in the crossing they were easily distinguished at any time. When this forward shed was to be used the sword or batten was placed in it and turned to its full width, as in the shed attached to the harness rod. The weaver usually began to work from the bottom up, but some worked from both ends, using a needle for the final weaving. She alternately opened the sheds, turned her batten in them, put her filling across, and drove it home with the batten by turning it flat and drawing it toward the finished weaving. She used a rude wooden comb to drive the filling home when she wished to batten in a few threads at a time, in order to make a design. If she needed to let down the warp threads, she loosened the lashings at the top, lowered the pole with the attached warp threads, wound up the finished weaving on the lower pole and made all tight again. When different colors were needed she used separate balls of colored yarn, white, gray, and black being favorites

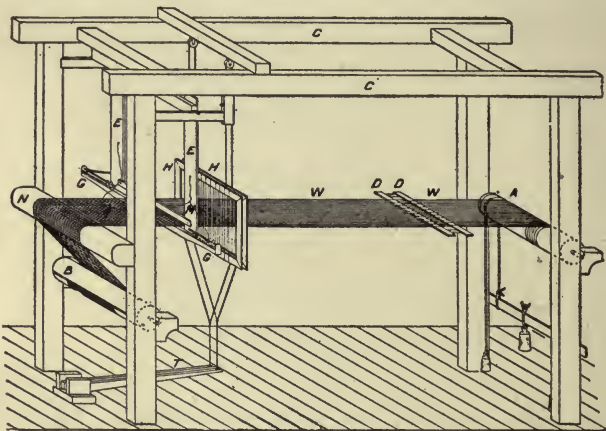


FIG. 34.—HAND LOOM.

From Watson's *Textiles and Clothing*, by courtesy of The American School of Home Economics.

with the Navajos, though red and yellow were also used. The Navajo's work is really tapestry weaving, for the design is put in by the fingers as desired, and is not dependent on the harness. When she had finished with one color, she allowed the roll of yarn to hang suspended while she took up the next color. The Navajos conduct their whole industry, growing the sheep, shearing, cleaning, carding, spinning, dyeing, and weaving.

The Hand Loom. — The centuries which have passed since such primitive methods were in vogue have brought many varied suggestions for increasing the efficiency of the loom. Finally the European hand loom (Fig. 34) was developed, on which the modern power loom (Fig. 47) is based. Continuous cloth was made, instead of the rug lengths of an earlier period. Our colonial loom was like the European hand loom, and the weaving was at first done in the homes. It is estimated that there were in this country one hundred twenty-five or more years ago about three and a half million spinning wheels, and a quarter of a million hand looms. When the inventions leading to power spinning and weaving made it more profitable to do the work in factories, a number of them were started in the East, and also

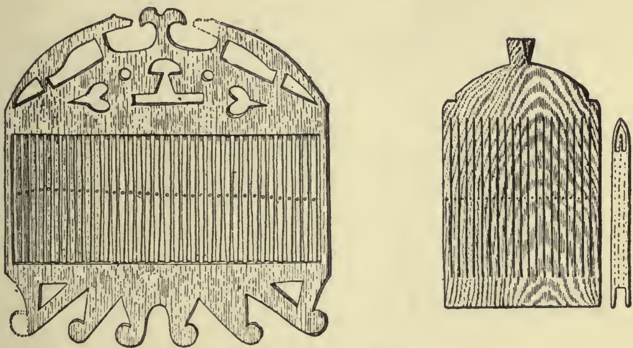


FIG. 35.—PRIMITIVE HEDDLES.

From Watson's *Textiles and Clothing*, by courtesy of The American School of Home Economics.

a few fulling mills were opened. Thus began our textile industry of to-day. The hand loom was used until about 1850.

The Parts of the Hand Loom (Fig. 34) were as follows: (1) *For the management of the warp:* The framework, *C*, usually of wood, and clumsily made, contained a warp beam, *A*, on which the yarn was wound, and a web, cloth, goods, or merchandise beam, *B*, for the finished cloth. These two beams were held in slots at each end of the framework; the warp, *W*, was stretched between them, passing through the harness, *H*, and the reed on the way. Weights on the beams or rollers kept the warp stretched. When the weaving was going on, and the weaver desired to wind up the woven cloth, and at the same time to draw out some of the warp, she could do so without leaving her seat by taking hold of a lever, which on being raised released a paul from a ratchet wheel, and loosened the warp beam. When she had drawn off sufficient warp, and had wound up the cloth, she could fasten the paul on the ratchet, thus holding the warp tight. The earliest looms did not have this device. Inserted through the warp threads back of the harness were two smooth sticks called shed sticks, *D*, which kept the crossing of the warp intact. If a warp thread broke, it could be easily traced by

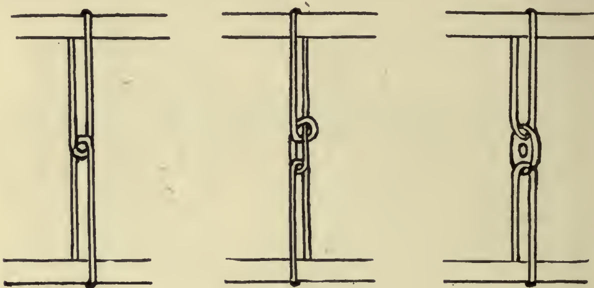


FIG. 36.—HEALDS.

means of these sticks. They were the earliest form of heddle, but are still in use as shed sticks on account of their value. (2) *Shedding:* The harness of the hand loom resembled somewhat a collection of heddles of the Zuni principle (Fig. 35). A series of healds or heddles were made of cord, and suspended on two laths or sticks. The cords were tied in various ways (Fig. 36), but in such a manner that there was an opening in their centers called the mail eye, through which warp threads could pass and be raised or depressed when a particular heald shaft was in use. Threads not needed passed between some heddles to be threaded through others. When a number of healds were on one lathe, it was called a shaft, sheaf or leaf of healds (Fig. 37). The office of each heald shaft was to affect certain threads by drawing them up to form a shed when the pattern required it. The method of threading these shafts, the number to be used and their succession, was indicated by the design and its draft. (See Chap. IV.) For plain weaving two or more shafts were in use. When the yarn was coarse two were sufficient, but when it was fine, four shafts or even eight prevented the friction of the threads. For complex weaving three or more shafts were used. The method of threading the healds and fastening the shafts to the treadles

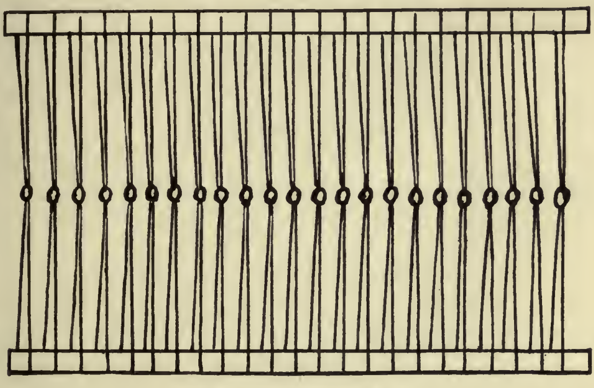


FIG. 37.—HEALD SHAFT.

T controlled the warp threads, which could be drawn down as needed to make the shed (Fig. 38). These shafts were suspended from the framework over a roller, or tied by jacks which worked on a pulley, and therefore could be moved up and down. The shed was made by drawing down the various shafts as needed. (3) *Picking:* This was accomplished by means of a shuttle which held a bobbin or quill with the filling thread. It was boatlike in shape, and had an eye in one end through which the thread from the bobbin came. As part of the warp was depressed the shuttle was thrown through by one hand and caught by the other. A new shed was made and the shuttle returned. A selvage was formed around the last warp thread on either side. Kay's patent of the picking stick and the fly shuttle, and his son's patent of the drop box, put a quicker means of working into the hands of the weavers. (4) *Battening:* The lathe, or sley, *E*, was set into a framework suspended from above or fastened below. It could be easily drawn forward by the hand, and pressed against the finished cloth, making it solid and even. In order to drive home every thread, a reed was set in the lathe. Reeds were made of a series of wires of a varying degree of fineness, according to the coarseness or the distance apart of the warp threads. One or two warp

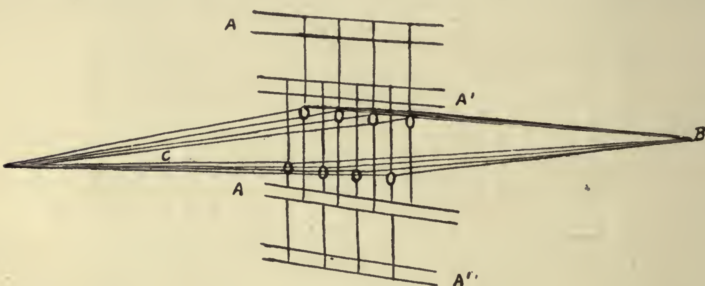


FIG. 38.—DETAIL OF HARNESS, SHOWING ONE HEALD SHAFT RAISED, THUS FORMING SHED.

A, A', Heald shaft. *B*, Warp threads. *C*, Shed.

threads were passed through each dent or division of the reed. The width of the threads as they lay in the reed was the width of the finished cloth. The lathe with its reed was the development of the hand-shaped comb or the sword used in early times. A temple or tenterhook (Fig. 39) held the cloth the desired width and kept the weaver from drawing the threads inward as she worked.

The Working of the Loom. — If a plain design is to be woven, every other warp thread must be up while the alternate threads are down. Consequently if two shafts are used there will be one treadle tied to each; but if four or eight shafts are used for plain weaving, two or four will be fastened to one treadle and two or four to the other. The usual way in hand loom weaving with four shafts is to fasten the first and third shaft to one treadle, and the second and fourth to the other. It is more common in power weaving to have the first and second shaft act together, and the third and fourth. The healds are threaded in such a way that the odd numbers, such as 1, 3, 5, 7, 9, etc., will be in the first and third shafts, and the even numbers in the second and fourth. The drawing-in is from the back of the loom and from the left to the right. The weaver depresses one treadle, with the threads attached to it, leaving the alternate ones up.

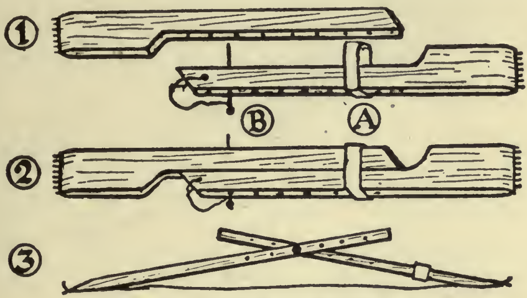


Fig. 39.—Temple or Tenterhook.
From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

She throws the shuttle containing the filling which passes out from the eye, leaving a thread behind in the shed (Fig. 40). She draws forward the swinging lathe or batten with its reed, through the dents of which are the warp threads, and drives the filling home. She then pushes back the lathe, and is now ready for the alternate shed. She removes her foot from the first treadle, and depresses the other, proceeding as before. If a thread breaks, as frequently happens, she stops to find it. The shed sticks are of use to her in tracing it, for it frequently breaks and springs back all the way to the warp beam. She must, therefore, after she has found her thread, tie a new piece of yarn to it with the weaver's knot, bring it under and over the shed sticks, through the correct eye of the heald, and up to the cloth, where she holds it in place until she has woven

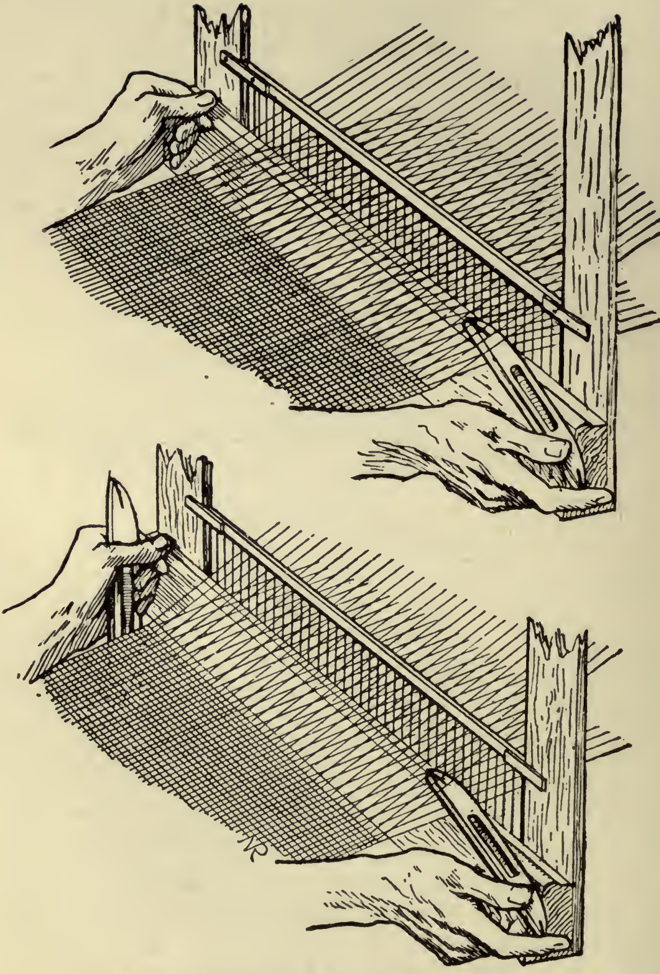


FIG. 40.—THROWING THE SHUTTLE THROUGH THE SHED.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

a few lines. After it is well woven in, the end can be cut off. If the filling gives out, or a new color is to be used, she opens the shed which contains the end of the last thread, lays the new thread an inch over the old, battens the new into place, and continues weaving as before.

Winding, Reeling, Warping, and Drawing In. — The threading of the hand loom is a tedious process. The procedure is virtually the same in the power loom. A warp is formed of as many threads or ends as are needed in the width of the cloth. Each thread must be the same length and wound smoothly on the warp beam. An important part of successful weaving is the preparation of the warp and the threading of it into the harness, or the drawing in. This was done by hand at first, but power now accomplishes the same result by an elaboration of parts which take the place of the hand. The necessary steps as taken by the hand workers are given in the following outline:

1. The bobbins of spun yarn are taken from the spinning wheel.

2. The yarn is wound from the bobbins on a reel, thus making a skein of definite length. The clock reel (see Fig. 8) is used, as the click indicates the time when the skein should be tied or removed.

3. The skein is put on a swift (see Fig. 8) and the yarn is run off on bobbins.

4. Bobbins to the number required are put on a creel, scarne, or bobbin frame. (See Fig. 9.)

5. The creel with its bobbins is put in front of the warping bars. (See Fig. 44.) The yarn is drawn from the bobbins to make the warp, a lease being kept carefully at one end of the warp.

6. The warp is taken from the bars or from the drum in (1) a chain form; (2) on a niddy noddy (see Fig. 8), or (3) on a stick, the lease always being carefully preserved.

7. The chain is taken to the loom, from which the harness has been removed. A special frame holding the warp beam is sometimes used. Two people are required to do the work. One lets out the chain from the end taken last from the bars or drum, and the other rolls up the warp on the beam as the chain is let out.

8. Cords are put through the lease of sufficient length to stretch the warp to the purposed width of the cloth. Careful watch is kept for broken threads or for threads out of place.

9. The threads must now be attached to the warp beam. They are slipped over a thin, flat stick which is attached to a piece of cloth fastened to the warp beam. Holes are punched at intervals in the cloth, and strings through these holes are tied to the stick. The warp threads or ends are stretched the required width on the stick.

10. The warp threads are distributed evenly on a raddle (Fig. 41) to a couple of inches wider than the cloth will be. The raddle is placed near the warp beam, that the ends of warp may pass through it and wind smoothly on the beam.

11. The warp beam is slowly revolved by one worker and the chain is let out by the other, who stands on the other side of the raddle. The threads

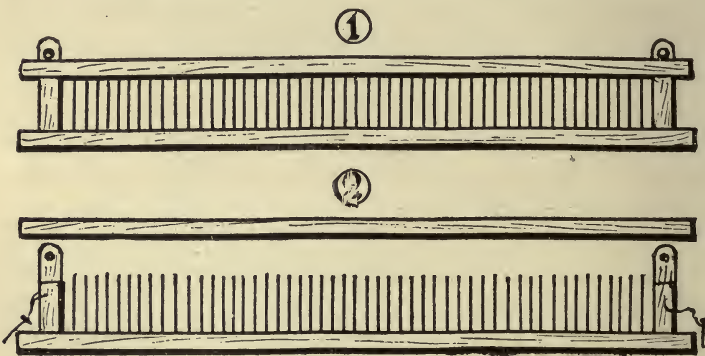


FIG. 41.—RADDLE.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

pass through the raddle and the lease and are wound up evenly on the beam until the end of the warp is reached. A coarse brush is often used to lay the threads parallel.

12. Two sticks are placed through the lease in place of the cords. They are tied together at each end to keep the threads from slipping off. The raddle is removed, the threads of the warp are cut through and tied in bunches of ten or twenty on the harness side of the lease. It is extremely important that the threads shall go through the harness in the exact order that they come from the lease.

13. The ends of warp are now threaded carefully through the eyes in the healds of the harness. The order in which this shall be done depends upon the particular pattern required, and is indicated by a draft. (See Design and Draft.)

14. When the threading of the harness is complete, the warp threads are taken one by one through the correct dents in the reed (Fig. 42).

15. The warp threads are passed over the breast beam and fastened evenly to the cloth beam in the same way as on the warp beam.

In general, when a warp comes to an end in a loom the threads are not pulled through the harness, but are left hanging in small groups and are tied together so that they cannot slip through. When that arrangement of harness is needed again, the new warp threads are tied to the old by a flat or weaver's knot, or twisted one by one to each of the former threads. This method saves much time. A good worker can twist in seven thousand new threads in a day. Machinery which does this work as well and more rapidly

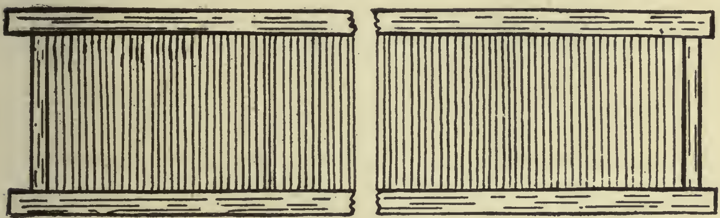


FIG. 42.—REED.

is on the market. It is expensive and not found in the smaller mills. Hand threaders are generally employed. Two workers are usually found sitting on either side of the harness. One pushes the warp thread through the mail eye with a little metal device, and the other receives it. Single warp threads are sized before weaving and after they are on the beam, to give them strength to bear the strain. Filling threads are not sized. For numerous details of warping and drawing in, see *Hand-loom Weaving*, by Luther Hooper.

Several processes mentioned in the above outline are given in greater detail below.

The creel (see Fig. 9) is an upright frame with a number of wire rods across it on which bobbins filled with yarn may be slipped. Threads are drawn from all the bobbins at once. The creels used by hand workers are of various sizes, carrying from ten to eighty bobbins. Those used for power warping frequently hold many hundreds. In hand warping the creel filled with its bobbins is placed beside the warping bars or

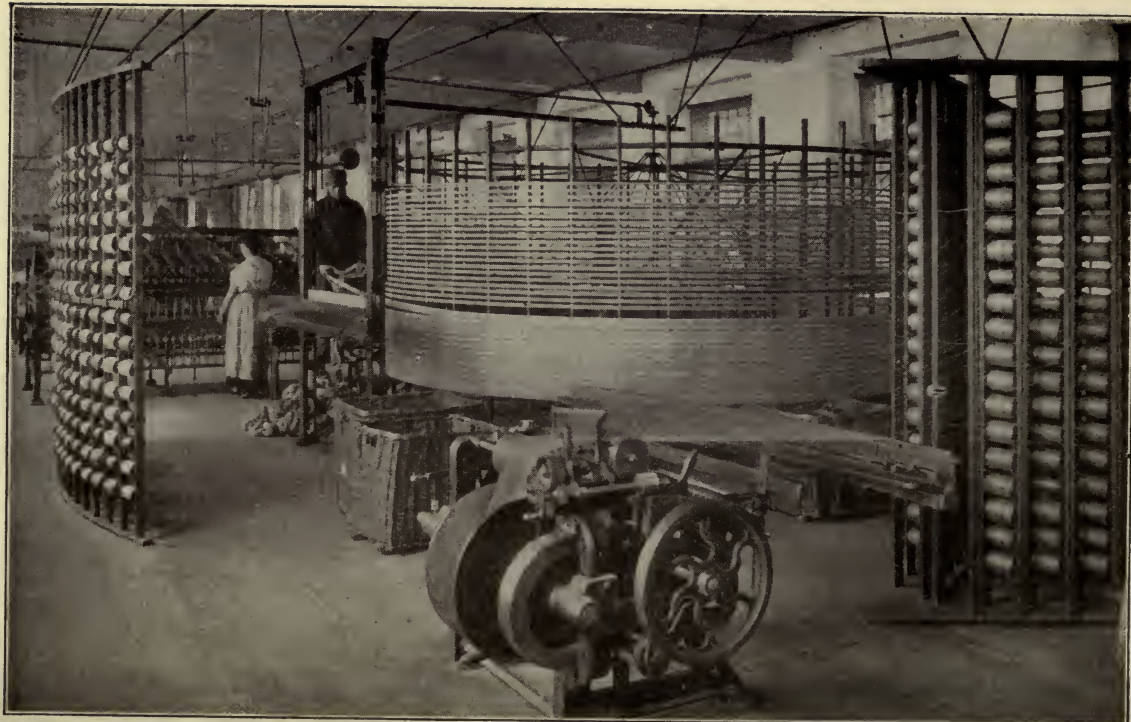


Fig. 43.—Hand and Sectional Warping. The Attendant is removing a Warp in Chain Form from the Drum.
Courtesy of The York Street Flax Spinning Co., Belfast.

drum, that the threads may be drawn from it for the warp. (See big reel in Fig. 43.)

Warping. — The purpose of warping is to lay in parallel order the required number of threads for the width of the cloth. These threads must be the length of the finished cloth. The method used is to draw a small number of threads to the required length and repeat until the full number for the width is secured. If a drum three yards in circumference is used and ten threads from the creel are carried ten times around it, the result will be ten threads thirty yards long. By reversing the movement of the drum and carrying other ten threads back, there will be twenty threads thirty yards long. The same work may be accomplished by a series of pegs, called warping bars (Fig. 44), set at a distance of three yards apart, on which the yarn is carried back and forth.

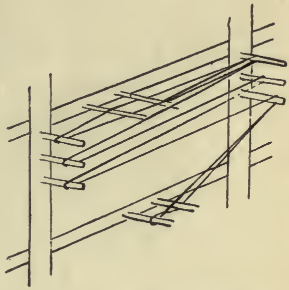


Fig. 44. — Warping Bars.

Making the lease is an important part of warping, for thereby the threads can be kept in perfect order, or if they become tangled can be set right again. Three pegs are placed on the warping bars or on the drum for the purpose. The threads are drawn from the creel, the ends knotted together and placed over the first peg on the drum, the two remaining pegs being used for the lease. The warper begins by grasping the threads coming from the lowest row in the creel in the palm of her hand, twists her hand as she takes the second row, so that these threads pass over its back, and continues this alternation through the succeeding rows. She now has the lease in her hand and places it on the pegs, noting the order of placing. She revolves the drum, letting the threads from the creel lie on its surface, until she has drawn out the length of the warp. At this point there are two pegs, around which the threads are wound under and over, but not in a lease, before bringing them back over the same track. She ties the bunch of threads together that she may later count them more rapidly. By reversing the drum she brings the threads back to the lease pegs. She must now make the lease again, remembering that she is reversing the manner of making it, but preserving the first plan. If the manner of placing has been such that the threads on the palm are on the

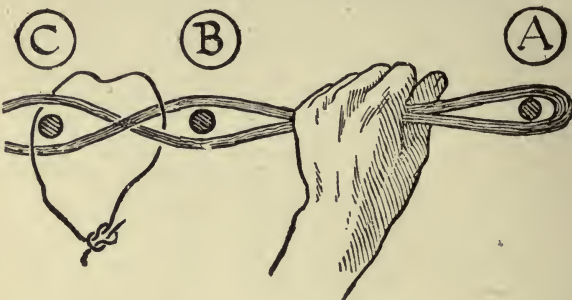


FIG. 45.—TAKING OFF THE WARP.
From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

second peg and those on the back of the hand on the third, on the return the reverse order brings the threads on the back to the third peg and those on the palm to the second. When the warp is complete and ready for removal two cords are inserted in the lease to keep the alternation perfect, and a cord is tied over all the groups of threads at the end. The first peg, to which the threads from the creel were tied, is removed, which loosens the warp, and it is taken off by looping it into a chain or taking it around a stick or niddy noddy (Fig. 45).

Power warping accomplishes the same object as hand warping. Many methods have been invented to meet peculiarities of the fibers. Filmy silk threads require different handling from cotton or wool. The yarn is in general prepared for warping on a spooling frame, and the bobbins or spools are placed in the creel. The threads are all drawn through a coarse reed. A lease is made automatically, a measurer indicates the length of threads passed through, a stop motion throws off the power if a thread breaks, and a distributer winds the threads evenly on the beam. Large drums or reels for winding the entire warp at one time, and also sectional warpers are used. (See Fig. 43.) The latter forms the warp in small divisions to be later united on one beam. Creels are V-shaped and also semi-circular.

Taking Off the Finished Cloth. — The warp threads are cut a few at a time far enough from the finished cloth to prevent raveling, and from the harness so that they will not pull through. They are then tied with a flat knot in small bunches, to keep them from slipping through the mail eyes of the harness. The paul is released from the ratchet and the cloth beam is taken out and the cloth unrolled.

Tapestry Looms. — The modern tapestry looms are found in horizontal or vertical form, the latter looking much like the vertical looms of antiquity. The warp is stretched tightly in the frame, and the pattern is put in by the fingers. The filling is inserted as a plain weave, but the use of color forms the pattern. Many colors are often used for the filling, and are usually put in by a sort of needle or bobbin. Two heald shafts are generally used, so that the alternate threads can be raised together and simplify the weaving, not only when the filling is to be thrown all the way across the warp, but also when only a small section is needed. The vertical loom was quite usual in Europe until about 1400, when a horizontal loom took its place. France developed tapestry weaving in the time of Francis I., especially in the city of Arras, the weaving being called Arras work. Raphael and his students were designers for these tapestries. The Flemish tapestry weavers were considered the finest. Ghent formerly had seven streets devoted to this class of weaving. Although the industry has declined, tapestries are still woven. Some of the noted modern studios are the Gobelin atelier in Paris; the weaving sheds at Merton Abbey in England, where William Morris revived tapestry weaving; and the studios of Albert Herter in America, where French Aubusson weavers are employed, the work being done on horizontal looms.

CHAPTER IV

POWER WEAVING

The Transition to Power Weaving. — During the early Middle Ages an increased demand arose in Europe for rich and elaborate materials. It was difficult to weave these on the plain hand loom. The Crusaders are given the credit of introducing the Draw Loom into Europe from Damascus, the term damask, used for elaborately designed linen, being taken from this city. The hand loom was naturally limited in the number of heald shafts and treadles which one worker could control. The draw loom allowed a wide scope in patterns. The shed was controlled by a series of cords attached to the heald shafts, which were pulled down in succession by an attendant called the "draw boy." The weaver gave his attention to the weaving. Later an automatic attachment providing for mechanical shedding was invented, which took the place of the boy. A similar loom without the automatic attachment is still used in the East.

In 1678 a loom was invented by M. de Genres of France, which embodied many modern principles, but little was heard of it. In 1745 another Frenchman, M. Vaucanson, brought forward his loom, which had the principle of shedding later used by Jacquard. It also had an embryo friction roller and a take-up motion, which are now found on the modern power loom. The invention of automatic spinning in England gave an impetus to weaving in that country. In 1733 John Kay invented the fly shuttle (Fig. 46) which increased the power of the weaver many times. He placed a shuttle race on the lathe, with a box at each end to receive the shuttle which the hands of the weaver had caught heretofore. Each shuttle box had a picker stick or driver connected with it, which when moved threw the shuttle across the race and through the shed. The motive power for the picker stick was a cord extending from one driver in a shuttle box to the other, and a peg in the center of the cord was held by the weaver. If he wished the shuttle to fly from either side, he drew the handle sharply to the opposite side, which caused the driver to give a sharp blow to the shuttle.

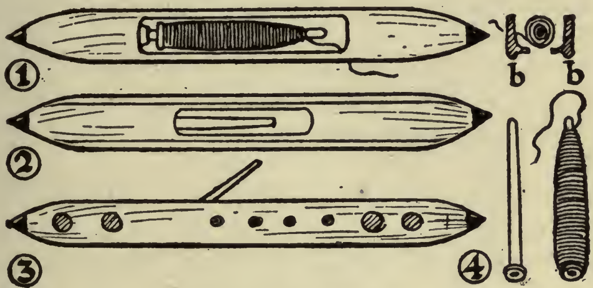


FIG. 46. — FLY SHUTTLE.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

The hand looms before Kay made twenty picks per minute, but the fly shuttle increased this to forty picks, and further improvements made possible sixty picks per minute. The early power loom brought the record up to a hundred picks per minute with one man in attendance. To-day one man can attend to from four to six looms, which according to the kind of materials woven will make generally from two hundred to two hundred sixty picks per minute, and have even made four hundred. On plain goods at the present time, one weaver has watched as many as two dozen looms.

In the middle of the eighteenth century it was still necessary to stop the hand loom every time a new color was needed in the filling, in order to place a bobbin or quill with this color in the shuttle. This difficulty was met in 1760 by Robert Kay, the son of John Kay, by his drop box. Several shuttle boxes were placed at one or at both ends of the lathe in place of one at each end. The shuttles held bobbins of different colors, and the boxes fell into place automatically. These two inventions of the Kays were of great importance in the history of weaving, and helped to bring on the Industrial Revolution. They made more weaving possible, but the spinning wheels of the day could not provide enough warp. The inventions of Hargreaves, Arkwright, and Crompton, however, made increasing quantities of yarn possible, and more effective weaving was soon needed. In 1775 a power loom was invented which had much merit, but unfortunately was not pushed. It was 1785 before Dr. Cartwright, of England, a clergyman of the Established Church, who had mechanical genius, brought out a heavy automatic loom. It was later improved and became the basis for the power looms of to-day. It required mechanical power to move it, the hand not being strong enough.

The Power Loom (Fig. 47). — The hand looms passed away slowly before the power looms. In 1830 Roberts invented his power loom which had a majority of the parts of the modern loom, and therefore required little attention. The hand weaver spent much of his time letting out the warp, winding up the cloth, moving the temple or tenterhook, changing bobbins in the shuttle, and mending broken threads. The modern power loom is a time saver, for everything is automatic. The harness, the pacing, or the let-off and take-up motions of warp and cloth, the self-acting temple, the fly shuttles and drop boxes move smoothly without attention. A detector in connection acts when the bobbin in a shuttle is empty, and causes the magazine to pass a new bobbin to the waiting shuttle, which can then finish its path. The empty bobbin falls into a receptacle below. A loose reed invented in 1841 (a fast reed had been used previously and is still in use) is so placed on a movable retaining board on the lathe that it can be pushed out when there is sufficient warp obstruction, thus stopping the loom and preventing further damage. When a shuttle leaves its race and plunges into the warp, technically called a smash, much harm will be done, if the loom continues running. The electrical

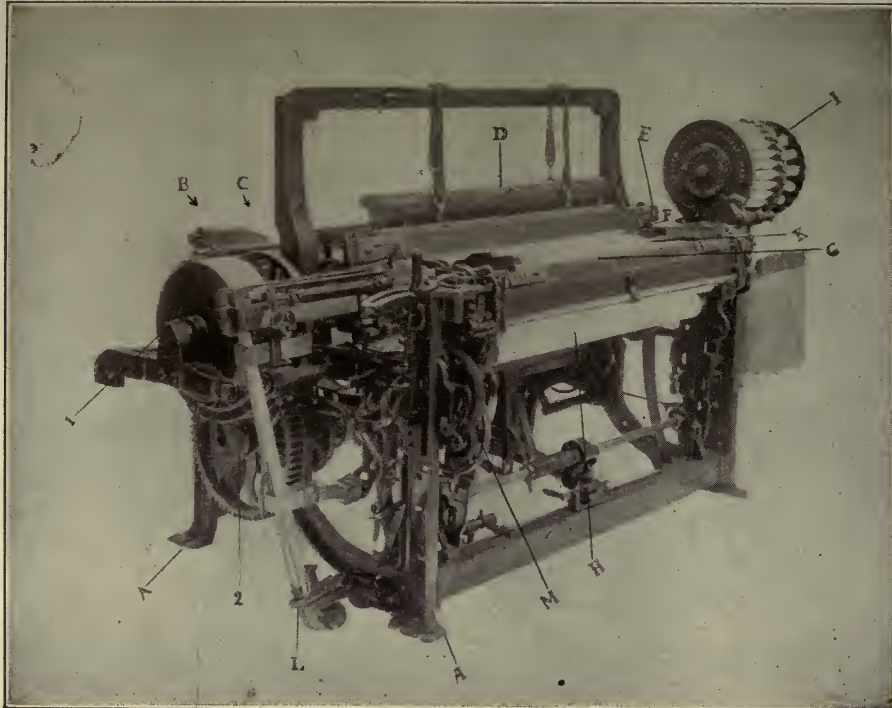


Fig. 47. — Power Loom.

Courtesy of The Draper Company.

" stop-motion " prevents this. It consists of wires which drop between the warp threads. If a thread breaks, the wire falls and completes an electric circuit which stops the loom. The filling stop is a weft fork which drops as the thread breaks.

It is easier to understand the power loom of to-day, if the principles underlying weaving and the simple parts of the regular hand loom of colonial days are understood. The power loom differs only in the multiplicity of parts necessary to take the place of the human hand.

Parts of the Plain Power Loom. — (1) *The Framework, A*, usually of cast iron, which holds the working parts. (2) *The Warp and its Manipulation.* The warp (ends) is wound on a beam, *B*, placed at the back of the loom. The figure does not show the beam; the letter *B* indicates that it is below. It passes over the whip roll, *C*, not shown in the figure, through lease rods or shed sticks to the harness, *D*, through the reed, *F*, which is in the lathe or sley, *E*, and over a breast beam, *G* (the place is indicated), to the cloth or goods beam, *H*. A temple, *K*, holds the width of the cloth near the last threads woven. An automatic letting out and taking up motion, *M*, gradually winds up the cloth on its beam as it is woven, and proportionately lets out the warp. The action is regulated through a cogged wheel set to the number of picks per inch in the cloth. In case of breakage the warp stop motion stops the loom. (3) *The Shedding.* This is effected by the motion of the harness, *D*, which is composed of as many shafts or leaves of healds as the pattern demands. (For Drawing-in, see below.) If a drawer-in has made an error and placed a wrong thread through any mail eye of the heald, it is sometimes rectified by removing the thread from the eye, taking a new bobbin, threading the heald with a thread from it, and carrying this thread through to the cloth beam. The bobbin is put on a spindle at the back of the loom to unwind with the warp threads. There are two methods of shedding, the closed and the open, based on different ways of separating the warp threads. (4) *The Picking.* By means of the picker stick, *L*, on each side, the shuttles, carrying filling bobbins, are thrown across the race on the lathe, *E*, when a shed is made, entering the shuttle boxes first on one side and then on the other. A stop motion is connected in case the filling breaks. Single or drop boxes or a magazine, *I*, are used to hold the shuttles. (5) *The Battening*. This is effected by the reed, *F*, combined with the weight of the lathe, *E*. The reed may be fast or loose in the lathe. (6) *The Temple*, *K*, holds the cloth firmly at either selvage. As threads are often strained by the temple, it is customary to have a close weaving near the selvage, or twisted or stronger threads are used in the warp at each side. Mistakes made in weaving because of broken warp threads sometimes do not show until the finishing, and are then hard to repair; therefore in some kinds of cloth weavers will raise the shafts of the harness several times a day to be sure each mail eye is filled with its thread of warp. Warp threads are frequently sized beforehand to make them smooth and strong for the strain of weaving. The jar on the warp is often so great in stopping the loom that a spring has been put on the framework to lessen the shock.

The Driving Parts of the Plain Loom. — Methods of actuating the loom differ somewhat in the various makes, but the following is representative of the direct loom control by the main shaft: The main or crank shaft, 1, extends a little beyond the framework, *A*. It is driven by a pulley, and is connected by wheels with the lower shaft; consequently the motion of the former is communicated to the latter or is reciprocal. The main shaft is cranked, and has connecting rods which give motion to the lathe, *E*, which oscillates on sley swords. The number of movements of the lathe is governed by a wheel which is set for the number of picks per inch in the cloth. The taking-up or pacing motion of the warp and cloth beams is connected with the motion of the lathe, and causes the cloth roller to move forward with each oscillation. The taking-up roller is a friction roller which moving against the cloth beam winds up the cloth. The other parts of the loom are moved by the lower or tappet shaft, 2. The transfer of power from this shaft to the other working parts is by a tappet wheel or by cams. By means of this lower shaft, the harness, *D*, which forms the shed, is depressed as needed by a tappet or by cams acting on the treadles. The picking motion is also controlled from this lower shaft through the arms of rocker shafts hitting the picking sticks alternately and thus throwing the shuttle back and forth through the warp each time the shed is made.

The loom is sometimes controlled through the lower shaft or by indirect motion. Many consider this gives a more uniform action of the parts. Whatever method is pursued, the important thing is the careful timing of each motion, so that one will succeed another without interruption, injury to the cloth, or too constant attention of the weaver or the loom fixer.

Looms vary somewhat according to the materials woven upon them. The terms "ribbon looms," "gingham looms," "worsted looms," "plush looms," "double cloth looms," and "carpet looms" are illustrations of adaptations to needs. The fineness of cloth is expressed by the number of picks and ends per inch with any count of yarn; thus in cotton 32 ends and 26 picks is coarse and 80 picks by 92 ends is very fine.

The modern power loom has become an almost perfect machine, the modern weave room a bewildering, throbbing mass of machinery. (See Fig. 96.) The inventions of the present are toward greater rapidity and toward the correction of small defects. Illustrations of this are the warp tying machines, invented to take the place of the "drawer-in"; elimination of oil stains; devices to prevent slack threads in the warp or bunches in the cloth from almost spent filling; or imperfect action in the numerous parts, such as skips and unevenness in the weaving. A simple power loom costs from $50 upward.

The Jacquard Loom (Fig. 48). — Harness looms are limited in pattern, but the Jacquard loom allows four hundred or more changes—practically an unlimited variety. The cost of working

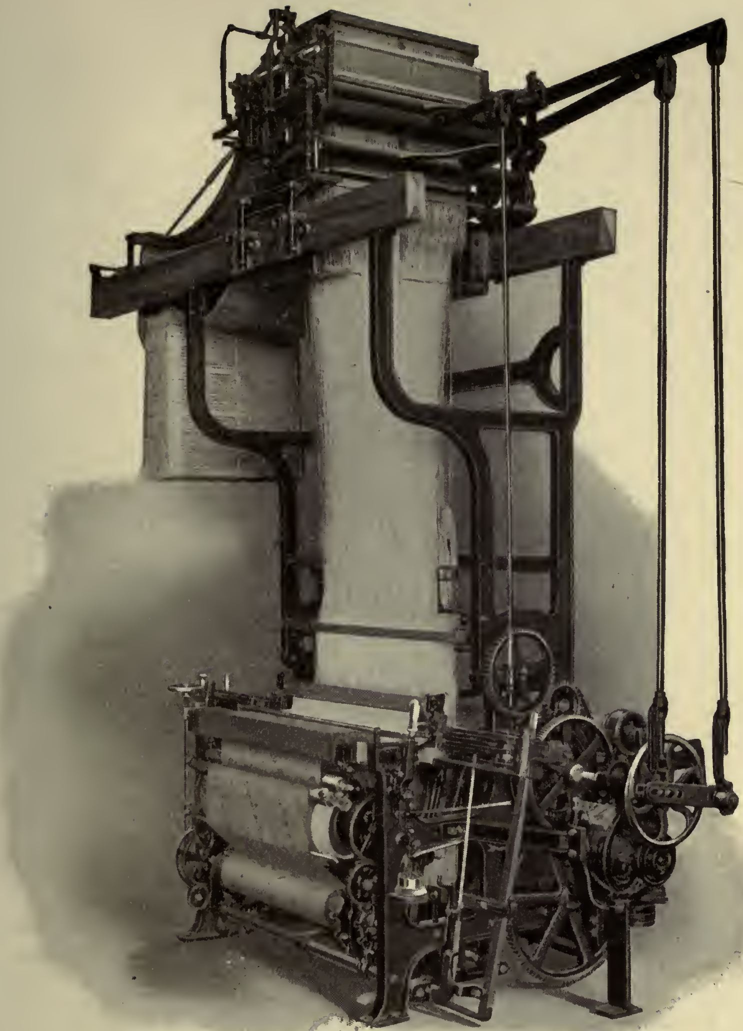


Fig. 48. — Jacquard Loom.

Courtesy of Crompton and Knowles Loom Works.

on the Jacquard is greater than on the plain loom. A twill containing sixteen changes (16-end) can be made on either the Jacquard or the harness loom, but the expense would be less on the latter.

The Jacquard was invented by Joseph Marie Jacquard, a straw hat manufacturer of Lyons, France, in response to a demand for a method of weaving more elaborate designs in silk and linen materials. His ideas were undoubtedly drawn from the Vaucanson model. The loom which at present is known by the name of Jacquard has many improvements over the original. The invention consists of a new method of shedding (Fig. 49), influenced from above the harness, whereas the harness loom is by treadles worked from below. It may be said in a general way that the principle of making the shed in the Jacquard loom is the raising of the harness cords (healds), *A*, by means of wire hooks, *B*, to which each cord is attached at its upper end. Each harness cord has a mail eye, *C*, through which a warp thread passes; consequently if the cord is drawn up, the warp thread rises also. Weights or lingoes, *D*, are attached to each cord at its lower end, which draw the cords back into place after the hooks have raised them. The warp threads are stretched between beams, as in the plain loom. In the Jacquard harness each warp thread is influenced singly, including the repeats of any one. In the simple loom the warp threads are controlled in the groups on any one shaft.

There are single and double lift Jacquard machines. The principal parts of the single lift Jacquard harness are the harness cords, *A*, the hooks, *B*, the mail eyes, *C*, the lingoes, *D*, and the beams (these have been mentioned already); the griffe or hook lifter, *E*, consisting of a series of blades, knives, or bars, which lift the sheds as do the tappets or cams of the plain loom; the needles, *F*, which work horizontally, and have one end bent back to come in contact with the spring in the spring box, *G*, and an eye in the center, *H* (the double lift machine has two eyes in the needle), to allow the hooks to pass through. The duty of the needle and cylinder, *I*, is to press forward against cards, which indicate the pattern and are against the batten. The needles govern the hooks, *B*, which pass through their eyes. The

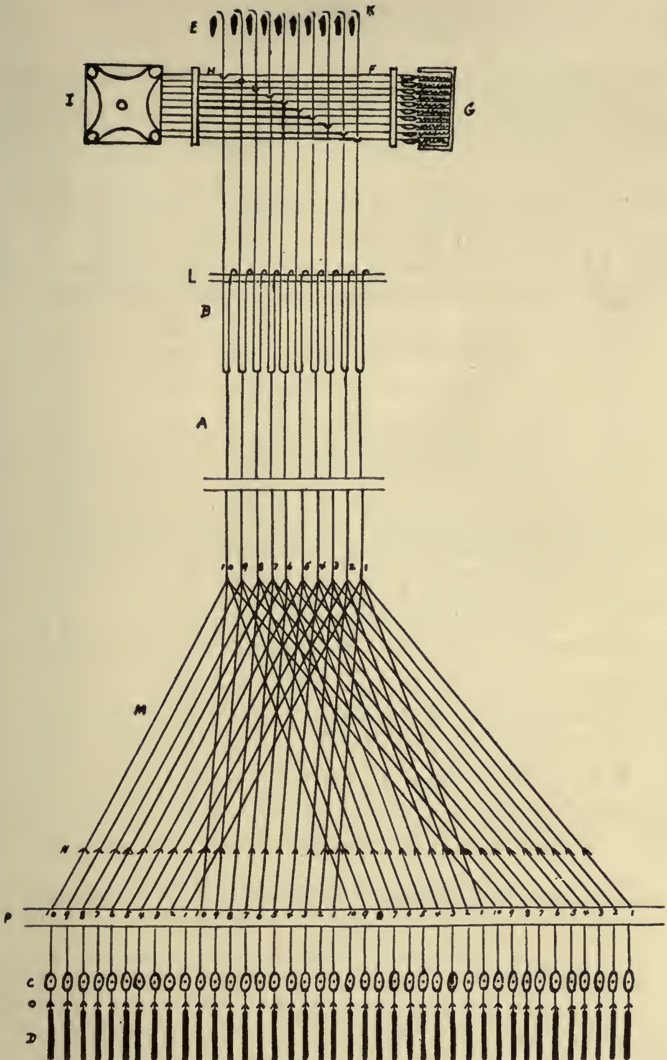


FIG. 49.—DETAIL OF JACQUARD LOOM.

A, Neck cords. *B*, Hooks. *C*, Mail eye. *D*, Weights or lingoes. *E*, Griffe or hook lifter. *F*, Needles. *G*, Spring box. *H*, Needle eye. *I*, Cylinder. *K*, Catch of needles. *L*, Hook rest. *M*, Additional harness cords. *N*, Couplings joining upper and lower parts of harness. *O*, Knots holding heald lingoes to cords. *P*, Comber board.

hooks work vertically and are made with a catch, *K*, at one end, which goes over the griffe but can be easily detached. They rise automatically with the griffe unless the needles are pushed back by the cards, which will throw the hooks from the griffe, thus lowering the warp threads and making a shed.

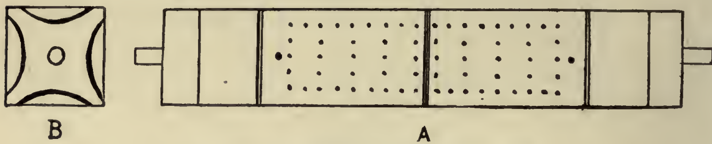


FIG. 50.—CYLINDER OF JACQUARD LOOM.

A, Cylinder. *B*, Cross section with cards.

The cylinder (Fig. 50) has four sides, and cards pass over it, coming in place alternately and indicating the pattern by pressing back those needles which are not required to raise the shed. The cylinder makes one quarter of a revolution with each pick of the pattern, thus placing one of its four sides in contact with the needles. The complete design is on the cards (Fig. 51), and each one represents one pick of the pattern. The cards are laced or tied together in perfect order at each end and in the center (Fig. 52). When

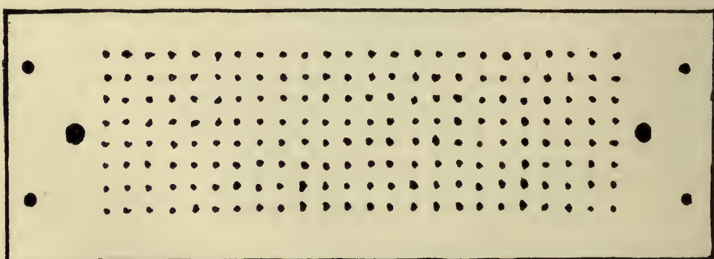


FIG. 51.—CARD OF JACQUARD LOOM.

the pattern is completed the succession of cards begins again. The cards fall in place at the right moment against the cylinder. If there are holes in the card, they come directly opposite those in the cylinder. All the needles advance automatically, and some of them pass through the holes in the card. Those that do not pass into holes are thrown back and the hooks attached to them are thrown from the griffe, thus lowering the shed.

Figure 49 shows only a part of the threads of the harness. For the complete loom see figure 48. The neck cords, *A*, are attached to additional harness cords, M, which give repeats to the pattern if any one of the neck cords are raised. At N are a series of knots or couplings, which connect the upper and lower portions of the harness, and at O are the knots which hold the heald lingoes to the cords. The comber board, P, keeps the harness cords from tangling, for each cord is passed through a hole in the board up to the neck cords. The number of cords in the comber is regulated by the threads per inch in the warp. The comber is divided into as many sections as there are hooks in the machine. An iron frame incloses the working part of the Jacquard loom. The power is applied as in the plain loom.

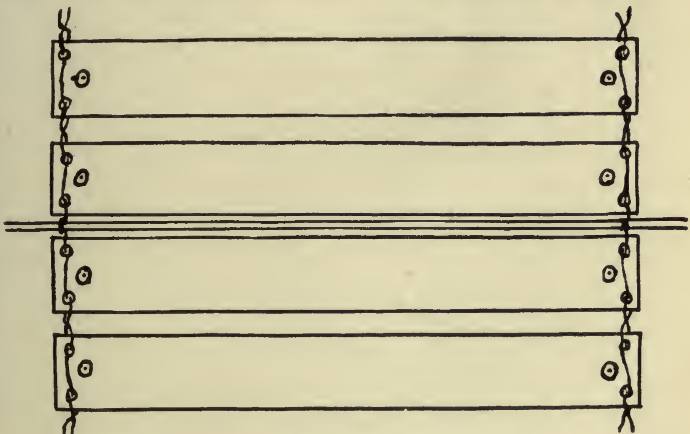


FIG. 52. — LACING OF CARDS (Jacquard Loom).

There are many varieties of Jacquard looms, from the small one hundred needle to the two thousand needle machine. While they vary in some particulars, there is a general standard. The double lift machine generally has eight hundred hooks, two to each thread, and also two griffes. Two patterns can be made at one time upon it, one for background and one for figure, as in damask table linen. The expense of the Jacquard lies in the making of the cards, the setting up of the harness, and the slow motion of the loom. For setting up an elaborate design requiring four thousand cards and four hundred needles, the cost would be about $120. The arrangement of the harness for such a design would take a man about five weeks. Exception-ally elaborate designs will have as many as twenty thousand cards at a cost of $600, and the setting up of the harness would be the equivalent in time of a year's labor of one man. Lace curtains are woven on special Jacquard looms in which there are three lines of threads, a warp beam holding those which run straight, bobbins holding the zigzag threads, and the pattern is made by threads coming from spools. In the ordinary Nottingham curtain as many as seventy-two hundred threads are often in the harness of the Jacquard. The lace curtain looms are very wide. Carpets, such as Brussels, Wilton, and Axminster, are woven on specially adapted Jacquard looms.

The making of the cards requires special machines, one for cutting and another for duplicating. Each design is made first on squared paper in the usual way. The cards are first printed with a series of dots upon them. Each card is to represent one pick of a pattern, therefore holes are punched through the dots when the pattern appears on the surface. The worker has the design before him and reads a line across, punching the cards as he reads. His machine is similar to the typewriter. The cards are carefully numbered as they are punched, and are later laced together and hung over the cylinder of the Jacquard.

The expense in Jacquard weaving led to further inventions by which the effect could be attained without the cards and elaborate harness. An English invention, the *dobby* attachment, which is placed on the harness loom, is an illustration (Fig. 53. Dobby in upper left-hand corner). The result of its work is similar to the Jacquard, but the shedding is effected by a chain of narrow strips of wood (lags) into which pegs are placed which indicate the pattern and take the place of the cards. Each lag represents a pick of the pattern. On reading the design for the pattern a peg is inserted when the pattern is on the surface. In the loom the work of the pegs is to raise the harness. They travel around the cylinder and come in contact with the levers which lift connected hooks, and the latter raise the shafts attached to the hooks and make the shed. A second chain controls the shuttle. Multiplier chains duplicate the pattern and save time which would otherwise be taken in preparing the lags. The modern dobby offers almost unlimited possibilities.

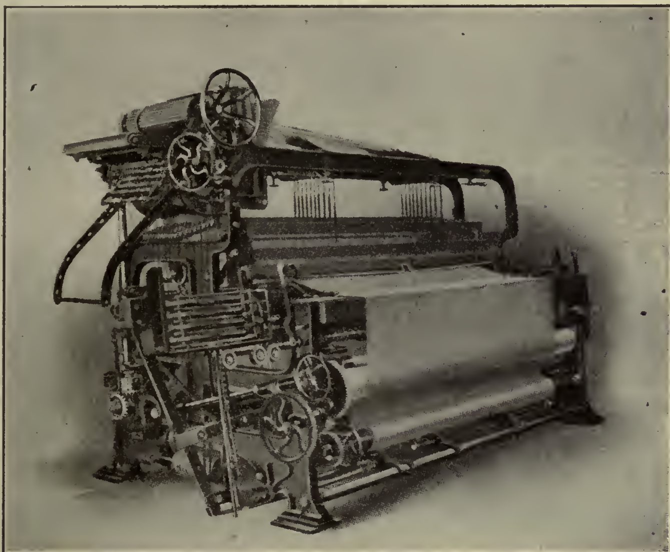


FIG. 53.—LOOM WITH DROP BOX AND DOBBY ATTACHMENT.

Courtesy of Crompton and Knowles Loom Works.

Another method of weaving intricate patterns without the use of the Jacquard harness is by the *head motion* attached to the harness loom (Fig. 54, showing detail). This is an American invention and is used extensively in the United States. The heald shafts in the loom are elevated or depressed by pulleys, but the series of mechanical devices which actuate the pulleys is quite different from the English dobby system. It is claimed that the head motion is simpler and more steady than the dobby. The pattern chain consists of high and low links, which control the elevation and depression of the shafts.

The chain is made of a series of rods on which bowls or small

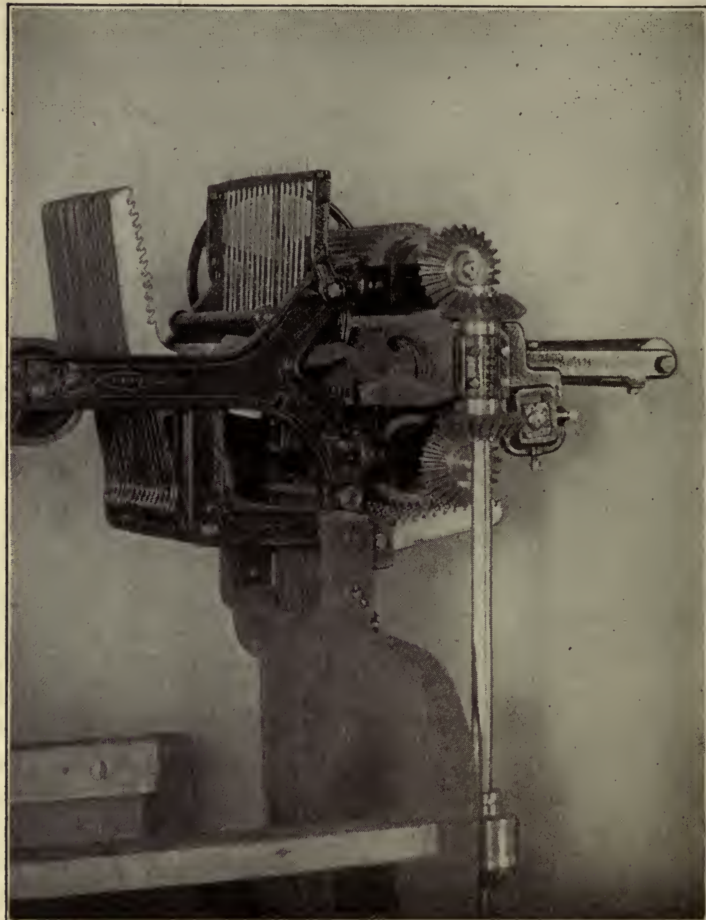


FIG. 54.—HEAD MOTION.
Courtesy of Crompton and Knowles Loom Works.

pulleys and lifters or risers and tubes called sinkers are arranged according to the requirements of the design. The chain lifts the shafts by means of the bowls or risers which come in contact with vibrators, and they again with the lifting cylinder connected with the heald shafts. A second chain is used to control the shuttle. A reversing motion is connected which is of great value when mistakes in weaving have been made.

Patterns may be woven on the surface of cloth to resemble hand embroidery, with an attachment to the regular loom called the *lappet*. It affects the shedding, and is used extensively for decorative cotton goods. The embroidery may be continuous or intermittent. The floating threads left on the wrong side of the cloth by the lappet frame are shorn off later by a finishing machine especially adapted to the purpose.

Swivel Weaving is somewhat similar to the lappet. It is used extensively in weaving silk ribbons and broad silk materials. The swivel attachment affects the picking motion and produces small continuous or intermittent figures without continuing the thread from one side of the material to the other. It thus prevents the waste of valuable silk by using it only when necessary. The cards of the Jacquard machine can control the swivel patterns. Swivel attachments are expensive and the action slow. The lappet frame is more economical. There are other varieties of embroidery attachments.

Leno or Gauze Weaving departs from the usual straight lines of warp, for in it adjacent warp threads twist about each other in various ways, letting the filling pass through, thus holding the cloth together and keeping the threads from untwining (Fig. 55). The

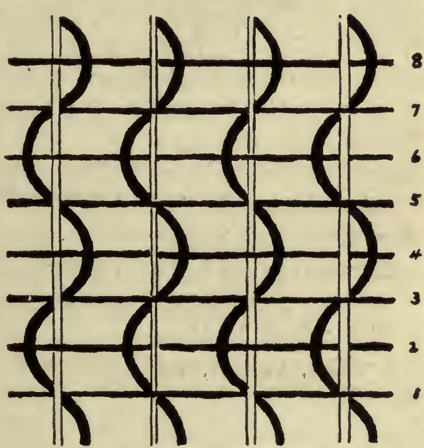


FIG. 55.—GAUZE WEAVE.

work is a sort of wattling and may be simple or elaborate. Leno weaving (Fig. 56) depends upon the manner of threading the harness. There is a standard heald and a doup heald. The latter can be drawn first to one side and then to the other of the standard heald, and the gauze can thus be made as desired. When closely woven, Leno weaving is enduring, but much of it is unsatisfactory. Marquisette is woven in this way. The same principle is used for making the yarn for chenille curtains.

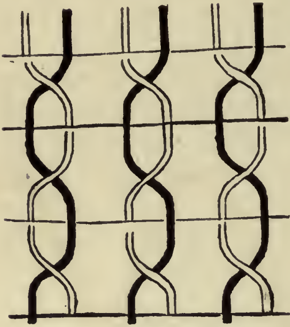


FIG. 56.—LENO WEAVE.

Pile Fabrics. — Terry fabrics used for Turkish toweling and other pile goods are made on looms which at intervals omit a couple of picks of filling and then push the warp together into loops. These are held in place by succeeding filling threads (Fig. 57). In cheap grades, the loop thread is easily pulled out of its place, for few filling threads are inserted between.

Silk and worsted velvets and warp plushes are made in various ways. Good qualities of silk velvet are woven much like Wilton carpet, that is, an extra warp passes over a series of wires having sharp edges, which when withdrawn cut the loops of warp. The cutting of silk velvet is along the width, that is, the warp is cut. Silk-faced velvets often have cotton backing. Cotton velvet is woven differently from silk velvet, the pile being made by the filling, and the cutting is along its length. Some plushes are

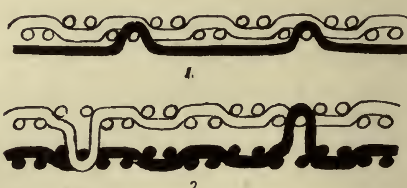


FIG. 57.—DOUBLE CLOTH INTERLACING.

1. Weft back. 2. Double cloth interlacings.

From Barker's *Textiles*, by courtesy of Constable & Co., London.

woven as double cloth, and are cut between the cloths, leaving a pile on each side (Fig. 58). Cotton velvets, corduroys, velveteens, and filling plushes are really varieties of double cloth. They are woven in a rib pattern, the cord being along the filling. The surface loops are cut by hand with a long cutter in the direction of the length. Cotton velvets require a great deal of finishing to make them look well. (See Finishing Cotton Goods,

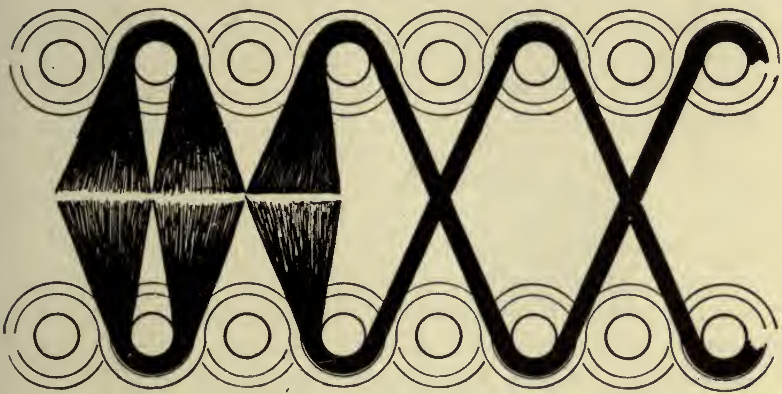


Fig. 58. — Plush Weave.

From Barker's *Textiles*, by courtesy of Constable & Co., London.

Chap. VII.) In their weaving the backing threads are brought forward to form part of the pile, and also to connect the two rows of warp threads. Different weaves are used to form the face and the back respectively, but the two must be designed to work in harmony with each other, or the finish will be defective. Crêpe or other crimped fabrics are woven in a variety of ways, plain, ribbed, or twilled. Some are made by using a sateen twill for the filling and a satin twill for the backing, the aim being to confuse the surface of the material by the way the stitches from the back break the face. Crêpe is also woven with the warp yarn twisted in one direction and the filling in the opposite. In the dye vat these yarns are differently affected and the cloth is inclined to cockle. They may be woven also with an extra special warp beam which allows the warp to be a little loose, while the threads on the regular warp beam are tight. When the filling is beaten up, the looser threads are rather full and the finishing gives them the crêped appearance. Wool crêpons are sometimes made with the backing threads of cotton. By mercerizing the material after weaving it, the floats of wool are drawn together by the cotton, which is contracted. Moiré or watered effects are made by the manner of finishing after the cloth is woven. The material is placed over hot milled rollers which are arranged to give a watered appearance to the goods.

Stitched, Backed, Double-faced, Double, and Multiple Cloths. — Looms are constructed to weave double and multiple cloths, but by special warps and double harness the regular loom can serve the purpose. Backed cloths referred to above are made by weaving them in such a way that extra backing warp is held by filling stitches to the face, making the cloth heavier. (For Draft see Fig. 69.) The stitch on the surface comes under adjacent face threads and is invisible. Double-faced cloths are made similarly to backed cloths, but are well finished on both sides, silk-faced ribbons being illustrations. Figuring on a plain surface by extra warp and filling threads is done in a similar way to the double-faced cloth, except that the design appears only at intervals. Cloths having long floats of warp or filling on the surface to carry out the design are made with a double warp or filling, and stitches come from the back to hold down the floats. Satin and sateen twills are much used for backing stitches. The double, triple, and multiple cloths have both double warp and double filling. They can be so woven as to be entirely separate, and when unfolded make a wide sheet of cloth several times the width of the loom, or they may be fastened together on one edge or on both edges and make tubular fabrics for bags, hose, or lamp wicks, or the two cloths may be held together at regular intervals and thus make reversible material for heavy coating and rugs. Backing yarn is frequently made of much cheaper fiber in order to decrease the cost while adding to the weight. Shoddy, coarse wool, and cotton are used for backing threads.

Design, Pattern, Draft, and Drawing-in. — Weaving may be very simple, with only an alternation of two sets of threads, as in cheesecloth (see Fig. 4), or it may be so complex that hundreds of changes are needed to complete the pattern, as when coats of arms or portraits of noted people are woven on Jacquard looms. When the hand loom could produce the intricate designs which we see in the Spanish, Italian, Sicilian, and Oriental cloths of the thirteenth century, a system of design was used to indicate the pattern, called drafting. A draft showed the weaver: first, the manner in which the filling should cross the warp; second, the entering or drawing in of the warp threads into the harness; third, the tying of the heald shafts; fourth, the treadling or succession in working the treadles. Figure 59 shows a common way of indicating to hand-loom weavers one variety of the diaper, bird's- or fish-eye pattern. The draft has therefore the following meaning: There are four heald shafts; *i.e.*, there are four straight lines representing the shafts, and four treadles are attached singly to each shaft. The method of entering, drawing in, heddling, or threading the heald shaft is shown in Fig. 59 *B*.

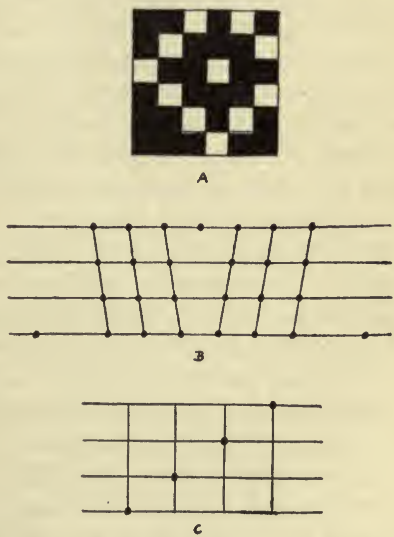


FIG. 59.—FISH- OR BIRD'S-EYE PATTERN.
A, Draft. *B*, Entering. *C*, Treadling.

The first heald of the first shaft takes warp thread number 1. In this same shaft will follow threads 5, 9, 13, 15, 19, 23; and thread 27 will begin the series again. The other warp threads are to be distributed in the other heald shafts as indicated. The treadles are fastened separately to the four shafts as shown in *C*. Every weaver has his own regular method of treadling, which he follows when possible, as it makes for speed. Elaborate patterns can be made by hand weavers from one set-up of the loom by different ways of treadling. In the early days of weaving each treadle influenced one heald shaft, but soon it was found that by tying the heald shafts together in various ways other effects could be gained. One shaft could work singly or in combination, hence, long before the power loom was invented, wonderful designs were made with even a few shafts. Two sets of harness were often used for controlling the warp. One set gave the background, the other the pattern. Damask of elaborate design was made in this way, having a twilled background and a complicated surface pattern. Each harness was used as needed, and the heald shafts hung free enough to be used singly or in combination.

Textile design may be structural (pertaining to the weave) or surface. Some varieties need have but a hasty mention, such as Oriental rug making, in which threads of yarn are tied around the warp thread and held together by filling threads, or embroidery in which the hand or machine makes the design on the completed cloth. The Swiss embroidery machines, the French Corneli, and the American Singer machine are illustrations of mechanical embroidery. The India shawl method of decoration, in which small, richly woven pieces are fitted together like a mosaic or like stained glass and sewed with a needle, is another instance. Surface decoration of textiles may also be done by the way of finishing the cloth, also by block or color printing by machine, either on cloth or yarn; by stenciling or batik work (Javanese method), or by discharge of color by printing designs on cloth with chemicals and then using heat to remove the color.

The principal structural method of ornamentation is by interlacing the threads; *i.e.*, by the way the filling or picks are floated, flushed or shot over or under the warp threads. To accomplish this interlacing the heald shafts carrying the warp threads through their mail eyes are lifted up, letting the filling pass under them; or depressed, letting the filling pass over them. In the first instance, the warp appears on the surface; in the second, the filling is on the surface. The varieties of pattern are attained by the manner of raising the sheds. Other factors may influence, such as the introduction of varieties of fibers, or different sizes or novelties in yarn. Even the plain weave may be thus ornamented, and effective ribs and cords given, or stripes either lengthwise or crosswise, by color alternations or checks and elaborate plaids. The omission of threads at intervals is also used to gain lacy effects. The great possibilities in design, and the elaboration of the draft to explain the intricate weaving plans, make the full study of drafting one for the expert. Fortunately, analysis of designs has yielded the fact that the chaos of patterns may be reduced to a few fundamental principles. In straight line warp weaving there is (1) the plain or tabby weave and its variations; (2) the twill and its variations; (3) the satin and its variations, including figure weaving (pile weaving, double cloth, and lappet weaving belong to this group). In curved warp weaving there are gauzes, lenos, and marquisettes.

In the designing and drafting for the weaving of textiles, whether by hand or power, there are two lines of threads to consider: first, the warp or ends, which run lengthwise of the goods; second, the filling, picks, woof or weft, which cross the warp at right angles. The manner in which the latter threads intercept the former makes the design, complex as well as simple weaving depending on the succession of sheds. In drafting for power weaving the work of the treadles is not indicated, as that is automatic. Textile designers use squared or point paper for their drafts; eight by eight is a common variety

(Fig. 60). The Jacquard design usually requires ten by ten or twelve by twelve. These papers also come lined to represent coarser threads one way than the other, which condition is often found in weaving by having a heavy filling and fine warp. In general the squared paper is preferred. Ways of indicating the method of procedure on the paper in the draft differ slightly. In the accompanying illustrations the shaded blocks represent the warp threads and the white blocks show that the filling is on top with the warp underneath. The numbers when given at the side indicate the number of shafts or leaves required by the weave.

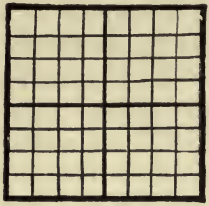


FIG. 60.—DESIGN OR POINT PAPER.

The simplest alternation of threads is called the plain, tabby, or cotton weave. It is found in muslins, ginghams, prints, Panama cloth, and in some canvasses and broadcloths. India and taffeta silks and crash toweling also use the tabby weave. See Fig. 61 for the draft, which looks like a checkerboard. The numbers at the side show that under the first heald shaft a warp thread is up and then a filling thread, followed again by a warp thread. In the second shaft the filling thread rises first. Two alternations complete the pattern. When coarse yarns are in use, a two-heald shaft is sufficient. (See Fig. 62.) In finer yarns, four or even eight shafts are used (Fig. 62), as a better distribution of the warp threads can be made, thus lessening the strain and liability to break. The threads are so inserted and the shafts connected that they act as two, the odd numbered threads being raised at one time and the even at the other. There are variations of plain weaving which give considerable latitude in design. Basket or Panama weaves (Fig. 63) have two or more warp threads crossed by

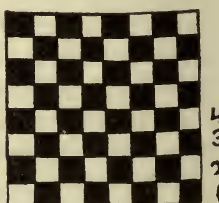


FIG. 61.—PLAIN WEAVE.

two or more filling threads, or there may be a greater number of threads one way than the other. Hair-line stripes, warp or filling way effects, can be made in the plain weave by alternating colored yarns in the warp and filling, or by alternating one way and having it plain the other. Bedford cords (Fig. 64) have a line stripe and raised cord effect running lengthwise of the cloth. The face effect is generally plain. Poplin or rep effects are made by very heavy warp threads or by groups of warp threads shot over by one or more filling threads (Fig. 65). The very twist of the yarn will affect the pattern (Fig. 66). If after interlacing the threads the twist is in one direction, a smoother effect results in the finishing.

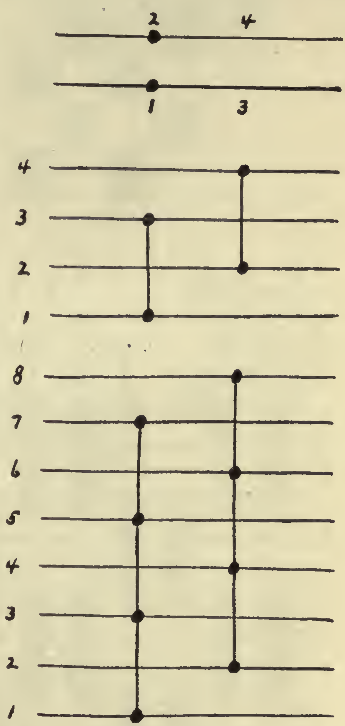


FIG. 62.—SHAFT COMBINATIONS FOR PLAIN WEAVES.

Twills are the first variation from plain design. The three-shaft, three-harness, three-end, or three-leaf twill, as it is variously called, is the simplest. (See Fig. 67 for four-leaf twill.) The names given to twills indicate the number of shafts which it takes to complete the pattern. In the three-shaft twill the filling threads go under one and over two warp threads in the first line, but instead of alternating in the second line, as would be done in plain weaving, the filling skips one thread to the right or left of the crossing of the preceding line, as the case may be, thus forming a diagonal line across the material. In the three-shaft twill, the pattern begins to repeat itself in the fourth line. Twills may run to the right or to the left or both ways. In the latter case the design is called chevron, herring-bone, diaper, bird's- or fish-eye. Twills may be so made that either warp or filling may be thrown on the face of the material. In the four-shaft twill (Fig. 67 *A*) the filling is on the face, for three filling threads are up and one down. In *B* the warp is on the face, as three warp threads are on the surface and one below; consequently the twill is made by the filling. For the warp-faced twill there would be three risers and one sinker on the chain of a head motion loom, expressed as 3/1. If it were a four-shaft twill, filling face, there would be three sinkers and one riser, throwing the filling on the face, and expressed by 1/3.

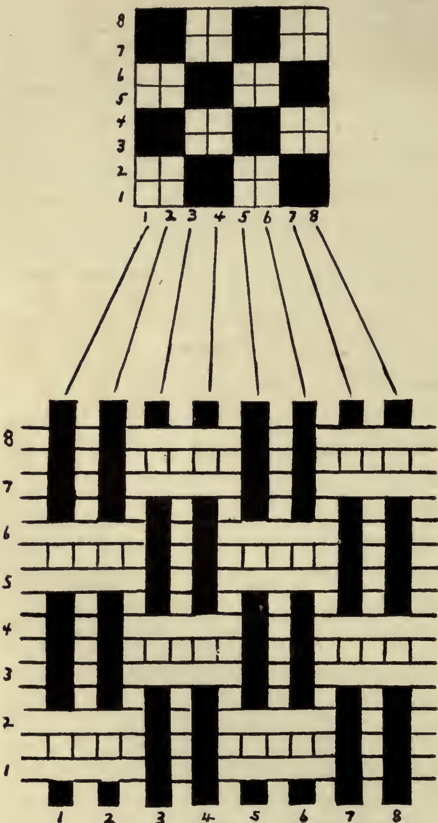


Fig. 63.—Basket or Panama Weave.

Drillings and jeans are often made on the three-shaft twill. Twills are among the most popular weaves. They may run as high as forty-eight or fifty shafts, each added number of shafts allowing a greater number of variations in the designs;

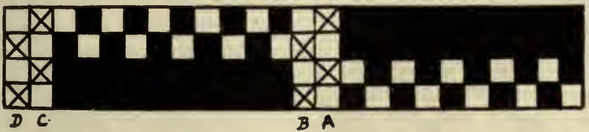


Fig. 64. — Bedford Cord.
A, B, C, D, plain weave throughout, forming line effect.

therefore it may be said that there is an almost unlimited possibility of pattern. Twills may be even-sided, filling and warp balancing; or uneven-sided, filling and warp uneven, each additional shaft having its own advantages and variations. The principle of designing for the twill can be understood from the simplest ones. The following varieties are in use: broken, skip, corkscrew, double, curved, combination, steep, wide-waled, entwining, checker-board, pointed, and fancy. The four-shaft twill is very useful in woolens and worsteds, being found in blankets, cassimeres, and shepherd's checks. It is much employed in double-backed and stitched cloths for the backing weave. The five-shaft twill is used extensively in heavy materials, in doeskins, satins and sateens, Venetians, drillings, diapers, and damasks.

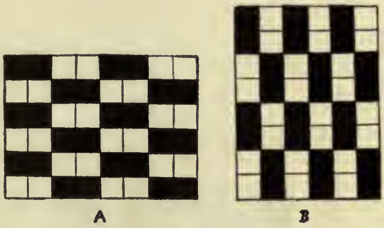
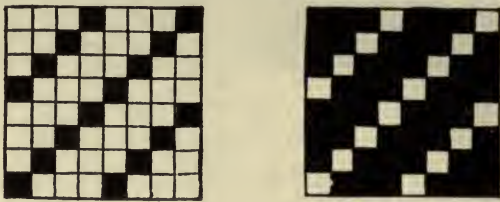


Fig. 65. — Poplin or Rep.
A, Warp ways. *B*, Filling ways.

Fig. 66. — Showing Twist of Yarn.
A, Left twist. *B*, Right twist.
C, Combination.

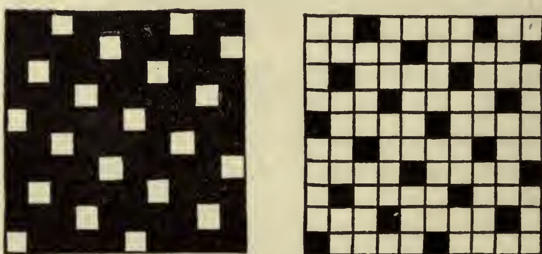
Satin weaving combines the characteristics of the twill and the figure, and may be included under twill weaving as well as figure weaving. The term satin or sateen (Fig. 68 *A* and *B*) is used to designate certain classes of design, such as five-shaft or eight-shaft satin. These same terms are often used inter-



A B

Fig. 67. — Four-leaf Twill.
A, Filling for face. *B*, Warp for face.

changeably, but according to some authorities the warp-faced design, *A*, is the real satin and the filling-faced is the sateen, *B*. The expression often seen, "weft-faced satin," would according



A B

Fig. 68. — Satin Weave.
A, Real satin: warp face. *B*, Sateen: filling face.

to these authorities refer to sateen, and "warp-faced sateen" would be satin. The word sateen was first used for cotton satin made to look like silk satin. Damasks are often woven with the background sateen and the figure satin, that is, the figure weave is a lengthwise twill and the background a crosswise one. The corkscrew weaves are on one of these principles;

they are a steep twill. The twill effect is made clearer to the eye if it runs in the direction of the twist in the yarn. Smooth-faced serges are woven in this way, and the effect of clear light

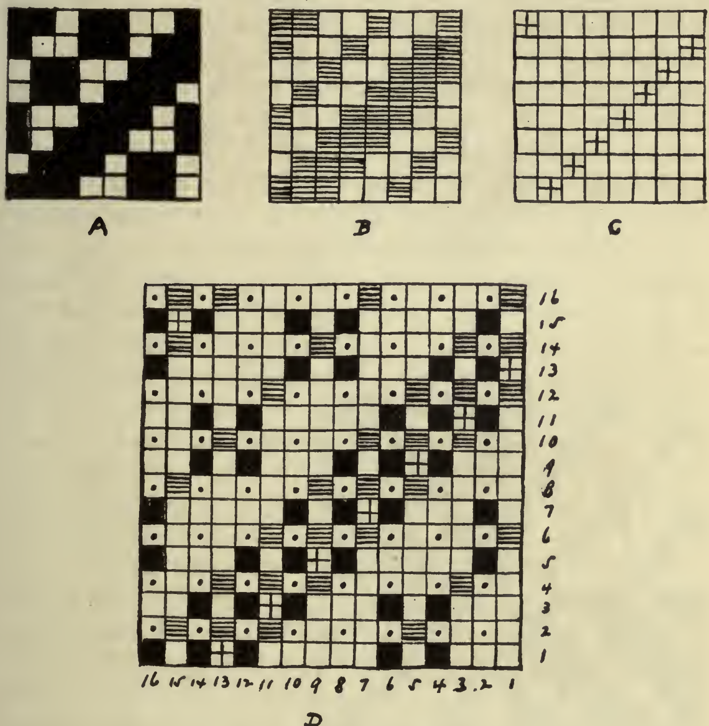


FIG. 69.—DOUBLE CLOTH WEAVE.

A, Weave for the face. *B*, Weave for the back. *C*, Arrangement for combining back warp with face filling. *D*, The complete weave. Repeat: 16 ends; 16 picks.

is increased by the finish. Rough twills are often woven with the twist of the threads running opposite to the pattern. Twills of various kinds are used extensively in elaborate floral figures and conventional designs, as a binder or stitch to hold together the warp and filling threads, that too long floats will not be on the surface. Elaborate combination twills look like Jacquard weaving, but are really only clever repeats, alternations, or reversals of pattern.

The stitches used to hold together double cloths are usually twills which come at intervals to the surface. (See Fig. 69 for explanation of the method of drafting.) In some classes of worsted goods the binder is frequent. The stitching requires care in planning, so that it does not make itself evident on the face of the cloth. The stitching stitches are now frequently employed in all classes of patterns. Cheap stock is often used for them, as it gives weight and does not show on the face. Cloths backed with shoddy or poor wool are usually rough on the wrong side.

Satins or Figured Weaves. — The step between twills and figured weaves is short. Satin really belongs to both, for it is a broken or skip twill. The object in satin or sateen is to throw a series of closely twisted threads on the face of the material, with a cross thread at intervals, that the floats of warp or filling may reflect the light. When the warp is constantly crossed by the filling, the reflection of light is interfered with. In the satin the cross thread binds sufficiently to hold, yet it is not noticed. Cotton-backed satins save expense, and the cotton thread coming to the surface is not seen. When well woven of good materials this class of satin is enduring. An odd number of shafts is preferred for the satins; the five-shaft is much used, but the seven shaft is considered a perfect satin. Diaper patterns (Fig. 70) and spots are illustrations of simple figure

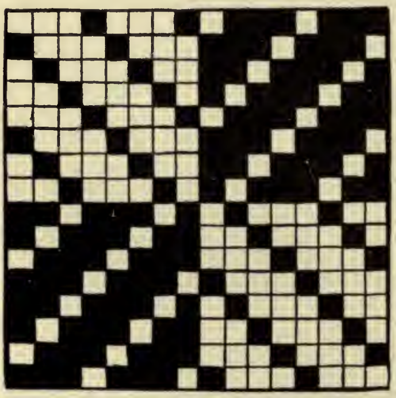


Fig. 70. — Diaper Pattern.

weaving, and Jacquard designs of intricate figure work. The damask designs are reversible, but brocades are woven with the patterns on the face only, though sometimes faintly indicated on the back. The filling threads which are not in use in an elaborate design are sometimes interwoven into the background until needed, and at other times are left in long floats on the back to be cut off in the finishing. Damask weaving is usually beyond the power of the simple loom, and the Jacquard harness is used. If the designer has a four hundred hook Jacquard and a cloth with one hundred threads in an inch, by dividing four hundred by one hundred he has four inches in which he must confine his design in width (the length is as he wishes it). He must avoid parallel and cross lines. Damasks are usually designed with warp satin and with weft satin or sateen for background and figure.

In figure weaving the background is generally a plain or satin weave. In designing, the relation of the pattern in the figure to the twill in the background has to be most carefully worked out, or the design will run into stripes or oblique lines. The number of needles in Jacquard weaving is also limited. The five- and eight-shaft satins for figure work are generally preferred by designers to the higher shafts. The use of color in silk designing brings in a large item of expense. As few changes as possible will reduce the cost of dyeing. The expense of the thrown silk is so great that computations of the amount of each color in a design have to be brought to the exact amount required, that nothing may be wasted. The silk designer must know these points. The design in Fig. 71 *A* is a lozenge or diaper pattern, with six changes in length and nine in width, used frequently in damask weaving. The complete diaper is made by a reversal. Fig. 71 *B* gives the arrangement of pegs in the lags for the dobby and Fig. 71 *C* the arrangement of the cards for the Jacquard harness. This design is a very simple one and perhaps would not be used on the Jacquard, unless an elaborate central or border design were included, but it

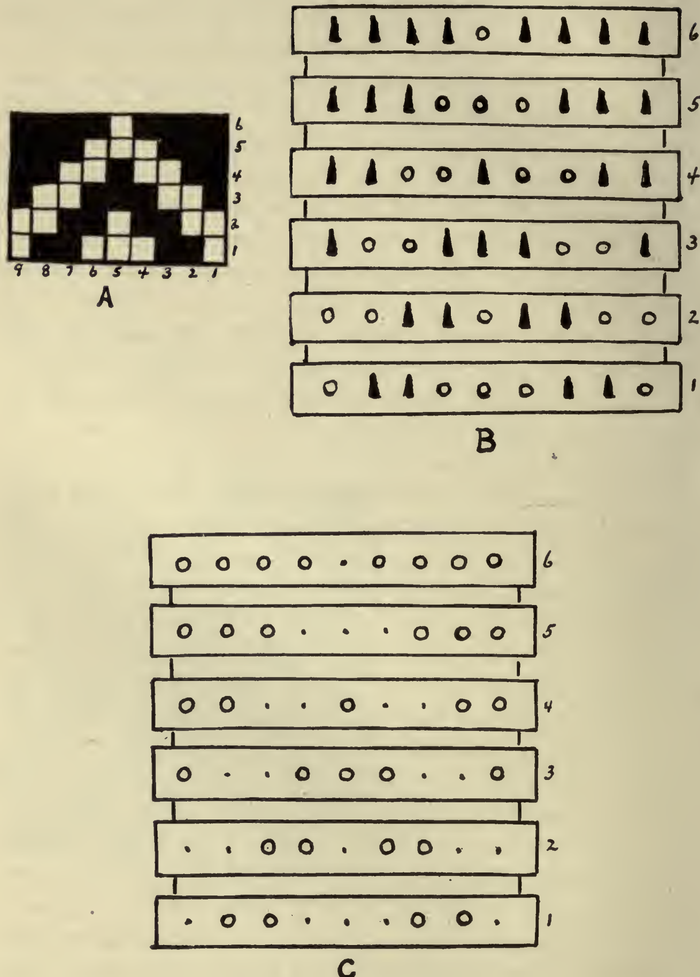


FIG. 71.—LOZENGE DESIGN.

A, Draft. *B*, Arrangement of pegs in the lags for the dobby. *C*, Arrangement of cards for the Jacquard harness.

illustrates the method of designing and preparing the cards. The numbers at the bottom represent the warp threads affected, and at the side the number of picks. In the cards the needles will pass into the holes and the connected hooks will remain on the griffes, but the other needles will strike the cards where the dots are, will be battened back, and the shed will be made by the hooks falling from the griffes; consequently in the first line the first, fourth, fifth, sixth, and ninth threads falling will make the shed and the filling will be uppermost, as seen in the design. The repeats of the pattern are provided for by the harness cords. In the lags of the dobby the pegs are inserted when the warp threads are to rise, consequently the filling passes under them. The first, fourth, fifth, sixth, and ninth will be down, and the second, third, seventh, and eighth up, which is what is required by the design. The repeats are controlled by the dobby.

Knitting. — Knitted goods are being used more extensively each year and include sweaters, underwear, hosiery, caps, gloves, neckties, and braids. The process of knitting differs from weaving, for the fabric is made by looping each succeeding line of thread into the one before it. Special machines of many varieties have been invented for the work (Fig. 72). Napped fabrics are made with a background of knitting through which soft yarns pass to the surface. Eiderdown flannel is an illustration. Knitting may be plain or ribbed, or both kinds may be found combined in one garment. Ribbed goods usually wear better, but they are more expensive. When the two varieties are used in one garment the article must be removed from one machine to the other, the loops being carefully transferred to the needles. Knitted goods when well made are enduring, but must be kept in good repair, for a broken loop will stretch quickly into a large hole on account of the readiness with which one loop slips out of another. Fancy knitted goods with open work and embroidery are made by special attachments or on special machines. Good knitted goods are elastic and firm to the touch, and have a fair finish. Mercerized and lisle thread yarns are used widely for knitted goods.

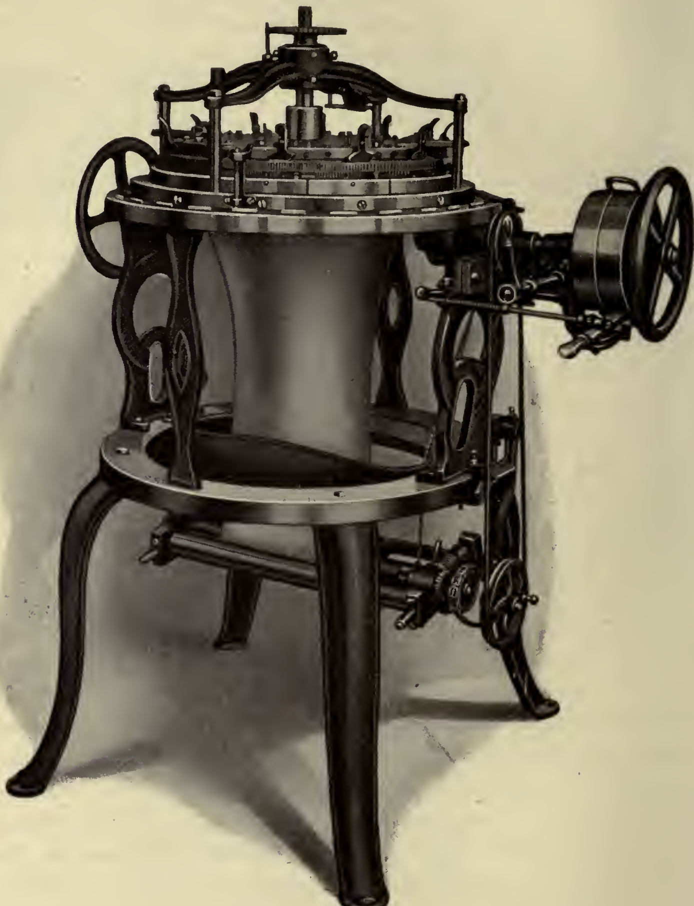


FIG. 72.—KNITTING MACHINE.

Knitting machines are circular in shape to make a circular article, or of a form to knit a specially shaped garment which can be cut and sewed together on a special sewing machine. The important part of these machines is the series of needles — the latch needle (Fig. 73), which opens and closes automatically, thus making the loop, or the spring needle, which accomplishes the same result in a different way.

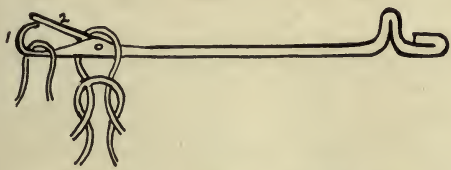


FIG. 73.—LATCH NEEDLE, SHOWING STITCH.
1, Hook. 2, Latch, moving on pivot.

Machines for sewing together the knitted pieces or for finishing necks or bottoms of garments, or for placing yokes of woven material on the knitted goods, are an essential adjunct to the knitting mill.

Methods of finishing by shrinking and steaming are very necessary in the final effect. The various ways of knitting stockings shows the method of these machines in producing inexpensive or costly goods. The cheapest hosiery is plain knitting made in a long tube on a circular machine, and lengths are cut from it. The stocking is finished by shrinking, cutting, and sewing the heel and toe into shape. A better class of seamless hosiery is made on a special knitter, and is finished by steaming, shrinking, and drying. The best kind of stocking is called full fashioned. The form of the stocking is made by a knitting machine in which stitches are dropped or taken up automatically, making the required shape. A special sewing machine unites the parts, and steaming and finishing follow.

The United States has many knitting mills, Pennsylvania, New York, and Massachusetts being the principal states.

CHAPTER V

WOOLEN AND WORSTED — RAW MATERIALS

Scope of the Industry. — Materials made from woolen and worsted yarns are among our most useful and valued textiles. The raw material is procured from the fleeces of various breeds of sheep, goats, and other animals living in all parts of the world. The cloths made from this wool or hair vary greatly, as the fiber ranges from the short staple, soft, crimpy, dull merino wool to the long, silky, lustrous wool of the Leicester sheep of England, the glossy hair of the Angora goat of Constantinople, or the long, coarse hair of the Chinese sheep. The length of the staple varies from two to twenty inches (Fig. 74). The fiber of most of the shorter wools is covered with minute serrations which are inclined to draw together when subjected to moist heat. This quality of shrinking or felting is utilized in making some classes of goods, such as doeskins and broadcloths. On account of these variations the industry may be said to include, in general terms: —

1. Materials made from soft, dull, loosely twisted yarn of uncombed, short stapled wool, such as blankets, sweater material, broadcloth, melton, kersey, and many flannels, which are generally termed woolens.

2. Cloths from carefully combed, long, more or less lustrous wool made into closely twisted yarn, and woven into serges, covert cloths, mohairs, worsted suitings, and diagonals, which are generally called worsteds.

3. Innumerable varieties of materials made from either long or short stapled wools, which are carefully combed, and combine, in varying degrees, clear surface patterns and felted face effects. This class offers many kinds of dress goods, suitings and flannels, knitted underwear, henriettas, and other more or less dependable goods.

A fourth division might be added, though it really belongs to the worsteds, *i.e.*, the coarse, hairlike, combed wools used in such heavy materials as carpets, rugs, and floor coverings.

The difference between woolens and worsteds was originally quite marked, for the short, serrated wools were used for the former, and the long, brighter varieties for the worsteds, but modern machinery can now comb the shortest staple wools, hence the difference is principally in the yarn preparation. The fibers which compose the woolen yarn are carded, but not

FIG. 74.— RELATIVE LENGTH OF STAPLE.

A, Merino.	Average length		$2\frac{1}{4}''-2\frac{1}{2}''$
B, Fine Crossbred.	"	"	$3''$
C, Alpaca.	"	"	$7\frac{1}{2}''$
D, Mohair.	"	"	$8''$
E, Lincoln.	"	"	$10\frac{1}{2}''$

combed, and cross and intermix irregularly, the appearance being soft and fluffy, and the preparation usually taking but a short time. The fibers, however, of worsted yarns are repeatedly carded and combed until they lie parallel and smooth, and are then closely and tightly twisted to make the yarn look regular and lustrous (Fig. 75). The preparation takes much longer than the carded woolen yarns, sometimes ten times as long. Woolen materials are usually soft, elastic, and of dull finish, and when they are felted the lines of weaving are more or less obliterated; while the true worsted cloth shows its pattern clearly from a firmly woven surface which reflects the light.

Value of the Industry. — In the entire world there were in 1912 about 627,000,000 sheep,[1] which contribute annually about $300,000,000 to the wealth of the world (Fig. 76). This includes the wool, pulled wool, and mutton industries. The countries producing the most wool were in round numbers: all Europe, 180,000,000 sheep; Australasia (Australia, New Zealand, and Tasmania), 117,000,000; South America, 110,000,000; North America, including Canada, Mexico, Porto Rico, and Philippines, 59,700,000; Africa, 51,000,000 (Fig. 77). The main countries consuming wool were the United Kingdom, 492,000,000 lbs.; United States, 480,000,000 lbs.; France, 457,000,000 lbs.; Germany, 380,000,000 lbs.; Austria-Hungary, 132,000,000 lbs.; Italy, 57,000,000 lbs. Fig. 78). The wool industries and their connected occupations are of prime importance to the ruling nations of the world. In 1912 there were about 39,000,000 sheep of shearing age in the United States, representing more than one half a billion dollars. The wool on these sheep amounted to about 300,000,000 lbs. This was about two thirds of the wool used in the mills of the United States in that year.[2] It can be seen that the growth and manufacture of wool are large items in the prosperity of our country. For various economic and political reasons the production of wool has decreased in the past few years, which condition may or may not continue.

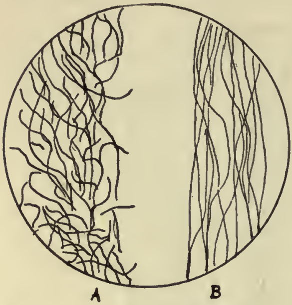


FIG. 75.—SLIVER OF WOOL AND WORSTED.

A, Wool. *B*, Worsted.

Although sheep are grown for both mutton and wool in most

[1] Bull. National Association of Wool Manufacturers, 1912.

[2] Much of the data has been taken from "Schedule K," Report of the Tariff Commission,

of the states, the great sheep-raising states are west of the Mississippi. The breed is generally merino of more or less full blood, but some long stapled wool is grown, and even the long

Fig. 76. — Sheep-Raising Sections of the World.

From Tarr & McMurry's New Geographies, Second Book, 1910, by courtesy of the Macmillan Co.

haired angora goat is cultivated. In the manufacturing of wool the leading states in 1911 were Pennsylvania, Massachusetts, Rhode Island, and New York.

Nature. — The woolen and worsted industries use both wool and hair. (See Chaps. XI, XII for physical and chemical structure.) Some wools have a great number of serrations, or scales, but these are rudimentary or apparently lacking in others. In manufacturing woolen cloth the wool having the most serrations

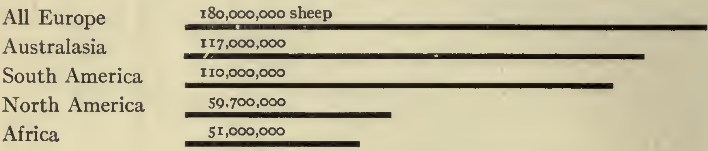


FIG. 77. — PRINCIPAL WOOL-PRODUCING COUNTRIES.

is desirable, but for worsted suiting the long, glossy wools with few serrations are best. Some serrated wools are lacking in felting qualities.

Desirable Qualities — Conditions Affecting Wool. — The qualities desired in the best wool for the manufacture of dress goods and suitings are present when the breeding, cultivation, and care of the sheep have been of a high character. These depend on climate, soil, food, and the crossing with other

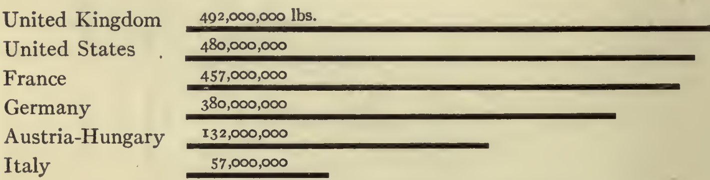


FIG. 78. — PRINCIPAL WOOL-CONSUMING COUNTRIES.

breeds. Careful wool buyers look for the trueness of breed which gives a clean, fine, sound, even growth of wool, full of vitality and elasticity. There should be no kemps or coarse, hairy fibers. The luster and length should be adequate in long staple wools, and the crimp and curliness in felting wools. Uncared-for sheep which roam at will on the plains and mountains develop coarse hair in their wool, but cultivation tends to increase the soft wool around the roots, and to eliminate the coarse hairs. The health of the sheep is quickly affected by climatic conditions, food, water, and incidents of life. When these factors are good a natural oil or yolk secreted in the skin gives softness and vitality to the wool. A very cold winter, though hard on the sheep, often develops a heavy fleece, but when the climate is harsh and the rainy season prolonged, the yolk is apt to be washed out, consequently the fiber grows unevenly and is likely to be brittle. Wool from poorly bred sheep is apt to be tinged in color and does not spin well; the dead hair will not take the dye, and cloth made from it wears unsatisfactorily. When the climatic conditions are good, the quality of the wool and its soundness depend on the herder's or shepherd's care and knowledge. The very soil has its effect. Sheep crop very close and must be moved frequently. Some soil tends to weeds, and the wool will gather the burrs; others bear poisonous plants which injure the health of the sheep. The herder must keep the flock calm and well fed, he must see that the feeding is regular between seasons, and must lead the flock to shelter when extremes of heat or storms menace. The well-trained shepherd and his ally, the sheep dog, are almost as important in the final condition of the cloth as is the superintendent of the mill with his heavy responsibilities. It is only when the environment and life of the sheep are satisfactory that the important qualities of trueness of breed, soundness of fiber, strength, softness, fineness, length, and pure white color are attained. The shrinkage of wool is also an important consideration. The carpet industries require the long, tough, enduring, hairlike wools. The sheep which provide these wools are hardy animals, and their long, hairy fleeces are a protection in their battle with nature.

Properties. — Wool possesses properties which on the whole make it our most valued textile for all climates.

Absorbing Moisture, or Hygroscopic Property. — Wool is capable of slowly absorbing a large amount of moisture and of holding it between its cells and in the very center of the cells. Under ordinary conditions it takes in from twelve to seventeen per cent of its weight, but when exposed to very damp air it will absorb as much as thirty to fifty per cent, thus making it much heavier. The legal amount of moisture at present is seventeen and one half per cent. Those who wear greatcoats of wool have perhaps noted the increase of weight when they have been exposed for some time to a very damp atmosphere. The hygroscopic quality affects its handling, for the weight of a certain amount of wool will vary under different conditions, and the weight will affect the price. Deceit can be practiced, and moisture-absorbing substances are often added to wool that a higher price may be received for it. Conditioning houses have been opened for the benefit of the community, to determine whether a given lot of wool is standard weight, and also if its condition is as pure as represented.

Felting or Shrinking. — Most varieties of wool are covered with minute scales or serrations composed of gelatinous material, which softens under heat and moisture. If pressure is brought to bear, the serrations are locked together permanently, and the cloth is shrunk, *i.e.*, reduced in width and length, and thickened.

Tensile Strength. — Wool is high in tensile strength, although the quality varies in different classes of wool, in parts of the fleece, and with the size of the fiber. Carefully manufactured cloth of pure wool is a strong, reliable material.

Elasticity. — Natural wool is very elastic, as may be noted if a lot of it in the raw state is pressed in the hand. Elasticity adds to the strength of cloth, and to its comfort as a covering for the body, but this quality is impaired by careless manufacture or laundering. An instrument called the dynamometer is used to test wool for strength and elasticity.

Electricity. — Wool is a good generator and a poor conductor of electricity, qualities which are advantageous in clothing.

Wool- or Hair-bearing Animals needed in the Woolen and Worsted Industries. — The fleeces of many varieties of wool- or hair-bearing animals are used in the manufacture of woolen and worsted cloths (Figs. 79, 80). In a very general way wool or hair (the term wool is used to cover both) may be divided into two groups: short staple wools, the fiber being from two to

FIG. 79. — AMERICAN MERINO RAM.

From Collins' *Woolen and Worsted Spinning*, by courtesy of the American School of Correspondence.

four inches, and long staple wools, the length of fiber being from four to ten or even twenty inches. (See Fig. 74.) Some wools occupy a middle ground.

The various wools and hair now used in the wool and worsted industries of the United States fall fairly well under the following headings: —

1. Merino (Rambouillet breed is used extensively in the United States).
2. Crossbreeds from the merino and other sheep, notably the Lincoln.

3. Pure blooded coarse- and long-haired sheep such as the Lincoln and Leicester.
4. Coarse wools from the sheep of China, East India, Turkey, Russia, and other countries.
5. Hair. Mohair, alpaca, camel's hair, and others.

The Domestic Clip. — The United States in 1912 grew about two thirds of the wool used in its woolen and worsted mills.

FIG. 80.—ANGORA GOAT.

From Collins' *Woolen and Worsted Spinning*, by courtesy of the American School of Correspondence.

Sheep are raised in most of the states, the mutton industry being often more important than the wool. New England breeds most of its sheep for food; the Middle States, of which New York had 625,000 sheep (April 1, 1912,[1]), subordinates its wool to its mutton. The South also inclines more to mutton breeds. The upper Ohio valley grows some of the finest merino wool equal to the Saxony, but the expense of raising is great, and mutton grow-

[1] Bull. National Association of Wool Manufacturers, 1912.

ing is as important as wool. The middle western states have over six million sheep, but the wool again is a side issue, for they are also kept for mutton, for scavengers, to destroy weeds, and to eat what would be otherwise wasted, to distribute valuable manure, and to improve the appearance of the farms. The sheep thus saves labor, eats waste, and yields good profit.

It is in the far western states that sheep growing for wool is most important. In the southwestern states, Texas, Arizona, New Mexico, and Colorado, sheep raising is the most important industry, and the range merino the principal breed. The climate and conditions are more favorable than in the northwest. California has different conditions from either the southwest or the northwest states, and its wool is listed by itself in market reports. Texas and Oregon are also sometimes listed separately in the same way.

In the northwestern states, Idaho, Wyoming, Montana, Utah, Nevada, Washington, and Oregon (Wyoming and Montana having each about 4,000,000 sheep), American labor is used in general, and wages are high, for there are competing interests. There are many varieties of sheep, and the mutton industry is also a factor.

In the United States the principal breed is the merino (Rambouillet) (see Fig. 79), which, in general, belongs to the short staple group. Selection and crossing with other grades of sheep have developed a longer staple.

Three groups are commonly given in the market quotations: (1) Fleeces (washed) grown on farms in Ohio. Pennsylvania, West Virginia, Michigan, Wisconsin, and New York, which have fine, not very long, staple wool sometimes equal to the Australian in fineness and felting quality; (2) Bright wool which is coarser, longer staple with much luster, from Missouri, Indiana, Maine, New Hampshire, Vermont, Kentucky, and other states. These wools are cross bred with merino, and according to percentage of crossing are spoken of as $\frac{1}{4}$ blood, $\frac{3}{8}$ blood, $\frac{1}{2}$ blood, and $\frac{3}{4}$ blood. They are marketed both washed and unwashed. (3) Territory wool includes sheep of all grades grown in far western states such as Montana, Wyoming, Utah, Idaho, Oregon, etc. This last class is usually marketed unwashed, hence the shrinkage at the mill is very great. Some of it is sold on the scoured basis. A few special wools are quoted outside of these groups, such as California, Colorado, Texas, and New Mexico. Some of these wools are marketed scoured, and are clipped twice a year, consequently send very short wool to market. Delaine is a longer staple than the ordinary merino, being developed by selection in breeding. It is taken from selected merino fleeces and is grown all over the United States. Lake (Louisiana) and Georgia wools really belong to the second group, but are listed by themselves. Various designations for fineness are given, such as Nos. 1, 2, 3, 4; the first being the best; or fine, fine medium, and medium, or choice, good, average, and others.

The Growth and Care of the Sheep. — Methods vary in different parts of the United States, but the following may be taken as fairly representative of the life on the northwest ranches. In 1912 in twelve of the Rocky Mountain states there were 20,000,000 sheep, of which about one fifth were run on government land. This is changing, for agriculture is coming in rapidly in some sections, driving out the sheep ranch. The cost of forage is high, if the sheep are fed on the ranches. Water is often scarce, owners are fencing in their water supplies, and conservation of forests prevents the herder from grazing his sheep at will. Whole flocks are often lost by cold, storms, poisonous plants, predatory animals, and other causes. On these great western sheep ranches as many as 60,000 to 100,000 sheep are owned by one man. These are divided into a number of flocks, the average size being 2500 sheep under a herder. The fact that sheep so easily follow a leader makes it possible for one man and a trained dog to control thousands of animals where limits in fences or hurdles are unknown. The herder is given his provisions, and in addition is paid from $40 to $50 per month. The sheep ranches have their camp tenders, each of whom is responsible for two or three herders. They supply the latter with food, magazines, and books every few weeks, and move the sheep wagon if necessary.

The cool nights in these western mountains clothe the sheep in heavier coats than in the South. A good dense fleece, the conformation for good mutton, the ability to herd in large flocks, yet to keep together on the feeding ground, are points desired in these sheep. The snow will cover the grass for days and the sheep will suffer from hunger, which if it does not kill the sheep will injure the wool, producing weak places in the fiber which will break in the spinning. If the land is weedy, burrs catch in the fleece and injure its sale, for they can only be removed by machinery or carbonizing. Insufficient feeding between seasons or poor food at any time injures the growth of the wool and tends to leave it harsh and dry. The flockmaster, in spite of careful preparation, may have all his calculations upset by a severe winter. Entire flocks are often lost or the wool permanently injured by extremes of climatic conditions.

The flocks are composed mostly of ewes, the wethers being sold young for mutton. The average price of one sheep on a western ranch, although it changes from year to year, is $5.20. Lambs are worth $2.00 from the fall after their birth. The shearing life of a sheep is about five years. When a ewe is too old for shearing she is fattened and sold for mutton.

When the shearing season comes the flocks are brought to the shearing pens which are usually near the ranch house. The large ranches make preparations for conducting the shearing at their own pens, and the dipping in their own troughs. A good worker can shear in one day from 100 to 200 sheep, and receives about ten cents per head, the average amount made being $12 per day. The heavy merino sheep takes longer to shear than the others, such fleeces having even weighed as much as thirty pounds. The average is from five to twelve pounds "in the grease."

Unless the shearer is careful he will cut the skin of the sheep, which not only causes suffering but also interferes with the even growth of the fleece. The usual method is for the shearer to throw the sheep on its haunches, clasp it between his knees and hold it with one hand while he uses the shears with the other. He cuts in circles from the neck or shoulders down to the tail (Fig. 81). The wool holds together and is stripped from the sheep in a complete fleece. The shearer rolls it in a bundle. In large flocks the sheep are next branded on the back or side with the owner's mark. Complaint is constantly made by wool buyers of the careless use of paint in branding, which injures the wool, making some of it worthless for spinning. After branding,

FIG. 81. — MACHINE SHEARING.

Courtesy of the Chicago Flexible Shaft Company.

the sheep are often dipped in an antiseptic solution to free them from parasites and disease. In some of the western states this is required by law.

The fleeces are taken to the wool packer (jamber) who sits on top of a wooden rack or framework (like a very high stool) which has a long bag hanging down in the middle of it, and a shelf at one side to hold the wool thrown up to him. The packer drops the fleeces into the bag and treads them down. One bag holds about forty fleeces, and weighs from 250 to 300 or 400 pounds. Unwashed wool in the west ranges from the low price of 10 cents a pound to the good price of 20 cents or the high price of 22 cents or more. In general, a wool that costs 16 to 18 cents a pound in the west is worth about 20 to 22 cents a pound in Boston, the principal wool market of the United States, and the cost when scoured would be 55 to 57 cents per pound, due to the increased amount of wool needed to make a pound. About 35 pounds of clean wool are obtained from 100 pounds " in grease."

When wool is sold in the grease it shrinks greatly in weight from the scouring process, — usually more than one half. Wool buyers can estimate with much accuracy what shrinkage will occur in scouring, although it varies greatly with the quality of the wool in different places. Foreign wool shrinks less than ours. Good western wool often shrinks from 63 per cent to 73 per cent; the average shrinkage is 62 per cent. The average shrinkage of fine merino wool imported into the United States from Australia and South America is about 48 per cent. The average English long-combing wools shrink a little over 21 per cent. The advantage of washing before shearing is that the fleece is whiter and the cost of transportation is less. The disadvantage is the brittleness of the wool on account of the lack of oil in it. Merino and crossbred fleeces imported into the United States, are, as a rule, " skirted " before shipping; *i.e.*, the poorest and dirtiest parts are trimmed off.

The marketing of wool falls under the following heads: —

1. Sold to dealers in raw wool.
2. Sold to the mills direct.
3. Purchased by order from foreign countries.

Boston, New York, and Philadelphia are the principal cities of the United States for the sale of raw wool. The wool merchants in those cities, who are the middlemen between the grower and manufacturer, send their buyers west about the first of the year to purchase wools. They visit the various ranches and learn conditions of the clip. The wool bought is sent east soon after it is cut. It does not go directly to the mills but to the wool merchant, who usually buys it on a scoured basis, that is, the buyers have estimated the shrinkage which will occur in any one wool, and pay for the raw wool minus the shrinkage and a few other charges such as freight and packing. The ability to judge the shrinkage of wool is an important asset for a good buyer. The wool usually comes east with all the oils, dirt, and waste in it. Consequently the freight is heavy and the packing costly. On arriving, the bags or bales are taken to the warehouse of the merchant or placed in public storage. The greater part of the wool is sorted after arriving, and placed in piles or bins from which the manufacturer chooses the variety he desires. The merchants usually specialize in certain classes of wool.

The Wool Supply.[1] — The merino sheep, originally from Spain, is the progenitor of many of the world's noted flocks. The Saxony and Silesian sheep of Germany are of the merino breed, and give the finest felting wool in the world. Merino sheep were early imported into the United States and were the basis of the present flocks. This wool is valued for its softness, warmth, and felting qualities, and is used in broadcloths, flannels, cashmeres, soft serges, suitings, and dress goods generally.

The Australian sheep are also to a large extent merino or crossbred merino stock. This wool ranks high for felting qualities, often equaling the Saxony. Australian wool costs little to raise, on account of favorable climate, abundance of food, cheap labor, and profit on mutton. It is estimated that ninety-three cents will cover the cost of raising one sheep in that country, while in South America it costs $1.15, and in the United States $2.11 per head.

In 1909 there were 718,527,132 lbs. of wool produced in Australia at a value of about $139,125,000. There is promise, in some sections, of increasing sheep raising, though in other instances agriculture is taking the place of pasture land. In 1910 there were about 100,000,000 sheep in Australia. The

[1] Data from Schedule K.

United States buys largely the Australian clothing wools and also some of the combing wools. Our market grades them as choice, good, and average. The principal ports for wool shipment are Sydney, Brisbane, Melbourne, and Adelaide. The great annual wool sales between September and April are attended by trained buyers from all the important wool manufacturing countries of the world. The Sydney sales of merino wool even threaten the supremacy of London, and in 1909–1910 represented a value of $55,000,000. As the sales in London are held the year round, many of the United States buyers find the English market better for them.

Great Britain (England, Ireland, Scotland, and Wales) grows both long and short staple wools. The climate is especially favorable on account of the mildness of the winters, the coolness of the summers, and the excellence of the grass and forage crops. Parasitic life, which in warm countries causes losses among the sheep, is little felt. In the sheep raising in Great Britain the production of mutton and the fertilization of the land are more important than the wool crop. The farmers are students of breeding, and produce many types of sheep, most of them for the dual purposes of mutton and wool. The sheep and lambs in 1910 numbered 31,000,000.

Great Britain has developed many noted breeds of sheep which grow long, lustrous wool, especially desired in the manufacture of fine worsted suitings. The Leicester is one of the oldest, and has white, shining, curling wool often twelve inches long. It has been much used for crossbreeding and developing other varieties. The Cotswold, with fine fleece less lustrous than Leicester sheep, is much used in western United States for crossbreeding with the range merino. The Lincoln, with very long staple, lustrous, heavy fleece, is used for bright serges, dress goods, braids, and coarse goods. This wool is too coarse for more than a limited use. Another long-wooled sheep is the Romney Marsh, similar to the Lincoln, but with less lustrous wool. Various other types of sheep produce wool of the long staple variety. The pure bred Cheviot, which has a soft wool of three to four inch staple, is found in South Scotland and in North England. The wool comes between the long and the short staple varieties. These sheep and the Leicester have been crossbred with the Highland sheep of Scotland, and have produced a type of wool from three to five inches in length, used in making cheviot cloths and high class tweeds. Wools of medium length are clipped from the Downs. These sheep grow principally in the central and southern part of England. The wool is fine and soft, and is used for hosiery and flannels; the longer staples are used for cloth. These sheep are noted for their mutton. The Southdown and the Suffolk are the finest, but the Oxford and Hampshire are good; the Shropshires are classed with the Downs, and the Dorset is very similar.

South America is second in importance to Australasia. Argentina, Uruguay, and the island of Tierra del Fuego are the most important sheep runs. Uruguay will long remain pastoral, but Argentina is giving up sheep runs for agricultural enterprises. The Uruguay wool is sometimes sent direct to Europe, but usually to Buenos Ayres, which has a big wool market. It is here assorted and sold for export. As a whole the wool is fairly dry and clean, but heavy with sand. The light shrinking wools are purchased by the United States in large quantities.

The New Zealand wool, of which much is purchased in the United States, is noted for its good color and for its sound, soft feel. The staple is rather long, with freedom from imperfections. This wool shrinks little, and is free from sand and dirt.

South Africa has 30,000,000 sheep, of which 19,000,000 are in the Cape Province. The climate is fairly good, similar to the American southwest, and periods of dry hot weather with drought are followed by fine rains and good feeding. The flocks suffer from predatory animals and disease. Most of the sheep are of merino stock. The best Cape wool is snow white in color, and is used in the finest dress goods.

There are many other classes of wools which are used in the industries. For the coarse wools, largely for carpet yarns, Russia produces the Donskois, which have long staple. From Central Asia we buy a number of coarse, similar wools, such as the Bokhara, Afghan, and Khorassan from Persia. From Syria we buy the Aleppo, Orfa, Damascus, and Jaffa. From India we obtain a number of wools called in general East India. Some coarse wools from various countries are also used in combination with finer clothing wools.

Canadian wools are in general shorn from English long-haired breeds, and are used in the United States for combed yarns, although there are also some merinos and crossbreeds from Canada used for carded yarns.

Wool from Adrianople is pulled from the skins of sheep killed for mutton. Several kinds are often combined in one bale; they are used for both clothing and carpets.

The mohair wool, taken from the Angora goat, is very long and silky, and from four to ten inches in length. It hangs in ringlets on the sheep. It is used largely in the manufacture of plushes and lustrous dress goods. Originally a native of Asia Minor, the Angora goat is now raised in Turkey, the Balkans, Cape of Good Hope, South Africa, parts of the United States, and Tasmania. The staple varies in length from seven to fifteen inches; it is strong and has luster. It is used for linings and dress goods. The alpaca, or Peruvian sheep, is a species of llama.

Cashmere wool comes from the cashmere goat of Thibet and the Himalayan mountains. The fleece has long, glossy outer hairs and a soft under down of wool, which is shed or combed from the goat in springtime and called cashmere. It is silky to the touch and grayish in color. The amount from one goat is small.

Camel's hair is also used to some extent. The best is from the interior of Asia Minor from the Bactrian camel, and is shipped to China, sold, and manufactured into clothing. The Russian camel's hair is strong and long, and is used for bagging and coarse yarns.

Wastes and Substitutes. — The world's wool supply is insufficient to make all the cloth demanded, consequently pure wool in the raw state is costly and substitutes are used in order that the material may be sold at a price within the means of the people. The United States imports much of its pure wool, but little of the wool substitutes at present. However, it obtains sufficient wastes from the home market, and the reclaimed wools are largely used in cloth production. The manufacturer of woolen goods uses noils[1] from the combing machines, waste from cards and other machines, coarse, hairlike wools, pulled wool from dead sheep, extract wool, shoddy, mungo, cotton, ramie, jute, and silk noils to combine with the pure wool. Worsted spinners are not users of wool wastes and substitutes, but can use pulled wool, coarse hairlike wools and some cotton, although the latter does not combine well with long combing wool.

The occupations connected with the collection and preparation of wool wastes have become very important. Rag markets are held in many countries. Germany has several noted ones, and some of the wool waste markets in England are perhaps the largest in the world. Shoddies, mungoes, mechanical wools, cheap clothing and cloth are taken there and sold in large quantities. America sends shoddies and wastes to the German rag markets. New York City is a center for the clothing trades, and many are occupied there in the rag industry. Old clothing and rags are collected, the buttons and seams are cut off from the clothes and the cloth is graded according to color and quality and sold in lots. These rags are beaten by machinery to free them of dust and later are fed to revolving cylinders armed with teeth which tear the cloth into a fibrous condition. The machine wastes are sold directly from the factories. When rags of cloth made of wool mixed with cotton are to be utilized, the cotton is removed by carbonizing before the wool is used again.

[1] Terms unfamiliar to the reader should be looked for in the Glossary at the back of this book.

CHAPTER VI

WOOLEN AND WORSTED — MANUFACTURE

It has been said that the manufacture of wool requires more brains than other industries. From the beginning of the mill processes to the turning out of the finished product conditions may arise to injure the cloth and reduce profits. The one responsible for the result must have a practical knowledge of mechanics, of chemistry, and of design, color, and weaves. He must know the qualities of both foreign and domestic wools, that he may select the right kind and color for his varied purposes. He must have experience in selecting wastes and substitutes to combine with the pure wools, that his recipes may be satisfactory and that the best results in cloth at the lowest price may be obtained. Having selected his raw stock, he must next watch the various processes of manufacture to see that the wool shows the right reactions and results. Each step, from the raw stock through spinning, weaving, and finishing, has its special difficulties, by which the product may be weakened or marred at any point. Machinery must be watched, or some trifling lack of adjustment will cause it to wear out too rapidly. Aprons, brushes, and other necessary parts will give better service, if special care is exercised. Oil stains, difficult to eliminate from wool, may occur through carelessness. Wool requires a humid, warm atmosphere, or the natural electricity becomes too high, yet it is hard to maintain the best condition without expensive apparatus. Dangerous dust and gases must be removed for the protection of the workers. Ventilation must be constantly considered, new labor-saving devices tried, and all waste and by-products must be utilized to the best advantage.

The superintendent must be keen as to efficiency and economy at every turn, yet must make a product which will please a fickle market.

Woolen and Worsted Spinning. — Preparatory processes for both woolen and worsted yarns are similar, the machines used differing only in their adjustment to long or short combing wools. The practice is increasing of putting several machines in a train or series by which the wool passes automatically from one to the other and saves handling. Each mill has its own method of procedure which has grown up through experience. Unwashed wool contains a fatty or greasy matter called yolk, which has been secreted from the skin of the sheep, and dust, dirt, burrs, and straws cling to the fleece. If the wool is fairly clean, scouring alone is required to prepare it for carding, but if it is full of impurities, it must be dusted and opened before scouring is advisable, and carbonizing must follow scouring when the wool is full of burrs. If the mill makes woolen yarns, the processes aim to clean but not to lay the fibers parallel in the yarn. On the contrary, worsted yarns must be repeatedly combed, that the fibers may lie side by side before they are twisted. It is impossible, therefore, to present a series of processes which are regularly used, but the general practice may be outlined as follows, although conditions constantly change with new inventions: —

Processes Common to Woolens and Worsteds

1. Sorting or dividing into qualities; classing.
2. Cleaning, usually required to some extent.
   Opening, when wool is matted and very dirty.
   Dusting, for dirty wools.
3. Scouring, for greasy or half-washed wools. There are usually three baths.
4. Dyeing in the wool or raw stock dyeing, used often with woolens. Dyeing sometimes follows burring by carbonizing, if the color will be injured by the chemicals.
5. Drying.
6. Burring. Needed when wool is full of burrs, which is frequently the

case with short staple wools. There are two methods of removal: (1) by machinery; (2) by carbonizing. Sometimes a burr roller attached to the carding engine is sufficient.

7. Blending or mixing the various kinds of wools needed for a particular yarn.
8. Oiling (sometimes done before blending).

PROCESSES FOR SPINNING

A. Woolen or Carded Yarn.

1. Picking. For opening, cleaning, and mixing. Sometimes the wool requires several of these machines.
2. Carding. Usually three machines in train. American names: (1) First Breaker; (2) Second Breaker; (3) Finisher. English names: (1) Scribbler; (2) Intermediate; (3) Condenser. The wool is frequently ready for spinning after the last card.
3. Drawing. Usually omitted as a separate process.
4. Spinning.

B. Worsted or Combed Yarn.

1. Picking or teazing. For mixing. (This machine is often omitted.)
2. Carding. These machines as in wool (*q.v.*).
3. Preparing gilling.
4. Combing. The result of this process is the top. Dyeing is frequently done in the top, and is called stock dyeing. It is also done in the yarn (skein) and in the piece after weaving.
5. Backwashing.
6. Gilling.
7. Drawing. Many times repeated. The last step before spinning is called roving.
8. Spinning.

Explanation of Processes

Sorting. — Wool usually comes to our market unwashed or "in the grease," and the fleeces must be sorted into their different qualities after they reach the mill. Some wools are scoured and carbonized before shipping to market, in which case the stocks are mixed and are not in the form of a fleece. The manufacturers, in general, prefer the wool "in grease." When the bags full of fleeces arrive at the factory they are opened and the wool is taken to the sorter's tables or benches (Fig. 82).

Fig. 82.—Wool Sorting.

Courtesy of M. J. Whittall.

The sorters are trained to recognize accurately the various qualities by look and feel, and quickly divide by hand a fleece into a number of parts, often six, eight, or even more, as occasion demands. The best wool comes from the neck, shoulders, and sides; the poorest, from the legs. The useless parts, which are often full of paint, tar, clay, and filth, are cut off and discarded, and the remaining portions are graded by the sorters. Foreign fleeces come to us with the worst parts removed (skirted); the remaining classes are called sorts. The terms picklock, prime, choice, super, and others are sorters' terms to designate the different qualities for the woolen industry. The same terms are used a little differently in the market. A very fine, short wool is often distinguished in the textile journals by the size yarn it will spin. For example, such terms as 60s, 70s and others indicate fine Saxony or merino wool. The sorters in each mill select the quality or qualities needed in that special industry, and the remainder of the fleece is sold. The fleece as it comes from the sheep may be graded into many qualities, as Fig. 83 indicates, No. 1 being the best grade and No. 14 the poorest. In a general way it may be said that the wool from the shoulders is fine; from the sides, long and even; from around the neck, fine but short; from the back, short and coarse; from the tail and legs, coarse and of little value, and under the body it is short and dirty. A special method of dividing the fleece into sorts is used in some of the mills of the United States. Good wool grows on tender flesh, consequently good mutton and good wool come from the same part of the sheep.

There have been and still are dangers to those who sort wool, especially dusty, Eastern wool. Wool sorters disease, anthrax, comes from a germ which enters the body through a break in the skin or by the internal organs. Many difficulties come from it, the most serious being blood poisoning and inflammation of the lungs. Medical knowledge is increasing as to the prevention of the wool sorters' disease, and modern methods of constructing the sorter's benches have minimized the trouble by placing wire gratings on the top, and exhaust fans below to carry off the dust. Some fleeces are so dirty that they are mechanically opened and beaten before sorting. After separating the wool into its different qualities, the classes are piled in bins marked with their names. Wools from all over the world — white, yellow, black and gray — rest side by side

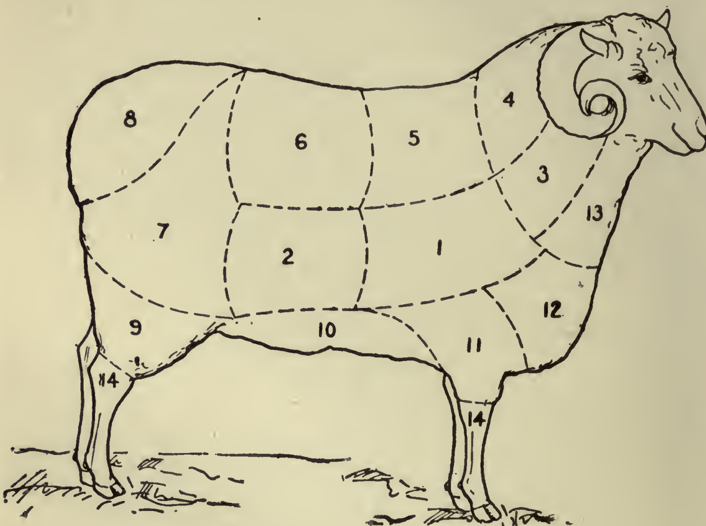


Fig. 83.—Position of Sorts.

From Collins' *Woolen and Worsted Spinning*, by courtesy of the American School of Correspondence.

ready for use. When the wool is needed, it is usually blown through pipes or carried by other automatic means to the part of the mill where it is needed.

The Feed. — (A species of opener.) When wool is very matted and dirty it must be cleaned before scouring. This process is required by short staple wool rather than by long. Wool impurities are difficult to eliminate. Sand and dust can be beaten out, straws and burrs require carbonizing, animal impurities are removed, in general, by washing. As much dirt as possible must be eradicated very early, or the cloth will be injured. In many mills automatic feeds are used before dusting, before scouring, and before carding, as a means of opening the wool and passing it on in better condition to the next process. Feeds are built either high or low, according to the length of wool which is to be passed through them. The wool is deposited in the hopper of the machine, and an apron of spiked slats carries it upward to an oscillating comb, which throws the surplus wool back into the hopper and carries the remainder to a revolving beater. The coarse spikes open the matted fiber, the dust is beaten out and falls below, and the wool is removed from the apron and passes to the next machine. A similar feed is used for cotton (see Fig. 101). In some mills a separate machine opener is found for matted wool, but the increasing practice is to have the feed a part of a train of machines which cleans, washes, and dries the wool.

Dusting. — Wool which is very full of straws, dust, and burrs requires repeated cleaning. The duster consists of a cylinder covered with coarse teeth or spikes, which opens the staple while a fan blows out the dirt. There are two forms of duster, the square and the cone. The work of scouring is simplified by this machine, consequently it is in use even for fairly clean wool. It often follows the feed in the train.

Scouring. — Wool, as already explained, contains a greasy matter, called yolk, which is secreted from the skin of the sheep, and makes scouring necessary. The cloth will be in better condition if as much dirt as possible is cast out beforehand so that the scouring process need not be too severe (Fig. 84). When this process is well done the wool comes out clean, soft, and fluffy, and free from the chemicals which have been used in the cleansing solution. Care must be taken, however, that the wool is not injured, for too hot water (it should not be warmer than the hand can stand) or a too strong alkaline solution will weaken the fiber and consequently the cloth. It is generally

Fig. 84. — Wool Scouring.

Courtesy of M. J. Whittall.

conceded that poor washing is followed by defective cloth. Each mill has its own washing formulæ, but potash, ammonium carbonate, and soda are in frequent use. The washer is a long, narrow trough, divided into several tanks or bowls of different sizes, according to the length of the wool used. The first bowls are scourers and are filled with warm, soapy, alkaline water; the last bowls are rinsers. A ducker plate pushes the wool on to the liquid. Fresh water flows in continually, and the soiled water passes out. Wringers are attached to each bowl, and the wool moves slowly toward them, carried along by rakes attached to the sides of the troughs. After each wringer the wool passes in cleaner condition to the next bowl, and in the final one is washed in pure water. It should issue from the last wringer clean, white, and soft, to be carried automatically to the dryer, unless it is to be dyed before drying. Violent treatment of the wool in the scourer leaves it felted, ropy, and stringy. A train of machines such as the Feed, Duster, Scourer, and Dryer can be attended to by one or two men without needing to handle the wool.

A naphtha system of cleaning is used in some mills, and it is claimed to yield excellent results. The wool is placed in a hermetically sealed tank filled with naphtha, which removes the dirt. The expense of this method of scouring has been an obstacle to its general adoption.

The market at times quotes the price of wool on a scoured basis. If a variety of wool in grease costs 25 cents a pound and loses 50 per cent weight in scouring, it will take two pounds of such wool to make one pound of the scoured, hence the price on the scoured basis would be 50 cents a pound. Wools differ greatly in their shrinkage.

The by-products left in the scouring water are of great value, and consequently are recovered and used again, or sold.

Raw Stock Dyeing. — When wool is very burry it is frequently carbonized before stock dyeing, unless the chemicals which are used in carbonizing will affect the wool so that it will not take the color satisfactorily.

Drying. — It is very important for the sake of future processes that the wool shall be evenly dried. A hydro-extractor, similar to the kind used in large laundries, casts out the excess moisture by centrifugal force. The wool is next spread on a series of frames, made of network, placed one above another, and hot air is driven through by a fan; or it is dried in a large drying chest, where it passes for a time over hot air pipes and is then carried to a huge drum, on which it is turned over and fed back to the pipes until it is thoroughly dried.

Blending. — In many mills wool is burred and picked or teased before blending, for drying often entangles the fibers, and they need to be opened. Blending is especially important in the woolen industry, as the combination of color is often the beauty of the finished cloth. The object of blending is, first, to combine wools of various kinds, such as Australian with Ohio, or with other wools of similar staple, or to mix shoddy, mungo, coarse wools, extracts, pulled wool, cotton, or silk noils with pure wool for the purpose of cheapening the cloth; and, second, to combine wools, or remanufactured wools, of different colors, into attractive effects, such as mixing wool dyed blue with white and with black wool to make blue gray, or combining various colored wools for heather mixtures. Blends must often pass through the teaser several times to perfect the combination. It requires ability, experience, and a feeling for harmony of color to mix wools well, and a successful blender has many cherished recipes. Samples of different wools or of colors are tried first on the hand combs until the right combination is reached, and then the percentages of the various wools are weighed carefully and laid in successive layers on the floor of the mill near the picker or teaser.

Oiling. — Wool loses its oil in the scouring process, and must be re-oiled to pass easily through succeeding machines. Oiling often follows blending, being done by hand or sprayed automatically as the wool lies on the floor, or as it passes on an apron to the picker or other machines. An oiler is often attached to the doffer end of the dryer. If cotton is in the blend, it is better to keep the oil from falling directly upon it. Mills differ in the oils they prefer, but olive oil, neatsfoot oil, tallow oil, and other animal oils are in use. The oil must be evenly spread over each fiber. In the manufacture of soft serrated wools into yarns which will be fulled after weaving, the oiling before carding is very necessary, for it preserves the serrations from injury during the passage of the fiber through the thousands of fine teeth.

After oiling or blending, the processes for woolen or worsted yarns begin to diverge. The machines used are often much alike, but, as different results are required from them, modifications in structure are necessary. Worsted raw stock, after oiling, goes directly to the card unless some blending is necessary, but the latter is less important than in the woolen industry. Worsted goods are distinguished by their combed, finely twisted yarn and clear weave, rather than for soft mingled coloring and obscure pattern.

Woolen Yarn

Burr Extracting or Burr Picking. — Short staple wools are often full of burrs which persist in spite of the work of sorters, and of various machines. These must be removed before carding, or they will injure the machinery and be so crushed into the wool that removal is difficult. Mills differ in the manner and time of burring. The elimination of burrs, seeds, and leaves is, however, usually effected by two different systems: (1) A mechanical method which consists of a roller covered with a series of toothed rings which open the wool, and a fluted beater or guard knife to knock out the vegetable matter. A brush strips the cleaned wool from the machine. The mechanical burring is used especially when fine wool is full of large burrs, the advantage of it over the second method being that the natural strength and color of the wool are not affected. (2) A chemical burring is also in use, which carbonizes the vegetable matter. The wool is placed in a bath (usually a sulphuric acid solution) which attacks the burrs but does not affect the wool. A rinsing of soda and water follows, to free the wool from acid, and it is then baked until thoroughly rid of the vegetable matter, which has become carbon. This method is considered to be very effective, and is especially good when the burrs are broken and matted in the wool. Carbonizing is often repeated after the cloth is woven, if vegetable matter is still present. Burring rollers are sometimes attached to the carding engine. In very dirty wools, both burr picking and carbonizing are often used.

Picking, Teasing, Opening, Willowing, and the Fearnaught. — (Names used in different localities for this process.) A picking machine is usually required after scouring and drying, to open the entangled fibers, but it often comes after the blend has been made in order to combine the various wools or other fibers, and to prepare for carding. The picker is much like the carder. In place of the mixing picker a toothed cylinder is often attached to the first card. The blend is placed on a traveling lattice or apron, and carried into the teeth of the cylinder, where it is opened, mixed, made pliable and flexible, and then is automatically passed to the card.

The length of time required to prepare and spin woolen yarn differs. Inexpensive yarns take but a few minutes from sorting to spinning, but the processes may be lengthened, repeated, or supplemented by additional machines when making higher grades of yarn.

Carding. — The carding for woolen yarn is done in a set of three machines, which are much alike except in their methods of doffing the slivers. In America these machines are called the first breaker, second breaker, and third breaker or finisher; a condenser often is connected. In England they are called scribbler, intermediate, and condenser card. The aim of the woolen cards is to open and clean, but not to lay the fibers in parallel order. The first breaker card (Fig. 85) is often preceded

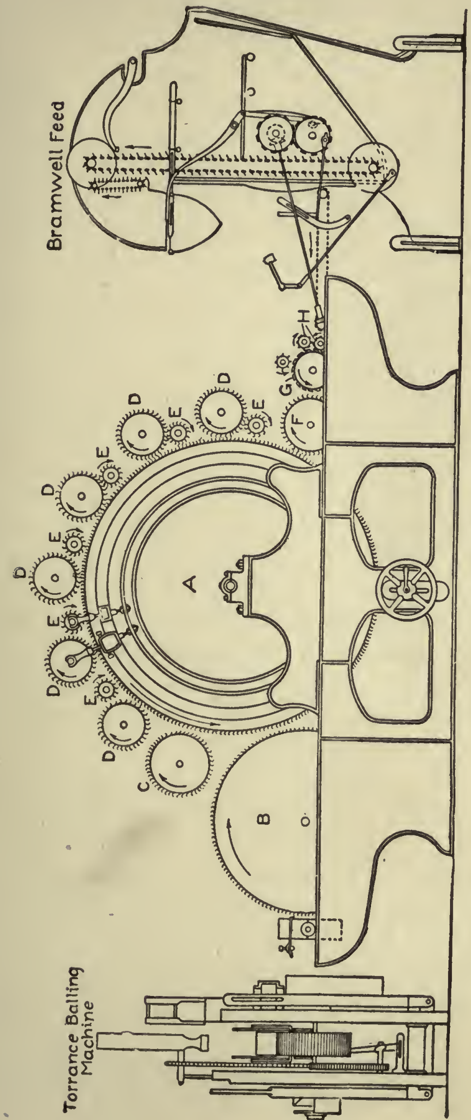


Fig. 85. — First Breaker Card.

From Collins' *Woolen and Worsted Spinning*, by courtesy of the American School of Correspondence.

by an automatic feed, which opens and blends the wool, delivers it to a weighing pan, and evenly deposits the correct amount of wool on an apron to be carried to the breaker. Each breaker card consists of a large cylinder against which small cylinders called workers and strippers revolve. Thousands of teeth clothe the surface of the cylinder, becoming finer in each succeeding breaker, and open up the wool. The first card combs the wool into a fine film or sheet, which in that form or in a sliver passes to the second; from the second breaker the film is delivered in various ways, but often is contracted into a wide sliver and fed diagonally ("on the bias") to an apron by an oscillating feed, which carefully deposits it back and forth, one layer half over and yet alongside of the other. The licker-in of the third breaker receives the wool from the side of the sliver, consequently the tendency to the parallelism of the fibers which has been given by the teeth of the card is counteracted. The product of this third machine is made ready to go to the drawing frames in the manufacture of some classes of yarn, or in others is condensed by a ring doffer and rub rolls into a coarse, lightly twisted roving wound on bobbins, which goes directly to the spinning frame. The heavy edges of the folded-back sliver are separated from the rest of the wool automatically when they issue from the breaker, and are later returned to the hopper of the feed to be carded anew.

Drawing and Doubling. — These machines are similar in all the wool industries, being based on the principle of drawing by rollers. (See Chap. II.)

Mule Spinning. — (See Fig. 22.) The intermittent motion of the mule spinning frame, which adapts it to the twisting of soft, short staple yarns, makes it of service in the woolen industry. The roving, which is soft and slightly twisted, with the wool fibers running in all directions, is placed in the frame, drawn smaller and twisted more, but has still the same characteristics as in earlier processes. The yarn comes from the mule spinning wound on bobbins.

Skein Dyeing or Dyeing in the Yarn. — If the yarn is now to be dyed, it must be wound into skeins or hanks on the swifts, (Fig. 86).

Fancy yarns are made in many ways. Colored yarns are united, threads are looped or knotted and often again twisted with other yarns, fibers of other textiles are combined with the wool, and yarns are twisted in different ways and again twisted together. Woolen yarns are used for knitted and crocheted goods, for blankets, for staple materials such as broadcloths, flannels, golf cloths, cheviots, meltons, kerseys, homespuns, cassimeres, chinchillas, and fancy dress goods, where the weave is soft and indeterminate or obliterated, and the colors are softly blended. Cotton warps are frequently used with wool filling, as in many flannels, blankets, and fancy dress goods.

Worsted Yarn

In making worsted yarn the wool fibers must be combed until they are parallel and flat before the sliver can be twisted into an even, lustrous thread. Many processes are required to do this satisfactorily, several days being sometimes needed for the work, hence worsted yarn is expensive. After the wool is blended (if this is necessary) it is carried on trucks or blown through pipes to the carding room. A feeder (Bramwell) is sometimes used before the first breaker card (Fig. 85). In some wools a burr roller is attached to the first card.

Carding. — Worsted carders (three cylinders are sometimes used as in wool) differ from those used for woolen yarn in several minor ways, such as slower movement on account of the wool staple; the doffing, as the fibers must be kept parallel, and the way of preparing the sliver for the next process. There are several methods by which worsted yarns are made ready for spinning. When very long staple wool is to be spun into lustrous, closely twisted yarn the combing and gilling processes are especially important, and carding is merely preliminary to the others. In such cases the first breaker card alone is used

Fig. 86. — Winding or Spooling Yarn.

Courtesy of M. J. Whittall.

(for too much carding breaks the long staple wool), and it is followed by preparers which straighten out the fibers for the comb. When, however, a short staple wool is to be combed for worsted yarn, the carding process becomes important as well as the combing and gilling. In some classes of carpet yarn the worsted carders do the work of opening and straightening the wool, and the combing and gilling are omitted. In general, however, worsted yarn goes through the following steps, but the emphasis on processes may vary: (1) Opening, cleaning, and separating the wool on the feed and the carders; (2) drawing, straightening, and leveling on the preparers (gilling); (3) extracting long fibers from the short, curly ones, and laying the former parallel in the comb; (4) drawing, doubling, and evening the slivers on gill boxes and drawing machines, and (5) drawing and twisting the roving into yarn and winding it on bobbins on the spinning frame.

Back Washing. — The wool becomes much soiled by oil in the carders as well as in other machines and needs washing. The process is used either before or after combing, or even at both times. A back washer is often attached to a preparing gill box. If this cleansing is not done, the cloth is apt to become shiny from the oil left in it. The principle of washing is very simple. Two or four bowls are used for washing and rinsing the wool. Wringers or squeeze rolls follow each bowl to press out the water, and a drying cylinder comes at the end. It is generally conceded that four bowls wash the wool cleaner than two, and that the finished cloth is benefited thereby. The best soap should be used and fresh water should flow constantly into the scouring bowls to keep the soapy solution weak. In place of a hot cylinder to dry the wool, a fan is sometimes used. Oil is sprayed on the wool after back washing.

Preparing Gilling. — A set of five or six preparers often follows the first breaker card, or the three-card cylinders may precede a set of preparers. The aim of these machines is to unite a number of slivers and to draw, straighten, level, and make parallel the fibers to prepare them for the comb. Sometimes as many as twenty-four slivers will be united in a preparing gill box. Gilling is done both before and after the comb, but the term gilling is not used for these machines until after the comb. Preparing and gilling are therefore practically the same process, and the machines are similar in construction. Each gill box has receiving and delivering rollers, between which is a series of bars or fallers covered with teeth or gills. The fallers move on screws from the receiving toward the delivering or draught rollers. As they move forward they press the wool down on a comb and lay the fibers parallel. When they reach the draught rollers they drop below, and are caught on a lower screw and carried back to the receiving rollers, where they are raised to the surface to begin again. The draught rollers move more rapidly than the rollers which are receiving the wool, and consequently attenuate the sliver. The speed is regulated by the size of the yarn desired, or by the length of the wool staple. When the product of the last preparer is to go to the Noble comb a balling head is attached to it, which winds the slivers in such a way that four unwind from one ball and are united in the comb.

Combing. — The slivers which come from the preparers are level and fairly parallel, but short, curly fibers are mixed up with the long ones. The object of the comb is to rid the sliver of the short, curly wool (noils), and to comb the long, straight wool into a more parallel condition, called tops. There are several methods of combing, such as the nip, square motion, and circular combs, but the latter is generally preferred. The nip comb is adapted to English long staple wools, but the Noble circular comb can deal with both long and short staple wools. The aim of the Noble comb is to do the work of the brush and comb, *i.e.*, to make parallel the long hairs and to catch the waste or broken hairs and throw them to one side. In order to accomplish this a series of elaborate and delicate adjustments is necessary. Eighteen balls of the prepared slivers are placed in order around the comb, four slivers coming from each ball. The end of each sliver is passed through a ring in the edge of the circle, and thence into openings which lead to a feed box. Through this they pass to a large, revolving, circular comb, 48 to 60 inches in diameter, where they are caught in the teeth of the combs (Fig. 87). The large circle has several rows of upright, pointed teeth, which become finer as they leave the circumference. Two small circles, 16 to 20 inches in diameter, revolve on opposite sides of the big circle. Rows of teeth decreasing in size are also on the small circles, and they come in contact with the teeth of the large circular comb and lay parallel the fibers of wool with which they come in touch. The longer wool is inclined to remain on the big circle, but the little circles comb it through and take away the short ends, which are called noils. The long hairs soon project free from the big comb, and are taken from it by vertical rollers to make the top, whereas the short ends are carried off in another direction. A dabbing brush presses the wool on the teeth of the combs, The slivers from the balls are carried by the feed boxes on an inclined plane so adjusted that they are at the highest point when they pass the dabbing brush. As the boxes descend the plane the wool is pressed down on the teeth. The fibers which remain between the teeth are automatically lifted out by knives and fed again to the combs. The slivers are kept from slipping back from the feed boxes by nips which hold them. The small circle on the opposite side from the large one combs through the wool which has not been combed by the first one. Both small and large combs revolve together and in the same direction, and rest on a steam chest which aids the combing by keeping the wool warm (Fig. 88). As a result of the combing two slivers come from the large circle and one from each small circle, and are united into one, a false twist being sometimes given to the sliver before it falls into a can. The combed sliver is called a top, and the processes following make it into a finished top.

The noil is removed from the teeth of the small comb by

Fig. 87. — Wool Combing. The Noble Comb.

Courtesy of M. J. Whittall.

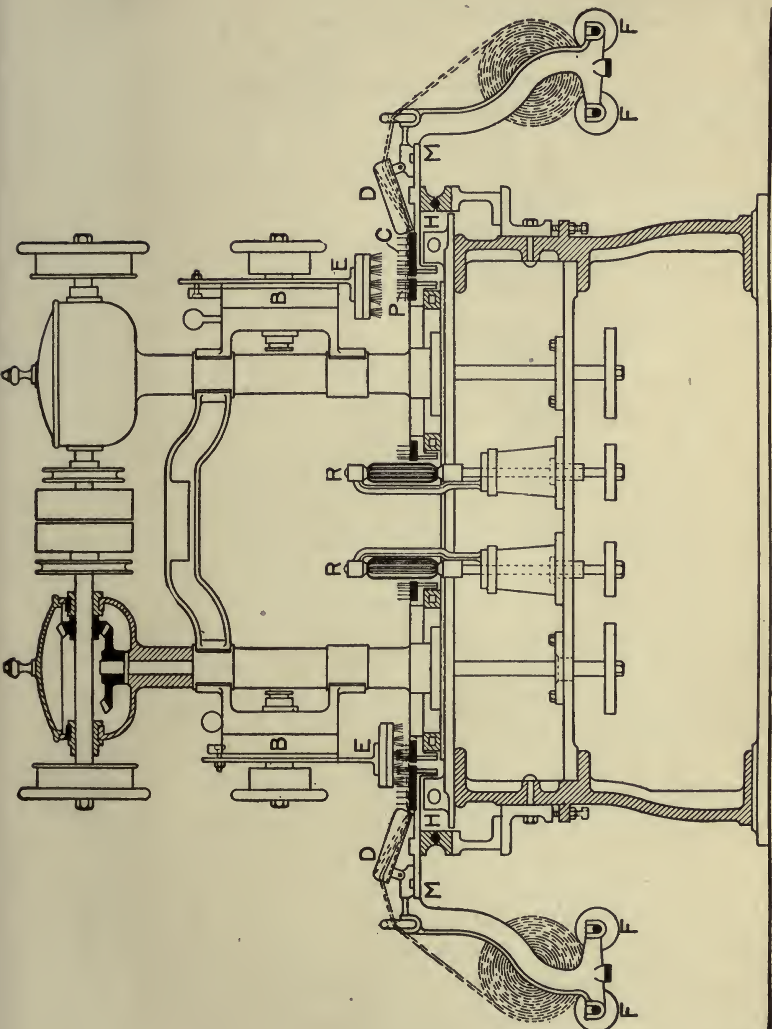


FIG. 88. — DETAIL OF NOBLE COMB.

From Collins' *Woolen and Worsted Spinning*, by courtesy of the American School of Correspondence.

knives and passed to rollers which convey it from the machine. It is used in many ways, being often combined with pure wools for dress goods and blankets. Some mills use their own noils, but frequently they are sold to other manufacturers.

Finishing Gilling. — The aim of the two or more gill boxes which usually follow the comb is to blend more completely different length fibers, to increase the parallelism, to apply moisture evenly to every fiber, and to wind the tops into a ball which will easily unwind. To accomplish this very fine teeth are necessary in these gill boxes. As many as twenty-eight

FIG. 89. — TOP.

cans from the combs are at times united in the first finisher gill box, the result of which is a heavy sliver. Three or more slivers are united into one in the last gill box, and by a balling head attachment the finished top (Fig. 89) is wound. In some classes of yarn no real twist has yet been given to the sliver. Many mills buy their tops instead of making them, as it saves expense. Combing and gilling are costly operations, and mills having well-equipped plants frequently do a commission business in tops, returning to the purchaser tops, noils, and waste. Wool sold in this form often has an excess of moisture in it, which increases its weight and consequently its cost to the buyer. To offset this condition, which is sometimes fraudulent, conditioning houses have been organized to test wool. Standards of moisture have been agreed upon, and variations from this affect the sale of the wool. Silk conditioning houses were long ago established in Europe and are now increasing in the United States. They now test both wool and silk for moisture as well as honest condition of the fibers.

Drawing and Doubling. — The tops must now be reduced to a size small enough to spin, as in previous machines a number of slivers are united into one. The drawing process is repeated from six to nine times, until the required size is reached. In some classes of yarn little twist is given until the machine which directly precedes the spinning (the roving), whereas in other varieties the thin yarn is repeatedly twisted. The product from these machines is wound on bobbins. It is stated that worsted yarn is often doubled a half million times before it is ready for the spinning frame.

Spinning. — (Fig. 90). There are two methods of spinning worsted yarns: the Bradford or English system, which thoroughly oils the wool before combing and gives a smooth, lustrous yarn fitted for worsted suitings as its final result; and the French or dry spinning, which uses shorter wool, little oil, and spins a soft, dull yarn. The latter system offers more difficulty in handling the wool on account of the increased electricity arising from the lack of oiling, and it costs more, but it yields a soft, clinging material much in demand. The principal difference between the two methods is in the drawing and spinning, as the former system requires much twisting, and the latter avoids twisting. Soft yarns are spun on the worsted mule, which is almost identical with the mule for woolen spinning, but closely twisted yarns require the throstle or upright frame, by the use of the flyer, cap, or ring principles.

Counts or Sizes of Yarns. — The sizes of yarns are variously indicated in different localities and countries. The United States has two systems in general use for woolen yarns. The first originated in Philadelphia and is called the "cut"; the second is used in other parts of the United States, and is designated as the "run." Both methods are based on the number of hanks or skeins required to make a pound, but differ in the

Fig. 90. — Spinning the Wool.

Courtesy of M. J. Whittall.

size of the hanks. The "cut" system takes 300 yards of one-cut yarn (the coarsest) to make a pound (one hank). As two-cut yarn is as fine again as one-cut, it will take 600 yards of it to make a pound, which will be in two hanks. In the "cut" system the coarse yarns in general use are five-cut to seven-cut (lower sizes are seldom used); medium yarns are eighteen-cut to twenty-one-cut, and fine yarns are thirty-cut to thirty-five-cut. The market expresses these cuts as 1/30s cut when speaking of single No. 30 yarn (thirty hanks), or 2/30s cut when speaking of two-ply No. 30 yarn.

The "run" system has 1600 yards to the pound for one-run yarn; No. 2 run yarn is twice 1600, or 3200 yards to the pound (being twice as fine as No. 1 run). Fine yarns are numbered in a like manner. In the "run" system Nos. 1 to 3 would be coarse yarns; Nos. 3 1/2 to 5 would be medium, and Nos. 6 to 8 runs would be fine.

The sizes of worsted yarns are numbered by the "count." In this system 560 yards of 1-count yarn weighs one pound, and higher "counts" are numbered as in the "cut" and "run" methods.

Worsted and combed wool yarns are used for weaving, knitting, and needlework (crewel, Berlin, zephyr, and Saxony). We find worsted yarns in serges of many varieties, diagonals, prunellas, panamas, Venetian cloth, and voiles, and as the filling with cotton warps in alpacas, mohairs, Sicilians, and other luster goods. Yarns from the combed wool industry are found in underwear, fancy dress goods, soft serges, and buntings. They are combined with cotton or with silk in such materials as poplins, henriettas, lansdowns, and challies.

Weaving and Sizing. — Yarn comes from the spinning frames on bobbins, but has still many processes to undergo before it is finally woven. When skein dyeing is necessary the bobbins must be run off into skeins or hanks on the swifts, and after dyeing wound back on bobbins. Filling yarn goes directly to the weave room to be wound for the shuttles. Warp yarns require closer twisting than those for the filling. Some yarn is doubled before being woven, and has to go to a special machine which twists the two yarns in the opposite direction from the previous twisting. Warp yarn is frequently prepared for the loom by winding it on large dresser spools. Forty or more ends come from each spool, and as many spools are required as will make up the number of threads in the warp. Thousands of warp threads are required for ordinary cloth. The spools are placed on a creel and the threads are drawn off on a beam in the order in which they will be needed in the loom. If the yarn is to be sized or slashed, it usually is done at this time. The object of sizing is to strengthen the yarn and keep it from roughing up in the drawing-in and weaving. Inferior yarns are often sized so that they will stand the strain of weaving. Single woolen and worsted yarns are usually sized, but two-ply yarns need it less. Many of the mills of the United States do not size their yarns before weaving, as the extra machinery and time consumed add to the expense. There are many ways of sizing and many ingredients used, such as Irish moss, dextrin, gum arabic, potato starch, cornstarch, glue, and mucilage. The slasher is ordinarily a long trough filled with size, through which the threads from the beam pass. Rollers press in the size and also squeeze out the extra amount, and a heated cylinder dries the yarn. Much of the size drops out in a fine dust during the weaving. The yarn is warped before it is sized, and afterwards is drawn in and reeded before it is woven. (See Chap. IV.) Piece dyeing follows weaving, but the exact time for it depends on the finish the goods must have.

Finishing. — The beauty of woolen goods lies largely in the finish of the cloth; and of worsted goods, in the weave. Both rely on attractive color combinations. Stamped patterns and elaborate Jacquard designs are not used as often as in silk and cotton materials. Many of the favorite weaves are simple, such as the plain or tabby, the basket, stripe, and check. Twills or diagonals, satins, corkscrews, herringbones, ribs, cords, crêpes, and double-faced cloths are also staples. Many effects are gained by the use of yarns twisted in novel ways, by combining other fibers with the wool, and by finishes and dressings applied after the weaving is over. Worsted suitings, when taken from the loom, look much as they will in the finished state, but woolen cloths, especially those which are to be fulled, are far from attractive, being coarse and rough and requiring many processes to develop their beauty. Woolen and worsted cloths may be finished in an infinite number of ways, but certain processes (which follow) may be taken as representative. The same processes are, in general, applied to both kinds of cloth, but when worsteds are fulled it is only to soften the weave, while the object in woolens is often to obliterate it entirely. Fulling can be watched and stopped when desired, but broadcloths and other dress face goods are given the maximum of shrinkage. The latter materials are woven both longer and wider than they will be in their finished state, for they frequently shrink one third in each direction. They are therefore woven as much as eighty inches wide that they may be fifty-two or fifty-four inches when finished. Broadcloth, melton, and kersey are usually woven with a twill which throws the warp on the face, consequently carded wool yarn is used for the warp, for when fulled it will cover the filling. Worsted filling is sometimes used in broadcloth, but the character of the weave throws it to the back. Cloth woven with the plain or tabby weave and fulled is sometimes called broadcloth, but is really a fulled flannel, and is less satisfactory than broadcloth. The present demand for very light weight, pliable broadcloths for women's wear has reduced their strength while increasing their softness, for any defects of stock or early processes combined with the close shearing leave them weak and liable to tear. The finishing of dress face goods changes the rough, coarse product of the loom into the soft, satiny appearance which distinguishes these materials. Good stock and numerous processes make these goods expensive.

Inspection or Perching. — Poor stock, careless scouring and blending, inferior chemicals, and injuries in the many processes show when the goods come to the finishing stage. The most rigid inspection by experts is given the cloth after weaving, after mending, and after finishing. The material is drawn over rods or over an inclined plane and defects are noted, marked with chalk on the cloth, and remedies are suggested. These difficulties sometimes require that the cloth be sent back to previous machines for treatment. If the wool cannot yield good results, surface finishes, artificial stiffenings, lusterings, and dressings are used. Even with good stock carelessness or machines out of order may have caused injuries which must be mended. The material is now weighed and measured.

Burling and Mending. — The usual difficulties with the cloth are unsightly spots caused by knots, bunches of threads, and thick or thin places, which are removed by special tools or by the fingers. This is called burling. Mending is required when the threads have broken or the weave is imperfect, and the design must be woven back exactly. The burlers and menders are generally women who are skilled handworkers and sewers. Worsted suiting requires very careful mending, as the final finish will not cover the defects, as will the fulling for dress face goods.

Washing and Drying. — The cloth is frequently soiled by the machinery, and must be washed before it is finished. Some woolen cloths go to the fulling mill without washing, but worsteds are usually scoured in a special machine in which soap, Fuller's earth, or other cleansing materials are in solution in warm water. Careful rinsing follows the washing, to rid the cloth of oils, glues, and chemicals, as well as of dirt. Moisture is removed by a hydro-extractor, and the cloth dryed in a cloth dryer or by a vacuum process.

Fulling, Milling, Felting, or Shrinking. — This process is a very important one. A large number of cloths are slightly fulled to soften the appearance of the weave, but materials which are thoroughly fulled lose their weave lines, and after further finishing present a soft, even pile which has given them the name of dress face goods. Fulling takes advantage of the property of shrinking which is found in many wools, but especially in those having numerous scales or serrations. Moisture, heat, and pressure or rubbing increase this tendency, for the rough under surfaces of the scales resist interlocking until softened. Woolen yarn felts easily on account of the crisscross arrangement of its fibers. Cloth woven from such yarn and fulled decreases greatly in length and width, while increasing in bulk. A pattern woven in the cloth will be reduced in size. Goods which are to be fulled are not only woven longer and wider in proportion to the shrinking which will occur, but must be woven loosely enough to be soft and pliable after felting, yet close enough to be substantial, for close weaving often results after felting in a boardlike cloth. Fulling strengthens good wool, but poor, tender wool cannot be made strong in this way, though it may have a solid appearance. Cloth which is to be fulled is sewed together in an endless belt, and it is folded with the selvages together and with the face inside. The fulling mill is a sort of huge chest or closet in which warm, oily, soapy water can act upon the cloth while it passes, twisted and hanging in loops over vertical rollers, under heavy hammers or in a trough. The friction also causes heat and aids in the felting. For slight fulling, as is needed in some worsted suitings, a couple of hours will suffice, but for broadcloths and meltons many hours are often required. Woolen cloths are not usually washed before felting, as they are cleaned sufficiently by this process and the washing which follows. Cloth which lacks in weight and density is frequently flocked in the fulling mill.

Flocks. — Finely cut up wool waste can be fulled into cloth, making it firmer. This is usually applied to the under side. Flocks made from good stock, and applied to pure wool cloth, are not a detriment to the finished material. It frequently happens, however, that flocks are used to cover up defects and to deceive the purchaser. The careless choice and preparation of the flocks and the use of them to thicken and give feel to material made of inferior wool, shoddy, mungo, and cotton, give almost worthless material. After a time the flocks drop out and the real poverty of the goods is evident. This short, fuzzy waste can be found frequently in the linings of wool coats and skirts, consequently it has become customary to leave the linings free, thus allowing the waste to fall out unheeded. Mill waste, sweepings, and clippings from the gig and shear are used. Fancy dress goods are sometimes made having as a surface design white or colored flocks which were added to the yarn while being spun. Flock wall papers are made with these same fine clippings, which are blown on the surface.

Washing, Drying, and Tentering. — After fulling, the cloth requires careful washing or rinsing to rid it of soaps. It is then dried in a hydro-extractor and perhaps later in a dryer. If vegetable matter is still present in the cloth, it must be carbonized. Before the cloth is dry enough to be "set" it must go to the tentering machine. In olden times the cloth was fastened between posts in the mill yard, where it dried for several days, but now it is stretched carefully on a long frame, gripped on each selvage and passed over steam coils. This process removes cockles and creases, and sets the cloth evenly across the filling, which is most important, especially if cropping is to follow, for irregularities of surface will be cut. Cloths which show their weaves, if tentered carelessly, have the filling threads running a little on the bias, or the materials lack in smoothness. Cloths which are to be napped are moistened with water to make the next process effective.

Napping, Gigging, or Raising. — These terms are almost interchangeable. Fulled cloth is rough and dull in appearance; the lustrous, soft pile which adds to its beauty and strength is made by roughing up the surface to disentangle the fibers and make them into a thick pile or nap, and then cutting them even with the shear.

Worsted suiting is merely napped enough to make the weave look clean and bright. Brushes are often used instead of teazles. Flannels are napped so that the weave is softened, but such felted goods as broadcloths and meltons have the pile so raised that the weave is completely obliterated. They have to pass many times through the gig to accomplish this. Defects are often concealed by softly raising a surface and finishing it to look well. The Raising Gig (Fig. 91) is a large, open cylinder on which a series of slabs or shallow boxes, the width of the cylinder, may be fastened. The best means of raising the nap is the teazle (Fig. 92), which is a vegetable growth something like a stiff thistle. Fine wire raisers are sometimes used, but have this disadvantage, that they break the cloth when in contact with a knot, whereas the vegetable teazles break first.

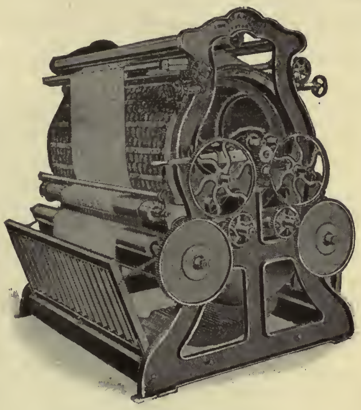


FIG. 91. — DOUBLE-ACTING GIG.

Courtesy of Curtis & Marble.

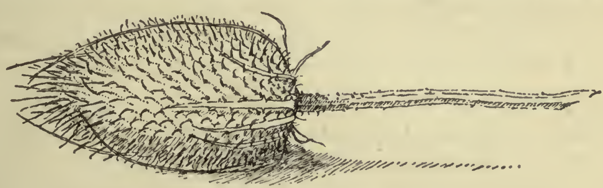


FIG. 92. — TEAZLE.

The narrow troughs or boxes are filled with the teazles laid lengthwise, so that they present a continuous napping surface. The cloth is stretched tight in the machine, a humidifier often sprays it as it passes slowly along, and the napping cylinder moves rapidly in the opposite direction, rubbing up the surface of the material with the teazles. The process is repeated several times, at first with old, soft teazles and gradually with stiff, new ones, until the surface is thoroughly covered with the raised fibers. The nap becomes finer as the gigging is repeated. There are two methods of napping, the wet and the dry. In the former, the cloth is kept moist, and the resulting pile is more

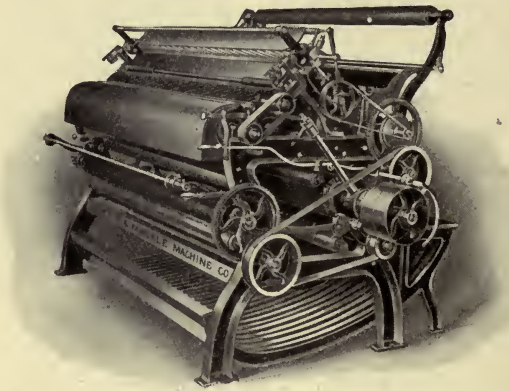


FIG. 93. — SINGLE CUTTER SHEAR.
Courtesy of Curtis & Marble.

shiny than in the dry raising. Dress face goods, such as broadcloths, are napped wet. The dry raising is used for worsted suitings and fancy woven goods. The small clippings from the shear are used for flocks or other purposes.

Shearing, Cutting or Cropping, and Brushing. — Cutting the nap and brushing it clean follow gigging or napping. One machine frequently combines all three processes of raising, cropping, and cleaning. The aim of the shear (Fig. 93) is to trim the raised nap to the desired height, it may be merely to even it off, or it may be to cut the nap close. The shear has to be adjusted to the need and requires care, for if the nap is too long the surface roughens with wear; or if too close, the material is weakened.

The cutting surface is a sharp blade arranged spirally around a cylinder which comes in contact with a sharp bar or knife. The two surfaces act as scissors and cut the nap as desired. The principle is similar to the lawn mower. A stiff brush or a set of soft teazles set in a bar follow, and rid the cloth of clippings and dust. Steam brushes are also used for some classes of goods, such as kerseys. After the wet napping and cropping to which dress face goods are subjected, the hand, when laid on the cloth, can move smoothly in the direction in which the fibers have been raised, but feels the opposing nap when moved in the opposite direction. In goods woven entirely of wool the nap is along the warp way. In dry raising, to which worsted suitings and trouserings are subjected, the fiber is lifted to an upright position and the shear cuts it off, leaving the weave distinct. The nap therefore offers no resistance to the hand when passed over it.

The differing order in which the many finishing processes are applied, their repetition or elimination, the appearance and use of new kinds of machines, and the large number of differing cloths, make impossible a definite statement of procedure. Perching or inspection occurs at intervals, and defects are found which must be corrected. Tentering, napping, and cropping are often repeated. Some mills, knowing that irregularities are apt to occur, have these repetitions as a part of their regular schedule.

General Finishes. — Boiling, steaming, pressing, and brushing are all used in varying degrees and times to give a final finish to cloth. Some wools, such as mohairs and alpacas, have a natural gloss which is increased by pressure; other wools can have a permanent luster brought out by treatment, and a surface finish can be applied to poor stock, giving it an attraction which is more or less enduring. Boiling or steaming, sometimes called crabbing, brings out luster, and is employed for some woolen goods and for many worsteds. It is used after tentering with some classes of goods, and after gigging and shearing, or even after pressing, with other kinds. The following are representative methods: (1) wrapping the cloth around a roller and boiling it for several hours; (2) wrapping the cloth around a perforated copper cylinder through which steam is forced, occupying several minutes; (3) placing the roll of cloth in a steam chest. The material in each instance is treated first on one side and then on the other. Cloth which is to be dyed in the piece is frequently sent to the dye house after steaming. It is sewed into an endless belt by uniting the two ends, and is passed through the dye until the requisite color is gained.

Sponging (decating) of cloth after its completion is necessary to keep it from spotting in the rain, as the luster is so fine that small drops of water injure it. All old housekeepers remember the careful sponging and pressing to which they subjected newly purchased cloth before it was made into a suit. The larger dry goods stores will now have the goods sponged before they are sent home. In the manufacture of woolens and worsteds in England and Germany the sponging is now done before it leaves the factory, both for the cut-up trade and the retail. As yet the United States has not made a specialty of this, but some of the largest mills are installing decating apparatus. This part of the business should be attended to at the factory, where it can be done to much better advantage than at home or in the small tailor shop.

Final Pressing. — A preliminary passing of cloth through the calender is often done before inspection occurs. Dress face goods are frequently thus pressed after the shearing and brushing, and are pressed again as a final finish. A calender is a highly polished heated roll on which the cloth is pressed smooth and given luster. Dry steaming often follows to make the gloss permanent, or steaming can be used to reduce an excessive luster. As a final finish a spindle or hydraulic press has been in use for some classes of goods, which gives a glaze to the material, but the calender is taking its place. The method of pressure in the spindle press is as follows: The cloth is carefully folded with press boards between the folds, so that one layer of cloth does not touch another. Hot plates are put above and below, and hydraulic presses or screws bring pressure upon the cloth. It is left over night in the press, and then taken out and refolded in such a way that parts not pressed before now receive an equivalent amount. Pressing adds to the look of solidity in the cloth as well as to the luster.

Brushing of various kinds is also used in the final finishing.

Special Finishes. — Cheviots, which partake of both woolen and worsted characteristics, though in general they are worsted, show the weave, but it is softened by some fulling and raising, and not as clear as in the regular worsted suiting. A good worsted cheviot costs about twice as much as when made of woolen yarn. In the latter case it feels softer and is less liable to wear well. The original cheviots were made from the wool of the English cheviot sheep. Venetians are made of wool, but the weave, which is a sort of upright twill, is definite and clear like a worsted. Thus worsted and wools partake at times of opposite characteristics, from variations in their finish. Flannels woven plain or with a simple twill are finished in many ways. At times they are subjected to the processes of worsteds and clearly show the weave. They are even woven with worsted yarn and dry finished. Still other varieties, such as the opera flannel and ladies' cloth, are woven of woolen yarn and fulled, napped, sheared, and pressed to look like broadcloths. They are sold at different prices, being made of pure wool or in many degrees of combination with cotton. When made of all cotton they can be chemically treated to feel like wool, given the finish to look like wool, and even labelled "all wool." It is sometimes difficult to distinguish differences in materials, even though they bear dissimilar names. Unfinished worsteds, for example, which have the nap left on, look much like cheviots, though the process of finishing has differed. The former, however, are more open in weave, which can be seen when held to the light. The worsted cheviot has a crisper feel in the hand than the unfinished worsted.

Special machines are used to give varieties of surface, the chinchilla machine being illustrative of such mechanical finish. The chinchilla cloth is made with a special weave, and is later fulled, gigged, and sheared to give it a long, soft nap, which is well opened and made erect with a wire brush. The cloth is now placed in the special machine, which has a rotary attachment, and rubs the nap into small rolls, bunches, or points. By adjustment of the machine these bunches can be made to lie in stripes or other designs. When this cloth is made of pure stock good results follow, but frequently it is manufactured of shoddy, cotton, or poor wool, and is unsatisfactory. Cotton warp with a wool filling thrown on the surface is frequently used in its construction.

The true worsted suiting is finished much more simply than the dress face goods. After weaving, it is generally sufficient to wash, tenter, brush or gig (to raise the nap which obscures the weave), crop the surface to make it bright and distinct, and crab and press to give permanent luster.

Fibers are removed from yarn or cloth by several methods besides shearing, such as gassing or singeing, in which the yarn or cloth is passed quickly through a gas flame, which singes it without burning. Scouring or dyeing often follow on account of a slight discoloration. Passing the cloth rapidly over white hot copper rollers also removes the surface fibers. The electric current is also used for napping and cropping as well as for other finishes.

Worsteds are usually dyed in the slub (top) or in the skein (spun yarn). A method of obtaining mixed effects such as the pepper and salt, called Vigoureux printing, has been used in France, and is being introduced into America. (See Chap. XIII.)

The use of surface finishings of innumerable kinds is very general. They are employed to beautify, to strengthen, and to conceal defects. Starches, gums, soaps, and chemicals are the usual dressings. Frequently they are injurious in character, or help to deceive the consumer as to the real nature of the fabric.

The feel of one textile can be given to another by chemical treatment. Cotton is made to resemble wool and wool to have a silky effect. Moiré and embossed designs can be made by special machines, by the use of gums and starches. Crêpon effects and waterproof and fireproof finishes can be given by chemical means. Goods are made absorbent or antiseptic, are made to have a pleasing feel and soft finish, or are given weight and substance as well as gloss and luster, by surface treatment. Many materials which are lightly woven are subsequently stiffened on the back to give them an appearance of body which they do not really possess. Poplins, bengalines, reps, and bedford cords are at times thus made to have a "good body," which is a questionable economy to the consumer, as the size comes out where any rubbing occurs and leaves the sleazy material. When materials are heavily weighted with vegetable matter they will deteriorate unless antiseptics are applied, which are often injurious in themselves, on account of their content, though the manufacturer may have bought them in good faith.

New discoveries in industrial chemistry are resulting in new methods of finishing. The chlorination of wools; printing in light and dark; the production of unshrinkable yarns; combinations in one cloth of felted and unfelted surface, and giving silk effects in the rustle as well as the appearance are interesting methods of gaining diversities in material. Reliable trade journals should be consulted constantly by those who wish to know of new finishes and whether practical results have followed from the experiments which are being tried.

Other Uses of Wool and Worsted Yarns. — *Felt* which is made of serrated wools was not woven originally, but was carded, felted, and pressed into cloth. At present it is frequently woven first, and fulled and finished later. A cheap kind of horse blanket is made which looks like felt, but is constructed in the following way: Sheets or laps of carded wool are placed on both sides of coarse burlap. These layers are made into one piece of cloth by means of thousands of needles, which pull the carded wool back and forth into the burlap, the rough jute or hemp fibers of which hold the wool in place. The finish gives the material an attractive surface. Large quantities of wool and worsted yarn are used for *knitted goods*, for cardigan jackets, sweaters, hosiery, caps, shawls, gloves, mittens, underwear of all kinds, boot, shoe, and glove linings, and classes of materials such as eiderdown flannels, used for wrappers and blankets. In eiderdown flannel the wool is knitted into cotton stockinet and is made both single and double faced. The finishing of this material gives it a soft nap. Cotton is used largely in combination with wool in the knitted goods industry.

Rugs and carpets are made of both woolen and worsted yarns, but the latter give the best wear and are the more expensive. These floor coverings were originally made entirely by hand by tying or twisting short ends of yarn around the warp threads and holding the loops in place by the filling. The loops were cut by hand by means of sharp knives. The machine-made products imitate the hand made, and are frequently constructed on specially adapted looms. The worsted yarn is made from coarse, hairlike wools. The yarn is not only doubled and twisted after spinning but often three of these two-ply strands are twisted into one, and several of these are used in each loop. The best carpets have a hemp or linen back and a well-dyed worsted yarn for the face. In good pile carpets the filling is thrown through the warp three times after each row of loops, which holds them well in place. There are many varieties of these floor coverings on the market, the principal ones being the Ingrain, which is woven like a cloth with two-ply or three-ply yarn. Venetians and Kidderminsters are similar. The weave is sometimes plain, but frequently there are elaborate designs which reverse the color on the front and back. Either side of the carpet can be used. Ingrain carpets with two webs are woven usually on Jacquard looms and are enduring and rather expensive when made of good three-ply yarn, but are made in all qualities and prices. They are manufactured with worsted in both warp and filling, or with worsted warp and wool filling, or with worsted warp and cotton, jute, or even poorer filling. The best quality has a large and definite number of warp and filling threads to the inch, but the poorer qualities reduce the amount and consequently the endurance. Drugget or felt is sometimes strong and serviceable, but often is cheap and poor. It is made plain or with a design printed upon it.

Pile carpets are constructed with the loops uncut, as in Brussels, or cut, as in Wilton. They have two warps. The best carpets have a worsted surface. Wool is used in some varieties. The kind of fiber used for the backing makes considerable difference in the expense of the carpet, and also figures in the wear. Flax, hemp, cotton, cotton waste, and jute are all used according to the price of the carpet. After weaving, pile carpets are finished usually by brushing and shearing. Brussels carpets are made in several qualities, depending on the stock used, the number of threads in a loop, the loops in a given space, the class of dye used in the yarn, and the material used in the backing. The number of colors possible in a design is limited, as the yarn for each color must be dyed separately. Brussels carpets are woven on a special Jacquard loom, in which the worsted yarns for the surface loops are wound on spools and placed on large frames at the back and slanting towards the loom. Each color is on a separate frame, and there are about two hundred and fifty spools on one frame. The warp which is used for the backing is either wound on spools also and placed on the lowest frame, or it is wound on a beam and set at the back of the loom in front of the frames. The backing threads, both warp and filling, are also dyed. A body Brussels, which is considered the best kind, takes its worsted yarn into its very foundation, so that the colored worsteds show on the wrong side of the carpet in the midst of the backing threads. If it is a five-frame Brussels it will have five colors on the frames, and when one of these colors appears on the surface of the carpet the others can be seen at the back. There are several threads in each loop. The filling usually is shot across twice in Brussels, for the loops are less apt to pull out than if they were cut, in which case a three-shot filling is better. Flax and hemp make the best backing for both warp and filling, but cotton is sometimes used satisfactorily. Well-made Brussels carpets are very enduring and also expensive. The loops on the surface are made by passing the worsted yarn from the frame over a series of wires and holding down the loops thus made by the filling threads. The rods or wires, usually eight or ten in number, come automatically in place, and are each withdrawn and placed at the end of the row after the filling holds the row of loops on the surface.

Tapestry Brussels carpet is a poor imitation of the real Brussels. Many colors are used in it. The design is made first on squared paper, the scheme of color in each pick of the pattern is studied out, and the succession of it sent to the printer. The skeins of yarn to be used for the loops on the surface of the carpet are wound on a large cylinder, attached to which are troughs of color which come in contact automatically with the yarn, and print it according to the succession of colors indicated in the design. The skeins are taken from the cylinder, showing crosswise streaks of varied color, and are carried to the steam chest to have the dye set. When the carpet is woven the pattern is complete, but has a less distinct outline than the real Brussels. The Jacquard harness and the frames full of bobbins are not needed, hence expense is spared. A simple harness is used, and wires are required to make the loops. The rows of loops are usually farther apart, and often but one thread is used in each loop. The backing is generally jute or some inexpensive fiber, and the face is a poor quality of worsted yarn. Flecks of color are often printed on the back to increase the resemblance to body Brussels carpet, and thus deceive the consumer. Tapestry carpet which has the loops cut is sometimes called velvet carpet.

The original Wilton rugs were, and are still, made by hand in England on upright looms. They are of great beauty and worth, and are high in price. The machine-made Wilton is a copy of these, and an excellent article, at a much lower price. It is woven like a Brussels carpet, but has the loops cut, for the wires over which the loops are made have sharp edges which cut through the worsted threads as they are drawn out from the row just made. The Wilton carpet is usually woven of better worsted and backing yarn, a greater number of fibers are in each loop, the loops are closer together, and the filling thread, which binds the loops together, passes across three times after each row of loops is made. The warp frequently requires as many as two thousand threads. The number of colors for a design in Wilton carpet is limited as it is in Brussels. The French Moquette carpet is similar to the Wilton, and also named from the town of its manufacture.

Axminster carpet is a pile carpet resembling the Wilton, but numerous colors are possible by a special arrangement for the supply of worsted yarn. The design is made, and the colored yarn as needed for each line of loops is wound on a separate small cylinder. These are placed in an endless chain above the loom, and the threads from each are passed through a series of slots or needles. Each cylinder drops in place when needed, and makes its row of loops. It then automatically passes up to wait until it is again needed in a repeat of the pattern. Royal Axminster carpets are expensive. In England Axminster carpets are sometimes called Moquette, but the latter is more like Wilton carpet. The terms velvet and Moquette have been used rather loosely in America for cut pile carpets. Chenille Axminster carpets were so called from the tufted cord of which the loops were made. A special loom was invented to weave a variety of cloth and then cut it into narrow strips along the warp, which formed the chenille cord. This cord is woven into the surface of the carpet. The principle is much used for the manufacture of chenille curtains. Glasgow has manufactured chenille carpets; the United States does not import them to any extent.

Wastes and By-products. — The large variety and value of wastes can be seen by referring to any textile journal, and noting the kinds of products under such headings as Rags new and old, Shoddy, Machine Waste, and the like. An efficiently run factory takes the pounds of machine waste and its disposal into account when estimating the cost of its product, as well as the expense of the raw material, labor, repairs, equipment, and overhead expenses. The final cost is reduced by selling wastes, noils, or clippings, and the effect is felt in the market price of cloth or of clothing. Mutton, pelts, leather, rugs, cloaks, and oils help to make the utilization of the sheep one of the greatest industries in the world.

Countries Manufacturing. — The leading manufacturing countries are: (1) Great Britain, to which we look especially for worsted suitings and diagonals. Leeds is a noted center, Preston and Manchester are well known for the special finish they give their goods, Bristol and Bath make dress goods and trouserings, and southern Scotland is looked to for tweeds. (2) France excels in fine woolens and combed wool dress goods. (3) Germany has many large manufacturing towns noted for woolens and worsteds. (4) The United States does a large business but exports little. Thirty states have woolen and worsted mills. Philadelphia is the leading city; and the principal manufacturing states, in the present order of their volume of business, are Pennsylvania, Massachusetts, Rhode Island, and New York.

Cutting-up Trade. — The great increase of ready-to-wear clothing for men, women, and children has caused a demand on the manufacturer for classes of goods made especially for the "cutting-up trade," as it is called. Some mills are working solely to supply these large clothing houses, and sections of trade journals are devoted to these interests.

WOOL AND WORSTED MATERIALS

	Width	Price
Albatross	36–45 in.	$.50–1.00
Albert cloth	54 in.	3.00–5.00
Basket cloth	42–54 in.	1.00–2.50
Beaver	54 in.	3.00–12.00
Bedford cord	50–54 in.	1.00–2.50
Blankets		7.00–29.00 pr.
Brilliantine	42–54 in.	.50–2.00
Broadcloth	50–54 in.	1.25–4.00
Carpets		1.00 up
Cashmere	42–44 in.	.75–1.50
Cassimere	54 in.	3.00
Challies	30 in.	.50– .75
Cheviot	42–48 in.	.75–3.00
Chiffon cloth	54 in.	1.75
Corkscrew worsted	45–54 in.	1.00–2.50
Covert	52–54 in.	1.00–5.00
Cravenette	50–56 in.	1.50–3.50
Crêpe cloth	42–45 in.	1.25–1.50
Crêpon	44 in.	1.25–1.50
Diagonal	45–54 in.	1.00 up
Etamine	42 in.	1.25–3.00
Felt	24–50 in.	.80–1.50
Flannel	27–36 in.	.55–1.00
Frieze	54 in.	2.00–5.00
Gloria	36 in.	1.00–1.50
Golf cloth	54 in.	1.25 up
Granite cloth	42–45 in.	1.00–1.25
Grenadine	42 in.	1.00–2.00
Henrietta	38–45 in.	1.00–1.50
Homespun	42–50 in.	1.00–3.00
Hopsacking	54 in.	1.75–2.00
Kersey	54 in.	2.00–5.00
Ladies' cloth	44–54 in.	1.00–4.00
Marquisette	36 in.	1.50–3.50
Melton	52 in.	2.00–4.00
Mohair	40–54 in.	.75–2.00
Nun's veiling	36 in.	.50–1.50
Panama	42–54 in.	1.00–1.85
Polo cloth	54 in.	2.50–5.00
Prunella	42–45 in.	1.00–1.50
Ratine	54 in.	1.75–3.00

WOOL AND WORSTED MATERIALS — *Continued*

	Width	Price
Serge	42–54 in.	$1.25–2.75
Shepherd's plaid	46–54 in.	1.25–2.50
Suiting	42–58 in.	1.00–3.50
Tweed	52–54 in.	2.00–4.00
Venetian	54 in.	1.00–2.50
Voile	42–45 in.	1.25–2.00
Whipcord	54 in.	.75–1.50
Zibeline	42–54 in.	1.50–4.00

MIXTURES WITH WOOL

	Width	Price
Alpaca	36–45 in.	$.25–1.00
Astrakan	36 in.	4.00–18.00
Bedford cord	46 in.	2.25
Brilliantine	44 in.	.50–1.50
Eolienne	42 in.	1.50
Henrietta	45 in.	1.00–2.00
Lansdowne	40 in.	1.25
Marquisette	36 in.	1.50–3.50
Mohair	40–54 in.	.75–2.00
Sicilian	42–54 in.	.50–2.00

CHAPTER VII

THE COTTON INDUSTRY

Economic and Commercial Conditions. — The vegetable fiber cotton is of more value to mankind than any one of the other textile fibers, on account of its cheapness, its availability, and its varied usefulness. The materials made from it range from the finest threads, mulls, and laces, to heavy blankets and sailcloths. Its value is enhanced by its resemblance, after special treatment, to linen, wool, or silk, by which warmth and attractive appearance can be gained at a small cost. It is probable that no other plant is so closely connected with the cost of living.

The invention of the saw gin by Eli Whitney in 1792 was one of the factors in revolutionizing the industrial condition of the world, and in substituting the problems of factory production for those of the home. His invention made the cotton of the United States available to the English spinners, and the demand for cotton cloth gave the special impetus to the inventions of Hargreaves, Arkwright, and Crompton. The influence of cotton on the commercial, political, and social relations of the United States is of noteworthy importance. Other countries are depending on us for it, and it may properly be said to make for peace between us and other nations.

Properties. — The properties of cotton which are especially noteworthy are the following: —

1. The fiber has a natural twist (see Chap. XI) which aids in the spinning of it into fine and coarse yarns. When long, fine staple cotton is used and the thread well spun it makes a strong yarn.

2. Cotton burns easily on account of the natural oil in it and its cellulose nature; it is said to be even subject to spontaneous

Fig. 94. — A Modern Weave Room, showing an Acre of Looms.

Courtesy of the Chicopee Manufacturing Company.

combustion. When cotton is nitrated, it is highly inflammable and is used for gun cotton. Treatment with nitric acid gives cotton more or less a feel of wool, but as it makes it burn more readily than before, there is danger if the material is brought near the fire. Many of these materials are napped to give them still more the effect of wool, and the danger of fire is further increased by the greater amount of air between the fibers.

3. Cotton is very free from impurities, and bleaching cleanses it still more. It can be stored for a long time without deterioration, unless sizings and starches and certain dyes are present. If kept clean it is a hygienic material for wearing next to the body.

4. The hygroscopic quality is less than that of wool or silk. Artificial moisture is needed in its spinning to produce good results. It absorbs water slowly, and does not give it up quickly, consequently it remains damp a long time. To render cotton absorbent, the cotton wax is removed. It does not dye readily unless it is made more absorbent or a chemical is applied for which both it and the dye have an affinity. This mordant, as it is called, holds the dye to the cotton. (See Chap. XIII.)

5. Moist cotton is stronger than dry cotton. When cotton is heated, as under a very hot iron, its strength is less. Alternate moisture and heat do not hurt cotton unless the heat is too great.

6. Cotton crushes and creases easily, and needs frequent pressing. The surface of napped goods and blankets easily flattens down and takes on a rough, shabby look unless often brushed and shaken.

7. Cotton soils readily on account of the numerous fine hairs protruding from the yarn. When it is new and has the sizing or finish still upon it, it will stay clean longer, for the fibers are held down.

8. Cotton shrinks in water and in certain chemicals. This is a natural property, but is augmented in weaving. The strain on the warp threads in the loom stretches the yarn to its full length, and the sizings and starches hold it there. Warm water and soap in the laundry loosen the finish and the yarn contracts.

The shrinking must be taken into consideration when cutting out and making garments. When cotton yarn is put into a bath of a certain strength alkali it will shrink and become stronger and heavier, and will take on a parchment-like appearance. (See Mercerization, Chap. XII.)

9. Cotton is a better conductor of heat than wool or silk, consequently when thin it is a satisfactory summer garment.

10. The elasticity of cotton is less than either silk or wool, therefore the thread breaks more readily when subjected to pressure.

11. The tensile strength is fair. The cotton fiber is stronger than the wool fiber. India Surat cotton is the strongest, and the Sea Island has the least strength.

12. Specific Gravity. This quality differs in various textile fibers, but it is least in boiled-off silk. Wool is lighter than raw silk, and mohair is the same as the latter. Linen and cotton are the heaviest. Cotton blankets and quilts are much heavier than those made of wool of the same consistency.

Botany and Growth. — Cotton consists of the hairs (plumose fibers) which protect the seeds of the plant. It is called a surface fiber to distinguish it from the bast or stem fibers, such as flax or Kentucky hemp. The stalks of the cotton contain bast fiber not utilized at present on account of the expense of preparation. Cotton is almost pure cellulose. While growing, the fiber is cylindrical in form, but as it dries it twists and when fully ripe is like a narrow twisted ribbon (see Fig. 128). This characteristic gives strength when the fibers are made into yarn. Cotton is often short in staple, but a fiber of even three fourths of an inch in length can be spun into a strong yarn.

The cotton plant (Fig. 96) may be an annual, biennial, or perennial. In the United States it is an annual which grows to the height of from four to six feet. In South America and India a more tree-like cotton grows. The leaf of the plant often varies in shape on different parts of the stem. The flower has five whitish or yellowish petals, which are almost saffron color at the

Fig. 95.—Cotton Field, showing Picker at Work.
Courtesy of U. S. Department of Agriculture.

base. They last a day, becoming purplish in color, and drop off, leaving a three- or five-celled pod, which increases in size and finally bursts into sections, disclosing the cotton fiber covering the seeds. Some varieties of seeds are covered with a soft surface down called linters, which adheres very closely. This is removed by a second ginning, and forms a valuable crop. Sea Island cotton has shiny black seeds from which the lint is easily taken. Cotton ripens differently, and a plant may contain at one time mature cotton bursting out, together with developing bolls, flowers, and opening buds. A cotton field in bloom is a beautiful sight.

Cotton belongs to the order *Malvaceæ*, or mallow, which also gives the hollyhock and marshmallow. The important genus of the mallow family is the *Gossypium*, which is found varying in height from two to thirty feet. The species are very numerous, for the plant develops new characteristics according to its habitat, the methods of cultivation, choice of seed, soil, climate, and position near or away from the sea. There are many agricultural varieties which have obscured the botanical species. Authorities differ greatly in classifying the species of cotton, but the following are fairly well established: —

Gossypium barbadense, which takes its name from the Barbadoes, where it grows. Sea Island and the Gallini Egyptian cotton come from this species, and the Peruvian is probably more or less related. The kidney cotton of Brazil is a Peruvian variety, the name kidney being given on account of the seed arrangement in the capsule. Peruvian cotton has a long, strong staple which spins to medium fine counts, 45s to 70s. The *Gossypium religiosum* of India is also considered by many to be a variety of the *barbadense*. The seeds of this species are black and free of down. The plants are both annual and perennial, the first growing to three or four feet in height and the latter to six or eight. The *barbadense* grows better in salt air and soil; the fiber is long and silky, and the natural twists are frequent. The yield is perhaps less than the short staple cotton, but the

Fig. 96.—The Cotton Plant.
From Brooks' *Cotton*, by courtesy of the American School of Correspondence.

value is greater. The highest counts of yarn are spun from it; 120s to 240s. The roller gin is generally used to separate the lint from the seed.

Gossypium herbaceum. — This species is probably of Indian or Asiatic origin, and is both annual and biennial. The Brown Egyptian is from this species, and the Surat of India, which is short in staple, is said by some to belong to it also. The Nankeen cotton of China is a color variation of the *herbaceum.* The seeds are covered with two kinds of fibers: long and silky, and short and dense. The seed cotton has to be removed very carefully, as the hairs adhere tightly to the seeds, and the down and part of the covering of the seeds are apt to come off at the same time. The South American cotton, such as the Santos, Caera, and Pernams, are sometimes ascribed to the *barbadense* and at others to the *herbaceum* or the *hirsutum.*

Gossypium hirsutum is probably of American origin. It is grown as an annual. The name *hirsutum* is given on account of the appearance of the seed, which is covered with a grayish or greenish down. The American medium length cotton staple, such as the Upland, comes from this species. Some experts consider *hirsutum* and *herbaceum* to be the same species. The lint spins to warp threads 34s to 46s, and to filling from 36s to 54s. It is usually cleaned by the saw gin.

Gossypium arboreum and *neglectum.* — These species are much alike, and have the seeds covered with down. They are natives of India, and grow to fifteen or twenty feet in height. They give the Bengal and Dacca cottons of India, and the China cottons. The *Gossypium religiosum* is thought by some to be the same as the *Gossypium arboreum.*

Cotton is cultivated to about forty degrees both north and south of the Equator, but grows best within thirty-five degrees either way. More than half the cotton is cultivated in temperate latitudes. It thrives in a warm, humid atmosphere, with ample rainfall, and a light, loamy or sandy soil which keeps damp yet holds the heat. In a moist, even climate with warm summers, and with salt in the air and in the soil it reaches its highest quality, as in the Sea Island cotton grown on the land near the sea or on the islands off the coast of North Carolina, Georgia, and Florida. Rain in the spring when the crop is growing helps the development of stem and leaf, but heavy rains in the summer when it is maturing injure the production of the bolls. Humidity in the air is better than irrigation, although cotton thrives well under a system of irrigation in Egypt. The plant is very sensitive to frost. The conditions in the southern part of the United States are very favorable, especially the gradual rise of temperature during the entire growth. The great heat in Brazil makes the cotton rough and coarse. Egypt with its warm, bright climate, good water supply, and system of irrigation, is an excellent place for growing cotton, but the area of growth is at present too small for large crops. India has excessive heat, and a want of sunshine during the monsoon summer, consequently the cotton is immature and short in staple.

Outside of the American crop, the leading cotton countries are Egypt, India, South America, Russia, and China. Egypt gives two main varieties, the long staple brown, and a white or rough cotton. The long staple cottons are in great demand in manufacturing countries for the making of strong warp yarns, for the backing of heavy material such as pile goods, for sewing cotton and fine knitted goods. Egyptian cotton is next in value to the Sea Island cotton of the United States. The brownish color of much of the Egyptian cotton is caused by the red coloring matter in the Nile, which stains while it nourishes the plant. It is found classed in three grades in the market. Egyptian cotton is much used in the United States, 121,212 bales of 715 lbs. being imported in 1912 for purposes for which this cotton is better suited than the American. India cotton is grown under adverse circumstances, and therefore is short and coarse. The United States uses little of it, but it is exported to Japan, and to Germany and other parts of Europe.

English spinners find it too coarse for most purposes, although it is used. It is adapted for poorer qualities of warp and filling threads. Brazilian cotton is rough, harsh, and strong. It is classed in three grades, and is imported into the United States to combine with wool, which it closely resembles. In 1912 28,315 bales of 185 lbs. were imported. Both Russia and China grow large quantities of cotton, but the crop is principally used in home consumption, and full statistics regarding it are lacking. About 200,000 bales of cotton are exported annually from China to Japan.

Planting and Picking. — In the southern part of the United States, cotton is planted from March until May, according to the locality. Machine planters are in general use. Methods of cultivation are improving, resulting in a better crop condition, and a better yield. It frequently happens, however, that an unexpected frost or a long wet season will ruin an entire planting and it must be repeated. Even after the growth is well started there are other dangers. Diseases of various kinds attack the plant, and insect enemies are greatly dreaded, for they injure the growth and even ruin the entire crop. Many farmers rely entirely on the cotton crop, for it finds a ready sale even before it is out of the ground, consequently the failure of it means disaster, and anxious hours attend its development.

The crop begins to mature in late July, and it continues to do so until frost, in November or even December. The moment the cotton matures and the open boll displays its seed cotton fully ripe, the picking must begin. It is usually conducted in three stages, in the order of the developing bolls. These open first on the lower branches. The lower and middle bolls contain the best cotton. The gathering is usually done by hand, men, women, and children being at work in the fields from early morning until late at night. A machine harvester would be an advantage if one could be invented able to discriminate between ripe and unripe cotton, leaves and pieces of bolls, and for which the price would not be prohibitive. Machines have been invented which seem almost human, but as yet nothing has been generally adopted for this purpose. The human picker takes hold of the ripe cotton inside of the open boll, and it easily comes off clean. An average picker can gather from 200 to 250 pounds of seed cotton in a day; twice as much, it is said, can be picked by unusually quick workers. Pictures sometimes show the cotton pickers with baskets, but at present they more commonly use long sacks slung over the shoulder and trailing after the picker as he goes along on padded knees. The average pay for gathering 100 pounds of seed cotton is forty to fifty cents. The cost of picking the crop is a large item, especially in low-priced cotton. Careless work is only too common, and affects the cleanness of the fiber. The seed cotton is taken to the nearest gin house, where it is delivered to the gins, usually through suction pipes.

Cotton Ginning. — After cotton is gathered the seeds must be removed. There are two kinds of gins in general use for this purpose, the Saw Gin (Fig. 9), which was Eli Whitney's invention in 1793, and the Roller Gin, which is probably the descendant of the Churka Gin of India. Eli Whitney, a Northern man, was teaching in a cotton district of the South. He saw that cleaning cotton was a laborious task, and that a method of facilitating the work was needed. His machine consisted of a drum with wire hooks or teeth, which rotated against a grate, on the other side of which was the seed cotton. The teeth caught the fiber and drew it through the bars, leaving the seeds to drop to the ground, and a brush took the cotton from the drum. The modern saw gin is an improvement on the Whitney gin. Where two men before Whitney's time could clean two pounds a day by hand, at the present time two men can remove the cotton from the wagon, attend six gins and clean twenty-four thousand pounds a day; *i.e.*, each saw gin cleans at least four thousand pounds a day. The modern gin has a series of circular saws, forty or eighty on a shaft, which project through a slotted plate. The seed cotton is received at *A* and carried against the picker roll *C* and the saws *E*. The seeds drop below and the brush *J* carries the lint cotton to a flue to be carried to the condenser. A single gin may be used, or a number may

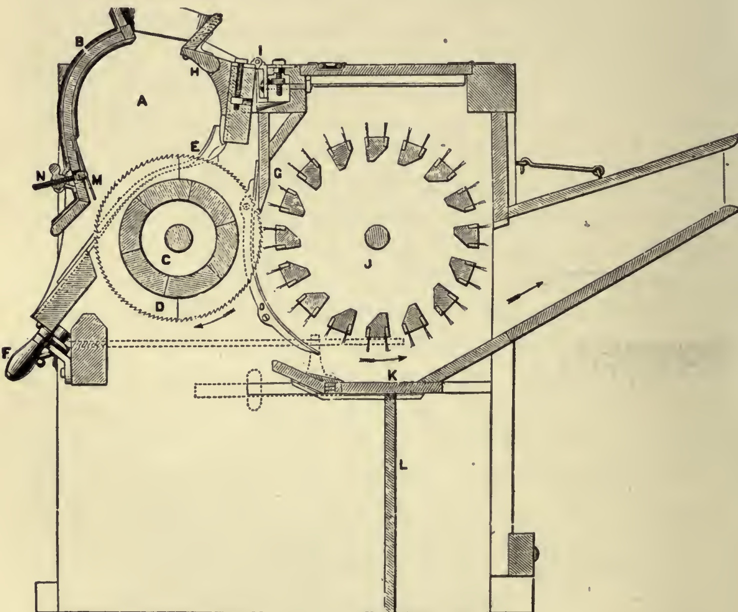


FIG. 97.—THE SAW GIN.
From Brooks' *Cotton*, by courtesy of the American School of Correspondence.

be combined, called a battery. One flue may be used for all the gins, or there may be one for each. The cotton is somewhat cleaned and straightened as it passes through the flue. A 60-saw gin revolving at 60 revolutions per minute will gin about 5000 pounds a day. The saw gin is suited to short-stapled cotton. The fibers of the lint after ginning are crisscross, entangled, and often full of specks and dirt. Several machines must follow in order to lay the cotton in parallel order and clean it.

Saw gins tear and snarl the cotton, consequently many advocate the slower method of the Roller Gin, although it adds to the expense. Gins which do less damage yet work rapidly are needed, and a combing gin has been brought out which claims to clean as much cotton per day as the saw gin without its injury and waste, and to leave it in better condition for spinning.

The Roller Gin is principally used for cleaning Sea Island and long staple cottons. The cotton is fed to a hopper, which has rollers at the bottom covered with rough walrus leather which seize the fiber. A fixed "doctor" knife presses against a roller and draws the fiber between the roller and the knife. The seeds, drawn to the point where the knife touches the roller, are gently but swiftly pushed off by two blades which strike the cotton alternately. The lint is carried on by the rollers and swept off by brushes. A recent roller gin cleans about two bales a day, or about a thousand pounds.

The seeds, which are covered with down or linters, are ginned and are then sent to the oil presses, which are frequently installed in the gin houses.

Baling. — The baling of American cotton follows the condenser after ginning. The method of reducing the bulk of the cotton is by a screw, steam, or hydraulic power, according to the equipment used. A covering of jute is fastened by steel bands around the contracted mass. The bales from the farms generally are not tightly packed, and will not stand long transportation, consequently the railroad and steamship companies have compresses which give a special baling before shipping. The Morse Lever Press is in general use. The cotton is delivered to a special receptacle and a sudden pressure of terrific force (5,000,000 lbs. to the bale) acts on the entire mass, thereby reducing it to a fraction of its original height. The covering and steel bands are fastened about it before the pressure is removed. The elasticity of the cotton and the air compressed in it cause the bale to spring to the turtleback shape characteristic of American bales. The size is usually for uncompressed cotton 56″ high, 28″ wide, and 48″ deep. The compressed cotton bale is approximately 56″ high, 24″ wide, and 32″ deep. These figures are obtained from actual measurement of a number of bales. The weight is about 500 lbs. The tare (covering, bands, etc.) is at least 25 or 30 lbs. Foreign buyers are allowed 6 per cent off the price for the tare, but additional weight is often added wrongfully. The poor and easily deteriorated jute covering gives way with the strain of hauling the heavy bale around with great hooks; the buyers tear cotton from the bale to test it; the cotton is subject to fire, and it is soiled and often weighty with water. The statement is made in a Report of the Department of Agriculture that our cotton bale is "the clumsiest, dirtiest, most expensive, and most wasteful package in which cotton, or in fact any commodity of like value, is anywhere put up. It has no friends among manufacturers, buyers, shippers, insurers, or producers. Custom seems alone responsible for this incubus on the industry." (Bulletin No. 33, *The Cotton Plant.*) The bales of cotton from other countries (Fig. 98) reach their destination in much better condition. The Egyptian bale (700 lbs.) is long, smoothly covered, and easily packed in the ships, so that the cost of carrying is reduced and the loss from dirt and bursting bales is much less. The India bale weighs 392 lbs., being smaller and of greater density than the American bale. The bale for Sea Island cotton is less tightly packed, and weighs 400 lbs. The American Cotton Company has invented a bale, compressed in the cylindrical form by the Bessonette press, which offers many advantages, but for various reasons it has not been popular and is little used.

The Industry in the United States. — The United States produces the bulk of the cotton used in the world (Fig. 99). The actual growth of cotton in this country during 1911 and marketed between Sept. 1, 1911, and Aug. 30, 1912, was about 16,000,000 bales of 500 lbs. The entire world crop was estimated as equivalent to 22,297,000 bales.

The importations of foreign cottons into the United States in

FIG. 98. — COTTON BALES. American bale in upper left-hand corner.
U. S. Dept. of Agriculture, Bul. 33.

1911–1912 were 121,212 bales of 715 lbs. each of Egyptian cotton, and 28,315 bales of 185 lbs. each of Rough Peruvian cotton. These cottons are purchased for special purposes for which American cottons are not suited, and do not therefore compete to any extent with our cotton. As can be seen, the importations of cotton are a small consideration.

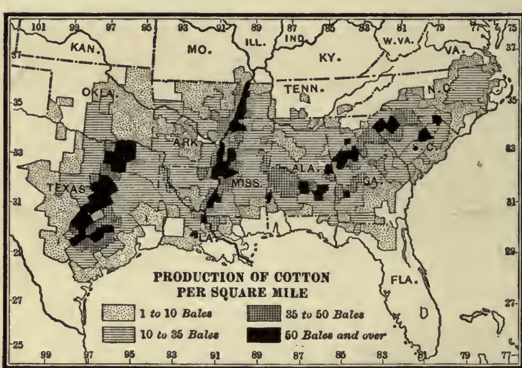


FIG. 99.—COTTON PRODUCING STATES.
From Tarr & McMurry's *New Geographies*, Second Book, 1910, by courtesy of the Macmillan Company.

The American crop in 1912–1913 is estimated at 13,820,000 bales of 500 lbs., exclusive of linters. At an average price of 12½ cts. per pound the value will be $855,920,000. It is estimated unofficially that the linter crop for the same period will amount to 491,300 bales. About two thirds of the crop is exported, but increasing domestic manufacturing interests tend to limit the export. In most of the Southern States cotton is the chief agricultural industry, more than thirty-four million acres being under cultivation in 1911–1912. It is also becoming an important manufacturing industry in many of these states as well.

Cotton in the United States is divided into two great branches, American and Sea Island. The term American cotton covers numerous agricultural varieties which are roughly classed as (1) cotton of the Atlantic States, or upland cotton, which is short in staple; (2) gulf cotton, a longer staple grown on the low lands of the states near the Gulf of Mexico; and (3) peeler cotton, a general term for good cotton grown in the states along the Mississippi River. Another classification which

FIG. 100.—COTTON ON THE SEED.

From Brooks' *Cotton*, by courtesy of the American School of Correspondence.

is virtually the same is (1) cotton grown on the uplands of the Southern States with a staple of $\frac{7}{8}$ to one inch; (2) cotton grown on swamp and bottom lands with a staple of $1\frac{1}{8}$ to $1\frac{1}{4}$ inches, and (3) extra or fancy cotton with a staple of $1\frac{3}{8}$ to $1\frac{5}{8}$ inches. The short staple cottons are principally used for filling yarns, the long staple are used for fine yarns, and the extra and fancy cottons for thread, velveteens, and when mixed with Brown Egyptian for hosiery yarns.

Sea Island cotton is the most valuable in the world, being noted for its length and silky appearance. It is grown on rather a limited area on the low, flat islands or coast lands of Georgia, South Carolina, and Florida, and to some extent in the West Indies. A very beautiful variety is grown in the Barbadoes and sells at about fifty cents per pound, but the crop is all taken by a thread manufacturer. Sea Island cotton is used for the finest yarns, from 120s to even 400s; for fine mousselines, laces, mixtures with silk, and for a good quality of sewing thread. It ranges in price from seventeen to twenty-four cents per pound. Egyptian cotton, which most resembles it, sells far below it. In 1911–1912 the crop was 122,766 bales, of which 96,057 were consumed at home, 19,398 went to Great Britain, and the rest to the Continent.

Classification. — American cottons are graded under set terms which carry special prices, based on the condition of standard middling upland cotton. Grades above or below this are measured by the condition of the standard; *i.e.*, the price of standard middling is the basis; better grades are listed as fractions above this, and the poorer as fractions below. The price is determined by a committee of experts of the New York Cotton Exchange, who know the state of the crop and trade. Contracts for cotton to be filled in the future may supply the demand a little above or below the grade mentioned, as crop conditions are uncertain. American cotton in 1912 is found under six full grades. Half grades are shown by the prefix "strict." Quarter grades are indicated by the prefixes "fully" or "barely," as Fully Good Middling and Barely Good Middling. In trade journals the quotations are sometimes under initials which indicate the grades, such as F. for Fair, and S. M. for Strict Middling. There is a tendency as cotton changes in condition from season to season to add new terms for the highest and lowest grades. The words "tinged" or "stained" indicate color variations. The term "linters" is used for the short fibers taken from the seeds by delinting in a second ginning. Low grade unbleached cloth, batting, coarse yarns, and carpet linings in which the clinging pieces of seeds are of no detriment, and artificial silk are made from the linters.

The principal cotton shipping ports of the United States in the South are New Orleans, Galveston, Memphis, Norfolk, Charleston, Wilmington, Savannah, Mobile, and Pensacola. The cottons that are sent from these ports are frequently called by the names of the shipping places, although the contents of the bales may differ greatly in condition. New York City ships a large number of bales to foreign countries.

By-products and Wastes. — During the past half century the by-products of cotton have assumed a large place in the financial world. At one time the seeds were thrown away after the ginning, but they are now used to advantage. In 1912 there were approximately 235,038,000 lbs. of linters alone. The by-products are: First, the linters or the down, which is left on the seeds after the seed cotton is removed. This is removed and used for poor grades of cotton cloth. Second, the seeds, which are pressed by special machinery and yield cottonseed oil, which is now largely used as a food and also has important industrial applications. The meal which remains is used for cattle food. The hulls give bran, fiber out of which high grade paper may be made, fuel, and fertilizers. In the spinning mills there is much cotton waste from the machines, which is sold to be used for cheaper grades of material, for cleaning machinery, or for other purposes. The rags left from used-up cotton garments are sold principally for the making of paper.

Judging and Testing. — The important qualities of cotton are length of staple, strength, fineness, smoothness, uniformity, color, cleanliness, and pliability. The cottons of different countries vary in these qualities, and consequently are adapted to the manufacture of different kinds of cloth. American cotton in general is noted for its whiteness, cleanliness, and regularity of staple. Sea Island cotton from the United States is noted for its length and silkiness, closely resembling spun silk. New

Orleans cotton is renowned for its extreme regularity of staple, which does not vary a fraction of an inch. Cotton manufacturers and buyers know the qualities of the different cottons, though temporary climatic conditions and methods of cultivation sometimes cause changes. Each season the cotton buyers must test the crop to select what they need. The cotton is generally in bales from which pieces are extracted with a hook. The buyer considers (1) the general look and feel of the cotton and whether it is clean (a few pieces of leaf do not matter, but if it is full of sand it is almost valueless for spinning); (2) strength and resistance are tested by pulling the fibers apart between the fingers and thumbs, and by a sudden jerk on the fibers; (3) length of staple and uniformity of growth are estimated by laying several groups of fibers on the dark coat sleeve and noting their appearance. The term "spot" cotton indicates that the cotton can be chosen by the buyer himself, usually in some large cotton market or in some port. The tendency is to decrease these annual sales at some intermediate market for more direct contact of producer and consumer, which will save cost.

Many bales of cotton are partly burned on account of inflammability. Sales of such injured cotton are attended by buyers who bid at a lowered price.

Complaints of the American crop are incessant, and many of them are well justified. The faults should be corrected, if we wish to keep our hold on the world's market. Defective ginning causes the fibers to knot, which will later interfere with smooth spinning, for the knots persist, and show as dense white spots in the web as it comes from the carding engine, and finally as irregularities in the finished yarn. These knots are called neps. The content of a bale is likely to vary greatly in value, as cottons of different length staple may have been ginned and baled together. This condition is trying to the spinner, for it makes uneven yarn. An excess of moisture is frequently found in the bales, which increases the weight.

Cotton may vary in moisture from $7\frac{1}{2}$ to $12\frac{1}{2}$ per cent. If it is above $10\frac{1}{2}$ per cent it is not considered normal, and a rebate of price is demanded. There is also complaint of the amount of tare found in some bales. Foreign buyers are allowed 6 per cent off the price (30 pounds off a 500-pound bale) for bagging, iron bands, etc., but when opened the bales are sometimes found to contain foreign matter which unduly increases the weight. If the buyer accepts the thirty pounds off, he may find when he opens the bale that there is much more tare in it than he was allowed. If he insists on having the cover taken off and the bale weighed before purchasing, he has to bear an added expense, and may find it unnecessary. Foreign lands complain that our 500-pound bales are too big and unwieldy, that our system of baling injures the fiber, that the jute covering of our bales easily deteriorates, that when they arrive in foreign countries they are in worse condition than the bales of any other country in the world, and that the cotton is often mildewed or burned. Our Manufacturers' Association protests against these conditions and claims that it is entirely possible to gin and bale better and with profit to us in the end.

Cotton Spinning has long been an important industry in New England and in recent years has grown rapidly in the South. The Southern mills in 1911–1912 consumed more cotton than did the mills of the North. The preparatory processes of cotton spinning differ according to the fineness of the yarn desired. Early steps are repeated when greater cleanliness is needed and for higher counts of yarn; machines are repeated or even new ones are introduced. The general aim in cotton spinning may be said to be (1) to clean by opening, beating, and fanning; (2) to lay the fibers parallel by carding or even combing; (3) to unite and draw out the fibers, and (4) to twist them into yarn. The constant tension on the fiber, and the millions of teeth which pass through it, reduce its strength. When cotton is poorly picked, ginned, or baled, it requires repeated cleaning to prepare it for spinning, hence it may be greatly weakened. When the preparatory processes have been carefully conducted, the number of machines may be reduced. There is also more waste when cotton has to pass through many mechanical processes, which adds to the expense of the cloth. Cotton is spun best in a humid atmosphere. The Southern States have a damper climate than the Northern, but the climate in America is less satisfactory for spinning than that of England. Humidifiers are used in good spinning mills.

The following processes of cotton spinning and manufacture are representative: —

Bale Opening. Cutting the metal bands and allowing the cotton to expand from its great pressure.

Bale Breaking or Cotton Pulling. A machine which opens up and mixes the staples of various cottons of the same length is used in some mills. The process, however, is still done by hand.

Picking, Opening, Willowing, and Scutching. (These terms are all used for similar processes.) The feed, the breaker picker, the intermediate picker, and the finisher picker of American mills cover the processes of cleaning and opening previous to carding. The result of the pickers is a wide lap wound into a roll.

Carding and often double carding of fine yarn may be required. The results of these machines are slivers.

Combing, used only in preparing the finest yarns. A sliver lap machine is required, if combing follows carding. The result of combing is a sliver.

Drawing, — usually three or more machines. The result is a small sliver.

Slubbing, by a bobbin and fly frame. A slight twist is now required in the product to give strength as the sliver has become attenuated. It is wound on a bobbin to be delivered to the next machine.

Intermediate Slubbing, by a bobbin and fly frame. The result is a twisted sliver wound on a bobbin for the roving frame.

Roving by bobbin and fly frame. A final slubbing when the soft rove is prepared for spinning. It is wound on a bobbin.

Spinning. The frame and mule are both in use, but the former is found more frequently.

Doubling and Twisting. The yarns are prepared in various ways.

Bleaching, Dyeing, Mercerizing, and Gassing of the yarn. These processes are used as necessary. The yarn may be dyed in skeins or warps.

Winding, Spooling, and Warping preparatory to weaving.

Sizing or Slashing to prepare the yarn to bear the strain of weaving.
Drawing-in to thread up the loom.
Weaving.
Finishing as needed, the principal methods being: pressing and glazing, starching and calendering, napping, bleaching, beetling, printing.

These processes are given in more detail below: —

The Bale Breaker or Cotton Puller is much like the wool picker. Cotton from different bales is carried on traveling lattices to the breaker, and is loosened up by means of four pairs of coarsely spiked rollers or beaters, each pair of which revolves more rapidly than those before it. It is thus prepared for the feed of the openers or pickers.

Picker, Opener, Willower, and Scutcher. — In India cotton was originally opened by beating with willow wands to open up the staple. The mechanical means of doing this was called willowing. The term "scutching," which means beating, was used in England for a more advanced willowing corresponding to the work of the intermediate picker and finisher picker of the American mills. The picker room of the usual cotton mill contains a number of trains of pickers, the object of each being to open out the cotton that the sand, neps, leaves, and dust may be eliminated, and to form the lint into an increasingly even and filmy lap. The first machine in the train is an automatic hopper feed (Fig. 101) which connects with the breaker picker (sometimes called cotton opener). The machine is similar to

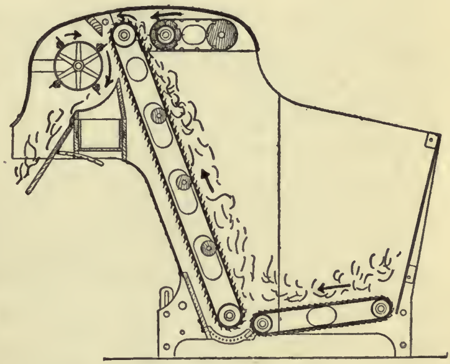


Fig. 101. — Sectional View of Feed.
Courtesy of the Kitson Machine Shop.

the Bramwell feed. Steel pins on an endless apron open the cotton, which is stripped off by a doffer and carried by an apron to the breaker picker.

Breaker Picker; Intermediate Picker; Finisher Picker. — The object and method of these machines are similar. The cotton fiber becomes cleaner, softer, and more parallel. The film is finally rolled into a wide lap to be taken to the carder. In the first or breaker picker the cotton is beaten by spikes or knives, and driven against cleaning bars or a grate where the dust falls out. The cleaned cotton is carried by a fan to a cage (a cylinder filled with small holes through which the air rushes), and the soft fiber clings to the outer surface of the cage to be carried by guide rollers to the second machine or intermediate picker. Four laps of cotton from the breaker picker are united. The intermediate picker has two or three blades with rather sharp edges which strike the cotton about two thousand or more times a minute. The cotton is then thrown on cleaning bars and carried to a cage as in the first picker. The sheet of cotton thus made is pressed between rollers into a lap wound on bars. In England these two pickers are often called a double opener. A finisher picker, similar to the scutcher of the English mills, is often used, in which about four rolls from the intermediate picker are united, the rolls being laid on an apron and unfolding over one another (Fig. 102). The cotton is beaten by a two- or three-bladed beater as in the intermediate and made into a lap for the carder. Attached to these machines are special parts to even the lap and measure the amount of cotton. The best classes of cotton are sometimes clean enough to require fewer than three pickers.

Carding (see Fig. 19). — This is a very important process. The aim is to clean and lay parallel the fibers. The wide lap from the previous machine is placed at the back of the card and fed to the great cylinder by the licker-in. The revolving flat card is in use for cotton, and closely resembles the wool card (see Fig. 85), but has narrow flat bars filled with teeth fastened in an endless chain over the big cylinder in place of the small

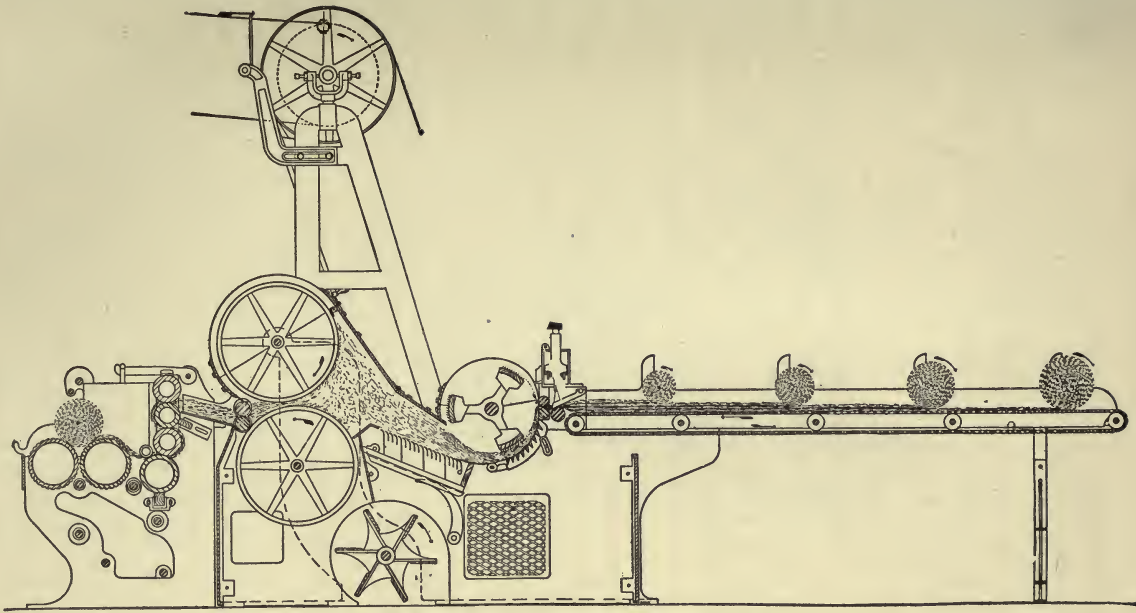


Fig. 102.—Sectional View of Finisher.
Courtesy of the Kitson Machine Shop.

worker and stripper cylinders of the wool card. The flats press the cotton on the teeth of the big cylinder and take out the neps and poor fiber, the action being like a comb pressing against a wire brush. The teeth of the flats are set in an opposite direction to the teeth of the cylinder. After the cotton is carded by the flats, it is passed to the doffer, but the waste cotton is brushed off in another direction. A cotton cylinder has often 700 or 800 teeth on one square inch. The large cylinder may have from four to six million teeth, and the speed is sometimes 2000 feet per minute. The strain on the fiber can perhaps be appreciated. A great deal of dirt is taken from the cotton in carding, and falls into a receptacle below. The thin veil of cotton is taken off the cylinder by the doffer, reduced to a narrow sliver by being passed through an eye or between rollers, or by a method of leather divisions in the apron, and then drops coiled into a can. For fine yarn the carding process is repeated, such yarns being designated as "double carded." The waste cotton from the card is used for many purposes, and special carders are now on the market which prepare yarn from it to be used for inferior grades of cloth. A lap winder prepares the card waste to pass through its own special carder.

Combing. — Cotton is combed when a very fine grade of yarn is needed. It is employed usually for long staple fibers, such as Sea Island, Florida, long stapled American, and Egyptian. This yarn is used for sewing threads, fine knitted underwear, mousselines, and silk substitutes. Short stapled cottons can also be combed by the newer combing machines. The machine follows carding or double carding. Slivers from the card are first united on the sliver lap machine and made into a lap to be fed to the comber. The machine extracts short ends of cotton and impurities, selects fibers of even length and lays them parallel and overlapping, and finally forms a sliver. The method of combing is intermittent, and is accomplished by a nip holding a bunch of fibers, while cylinders covered with card clothing — the needles gradually becoming finer — comb them out first from one end and then from the other. The newly combed fiber is then lapped over that previously combed, and the united fibers are combed again by a suspended comb and finally attenuated into a sliver (Fig. 103). The result is a

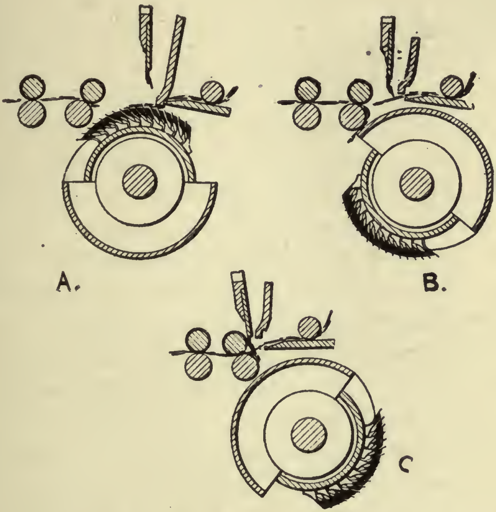


FIG. 103.—DETAIL OF COMBING MACHINE, SHOWING NIP HOLDING THE SLIVER AGAINST THE COMB.

very silky product. The short, rough ends are conducted out of the machine. Naturally there is a great deal of waste from the comber, consequently the process is expensive and is only used with high-priced yarns.

Drawing and Doubling. — This process is usually repeated three times. The aim is to unite several slivers, draw them together, thus removing weak points, and make an even, smooth sliver. The principle is by drawing rollers. The doubling in these and succeeding machines often runs as high for average cotton manufacture as 27,000 to 500,000 doublings, and even goes considerably higher for special yarns. From four to eight cans of slivers are united and drawn together by rollers in each of the three machines (Fig. 104). The slivers are greatly reduced in size and would break unless twist were now given to them.

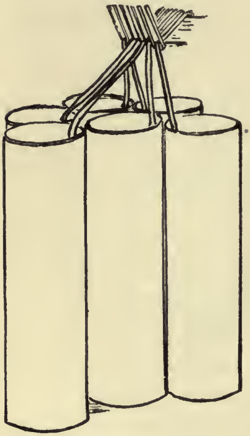


Fig. 104. — Slivers.

Slubbing by Bobbin and Fly Frames. — The first twist is now put into the yarn, and it is wound on bobbins. Two attenuated slivers or soft yarns are united into one in each machine. Slubbing is done by three machines — slubbing, intermediate slubbing, and roving. The methods are the same in each. The result of each machine's work is a finer and more twisted yarn. The final frame makes the roving which is the last step before spinning.

Spinning. — The spinning of cotton is done on the upright frame by the flyer or ring system, or by the mule. The first is a more rapid method and is in more frequent use, but the mule makes a softer and more attractive yarn. Frames with a new variety of spindle requiring almost no attention are appearing on the market, whereby the output of yarn is increased and the cost of production lowered. All modern machines have automatic attachments which stop the action if a sliver or a thread breaks.

Cotton Yarns are spun or twisted in various ways, and are used for warp or filling, knitting yarn, sewing thread, or for hand embroidery. The numbers run from No. 4 coarse even as high as No. 400 for fine yarns. After the yarn is spun on the frame or mule it is usually doubled and twisted before it is ready for service. There are many ways of doing this, and the yarn may be dry twisted or twisted in water. Cotton yarns for weaving may be single or several ply, and the direction of the twist lends variety. Knitting yarns have special twists. They may be spun on the mule, doubled and twisted slightly, with a resulting soft appearance and woolly feel as used in some classes of underwear; or they may be closely twisted in water, dyed, gassed or singed, glazed, and hard finished for lisle thread effects. Sewing cotton is frequently spun on the mule. For three cord sewing cotton, three yarns from the spinning frame are doubled and twisted. For six cord the yarn from the frame is doubled and twisted and three of these are united and twisted. The yarn is sized before being twisted in both cases. When a good grade of cotton has been used a strong thread is the result. Sewing cotton requires more twisting than yarn for weaving, for greater strength is needed. The numbers in sewing cotton run from 6 or 8 to 200 or more. Sea Island and fine long staple American cotton are used in the best grades. All sewing cotton is glazed, but special varieties to be used for the sewing machine have more dressing than those for hand sewing. The spools containing 250 or 500 yards are wound by machine.

Yarn which has been carded, double combed, and then spun on the mule has a lofty, soft appearance like spun silk, but the expense is much higher than when less preparation is required. Special treatment of cotton yarn with gums of various kinds and a later machine polishing between rollers gives the appearance of a linen thread. The cotton thread made in this way is strong but not pliable. Another way of preparing cotton thread to look like linen is by spinning it with small knots or rough places upon it. When the cloth for this yarn is woven and the fabric is finished it closely resembles material which is woven of flax.

Bleaching. — Cotton yarn becomes yellowish in color during the preparatory processes and spinning, and usually requires bleaching. For this purpose it is wound from the bobbins into hanks, which are slipped one inside the other into a chain containing perhaps five hundred pounds of yarn. Bleaching is done in various ways. (See Chap. XIII.)

Mercerizing. — Mercerized cotton is described in Chapter XII. Schreinerized cotton, because of its high luster, resembles mercerized material. The effect is produced by passing the cloth under engraved calenders, with pressure.

Dyeing (see Chap. XIII). — Cotton is usually dyed in the yarn. Dyeing in the unspun state, as in wool, is occasionally used, but this is the exception.

Sizing. — The shortness of staple and the softness of the cotton fiber make it necessary to apply sizing to the yarn that it may stand the strain of weaving. The sizing material is a starchy or glutinous liquid applied to the thread in varying proportions according to need. Sizing of cotton thread has been in use since before the dawn of history. Each modern cotton mill has its own special formulæ. The process, which is generally called slashing, is done after warping and before drawing-in. It is especially necessary for warp yarns. Special sizes or coatings are also used in the cloth to give the look of solidity and weight which are not always present. Clay is often applied heavily to loosely woven cotton materials. The dressings or coatings used for cotton yarns are too numerous to mention, and are employed in various combinations.

Counts or Numbering. — In the United States cotton yarn is counted by the number of hanks of 840 yards in the pound. No. 1 yarn (the coarsest, but it is seldom used) would have 840 yards in one hank, which would weigh one pound. Number 20s single would have 20 hanks of 840 yards each, or 16,800 yards in all in one pound. Single 20s yarn would be written $\frac{1}{20}$s or $\frac{20}{1}$; two-ply 20s would be written $\frac{2}{20}$s or $\frac{20}{2}$ and 16,800 yds. would weigh two pounds — or 1 lb. would contain only 8400 yds. of $\frac{20}{2}$ ply.

Sewing cotton is twisted into three cord (three threads twisted together) and also into six cord (three two-ply threads twisted together), but as the latter is smoother, stronger, and better adapted to the sewing machine, it is more in demand as serving both purposes. Three-cord sewing cotton number 60 would be expressed $\frac{3}{60}$s, and six-cord would be $\frac{6}{60}$s. A three-ply No. 8 yarn ($\frac{3}{8}$s) would be a coarser thread than single No. 8 ($\frac{1}{8}$s), for three threads of number 8 would be twisted together. Number 60, six-cord yarn, and number 60, three-cord yarn, are made the same size, but in the former case a finer yarn is used in the combination.

Winding, Spooling, Warping, and Drawing-in. — The preparation of cotton warp yarn for the loom is similar to that of other textile fibers, *i.e.*, winding the yarn into hanks, spooling it, warping it, slashing or sizing, and threading the yarn through the harness. (See Chap. III.)

Weaving (see Chap. IV). — A large number of standard cotton cloths, such as muslins, sheetings, many ginghams, percales, and sheer materials like nainsook, batiste, longcloths, cambrics, and lawns, are woven with the plain or cotton weave, as it is sometimes called. There are very slight differences in the body and feel of these materials until after the finishing. Regular twills and broken twills are found in denims, galateas, and sateens. Elaborate designs made on special looms or on the Jacquard, and double weaves of various kinds are found in expensive and bordered cottons, in fancy ginghams, leno weaves, and embroidered materials, in velveteens, Turkish toweling, and piqués, and in cloths which imitate linen, as in damasks; or silk, as in cotton brocades; and in imitation of wool and worsted materials, such as cotton coverts, chinchillas, beavers, diagonals, and worsted suitings. These materials are very soft and pliable when they come from the loom.

Finishing Cotton Cloth. — Cotton materials depend greatly on finishing for their effect; the only difference between some of the plainly woven materials is in the method of treating the cloth after the weaving, and the resemblance of cotton to other textiles is principally a matter of dressings and machine finishing. So numerous are the dressings used and the processes which follow, that it is possible to indicate only representative methods. By means of these methods feel and appearance are given, such as a soft or supple finish by glycerin, fats, oils, and waxes; or a full finish by starch and pressing; or gloss, as needed in percalines, silesias, and percales, by mucilage, gums, and ammonia water; or high luster by warm dressings and the hot calender and mangle alternately; or stiffness by mucilage and gums as required in linings, swisses, tarletans, and lawns; or weighting with clay that a solid appearance may be gained, as in cretonnes and canvas. To give a dull finish or the appearance of other textiles, special dressings are applied. Waterproofing, preserving, rendering sanitary, and taking away the natural inflammability, are also obtained through dressing. Elastic finishes are dependent to some extent on hand work. The material is starched, dried, beaten, squeezed, and worked by hand in all directions. Finishes are apt to pass off to some extent in the laundry, and the loss of the finish and crisp feeling, as in organdies, makes such materials unattractive, but starching or stiffening in the laundry restores to others much of the original appearance.

Cottons having designs woven in, such as fancy ginghams and madras, have frequently long warp or filling floats on the back. These threads are cut off by a special machine. When the designs are small, as in polka dots and lozenges, there is danger of pulling out the cut threads in home washing unless care is taken. Soft, rather open mesh cotton materials, such as fine muslins and batistes, have to be dried carefully so that the dressing will not settle in the mesh and make the material too stiff.

The calendering is an important part of the finishing of these materials. Some cloths require a soft face and a stiff back and are treated on both sides, as in piqué. Percales and calicoes also depend greatly on the finish. The face is shorn or singed to get rid of the fluff, and after dressing they are treated like sateens and beetled to soften them. Dimities are finished with light farina sizing, the cloth being delivered to the size in large folds, and the rollers with the preparation upon them pass back and forth over the cloth. The material is dried, and as it is apt to shrink it is stretched on tenter frames an inch wider than necessary to allow for further shrinkage in the calendering.

Many of the finishes are expensive, and make the cost to the consumer rather high. This is especially noticeable in the fine cottons which have been carded, double-combed, and finally given the most delicate finish, as in some of the exquisite French cotton dress goods. Enormous cotton finishing machines are used in large mills, and turn out 5000 yards a day, each finisher keeping five hundred looms busy.

Cotton is made to look like wool or worsted in various ways: first, by the preparation of the yarn; second, by weaving the cotton yarn into wool or worsted patterns; third, by chemical treatment or parchmenting to give the look of wool; fourth, by "animalizing" or so treating that cotton will dye in the wool bath; fifth, by dressing and calendering with rollers covered with cloth to give a rough or woolly appearance, or passing the cloth through a napper and shear. Outing flannel, flannelette, pile goods, and blankets are napped by being passed several times over cylinders covered with card clothing. Cotton requires more delicate manipulation in the napping gig than wool, for it is much softer and is less elastic. So-called woolen glove linings are frequently of cotton made to look and feel like wool, or the cotton is combined with a little real mohair or other wool.

To make cotton cloth look like linen requires much dressing, for the fiber of the former is soft, while flax has body. To give the effect of the shiny, long, smooth fibers of flax, which reflect the light, the cotton fabric has to be pressed down after dressing and then beetled, which makes the surface glisten like linen. Cotton toweling looks like linen on account of the yarn being spun with small knots in it at intervals, the design for the weaving being one of the ordinary huck or toweling weaves, and the dressing and finishing completing the resemblance. Linen is absorbent to moisture, and cotton can be made so by treatment, but the water does not evaporate from it the way it does from linen. Unfortunately, after laundering the cotton towel loses the effect of linen. By heavily loading closely woven cotton cloth and pressing it, cotton canvas can be made to look much like linen, and at a very much lower cost.

Silk effects are largely the preparation of the yarn in mercerizing (see Chap. XII), in weaving of a silk pattern, in gassing, dressing, and pressure. Satin finish for cotton sateens is gained by dressing with glycerin, and passing repeatedly through the calender. Glauber's salt gives the luster of silk, and common salt the "scroop" or rustle. Mercerized yarn woven in a silk pattern as in cotton pongee looks and feels like spun silk. Velveteens, corduroys, and cotton velvets (see Pile Fabrics, Chap. IV) require elaborate finishes after weaving, which differ according to the purpose and quality of the material. They may be, as in cheap velvets, lined and stiffened for cutting, after which they are soaked, washed, and hydro-extracted, which removes the stiffening that aided in the cutting. They are then brushed, shorn, brushed again, singed, brushed. The cloth now has a brownish appearance, and is frequently bleached before dyeing or staining. In the cheapest velvets a stain is put on the surface instead of full dyeing. They are finally finished by waxing the pile side, brushing the wax in to give polish, and peg finished by stroking the cloth across the width. A final brushing prepares the cloth for sale. In better classes of materials the pile is sometimes raised by forcing steam through.

Embossing machines make patterns in relief. After the material has a stiff finish, dots, checks, and twills can be placed upon it, but they pass away in the laundry. To represent embroidered cottons, dots of paste are printed on swiss; these will stand a little careful washing, but are darkened by the pressing iron.

Absorbent cotton is made by depriving the fiber of its oil, wax, and mineral salts. It will then take moisture rapidly. For surgical purposes the cotton must be very pure and kept absolutely sterilized. New Orleans, Texas, and Mobile cottons are considered good for this purpose.

Cotton Printing and Printing Machines. — The designs on cotton goods are frequently printed on the cloth instead of being woven in; calicoes or prints, percales, galateas, cretonnes, silkalines, lawns, and figured organdies are printed. There are several methods of printing, — by resist, *i.e.*, printing before dyeing in such a way that the dye bath does not change the color (see Chap. XIII); by discharge, in which the fabric is dyed and so printed afterward that the color of the design is removed (Chap. XIII), or by the direct method. In the past, direct printing was first by stencils and then by blocks on which the designs were cut, a separate block being used for each color which was to appear in the design. The cloth was stretched on a framework or table, the blocks were dipped in the dye and then pressed by hand on the cloth. This method is still in use by hand workers. Hand block printing is considered enduring, but is expensive, and machine methods of several kinds have superseded it. The customary way at present is by cylinders on which the design is cut or stamped. These revolve against flat rollers which are in contact with the color troughs. Any excess of color received by the cylinder is taken off with a knife, that the impression may be clean. There are as many cylinders as there are colors in the design, even twenty being sometimes used. These cylinders impress the pattern on the cloth in such succession as is needed; calicoes are usually stamped in one color only. If the background is to be in color the material is usually dyed first and the figure is stamped on later. Printing machines have usually a large drum over which passes an endless cloth into contact with the engraving cylinders, and the material to be printed is carried along by the cloth. As the drum is warm the color is quickly dried. The cotton material has to be prepared so that it will take the impression readily, and the woven cloth has to be bleached, if a white or light color is wished. Bleaching again takes place after printing when a very clear, white surface is required. The color is fixed by steam. Calendering under heavy pressure is given when gloss or luster is required. A breaking machine, which has blunt, spiral knives which come in contact with the surface of the cloth, softens the gloss. The material is finally pressed between pressboards in the hydraulic press.

Preparing the designs for machine printing is done by two processes; in both copper rollers are used to give the impression. In one method the die is cut of soft steel, which is hardened and pressed against soft steel to make another die with the reverse of the pattern. These dies are pressed against copper cylinders and reproduced regularly along the length. The cylinders are placed as required in the printing machine and carefully adjusted that the pattern may be perfect. When the design has served its purpose and will not again be required it can be scraped from the cylinder, which can thus be used again. Printing establishments often have very large sums of money invested in cylinders, which are kept in a storeroom ready to be used again or to be impressed with new designs.

The second method is by the pantograph. The design is drawn five times the required size, inked, and pressed on metal (zinc). It is then etched in and the design placed in a machine, which reproduces it in one fifth the size along a copper cylinder covered with varnish. This takes the impression which is later engraved upon it.

Manufacturing of Cotton. — The United States consumes more than a third of her own cotton crop in her mills, and the manufacturing interests are increasing. In the production, handling, and manufacturing of cotton nine million people are at work. In the year from 1911 to 1912 the United States exported 10,502,000 bales of 500 pounds each, and also 476,778,499 yards of cotton cloth, at a value of $31,388,998. We send our raw cotton principally to Great Britain and the continent of Europe, and our manufactured cloth to China and the West Indies. The South presents special inducements for cotton manufacture; the fields are near, the atmosphere is humid, labor is cheaper than in the North, and labor laws are less strict. The output from the South is principally print cloth, cotton toweling, sheeting, cottonades, drilling, bags and bagging, mosquito netting, wadding, ticking, muslins, and other lower grades of cotton materials.

The Northern mills make sewing cotton and both high and low grade goods. The output covers yarns, — coarse, fine, and mercerized, — hosiery and knitted goods, carded and combed yarns from Peeler, Egyptian, and Sea Island cottons, sewing threads, blankets, fancy ginghams, materials made of a union of silk and cotton, Jacquard cottons, dimities, chambrays, crêpes, lenos, Persians, sateens, novelties, velvet, corduroys and plushes, duck, upholstered goods, such as tapestries and brocades; lace, chenille curtains, cotton coverts and flannels, ropes, webbing and twine, prints, denims, batistes, nainsook, plaid muslins, gauze, bunting, percales, seersucker, damasks, challies, and absorbent cotton.

In general, the United States does not manufacture the finest classes of cotton goods: France is perhaps preëminent. The principal cotton manufacturing centers of the United States in the North are Massachusetts, Rhode Island, and Pennsylvania, and in the South, South Carolina, North Carolina, and Georgia. Fall River is the largest cotton manufacturing town in the United States, having four million spindles at work; the specialty is coarse cottons and prints; New Bedford is the center of fine goods.

The United States imported in the year 1911–1912 49,856,600 yards of cotton cloth, and 5,742,900 yards of cotton yarn. The bulk of the yarn spun in the United States is seldom finer than 60s. In 1912 there were 29,500,000 spindles in the United States, 56,750,000 in Great Britain, 42,500,000 on the Continent; making a total of 128,750,000. Great Britain is preeminent in cotton manufacture in the world. Realizing that competition is close, she has looked more to details than other countries. She is expert in manipulation of stock, and in general uses the finer raw cottons. Germany is advancing rapidly in cotton manufacture.

COTTON MATERIALS

	Width	Price
Batiste	40–45 in.	$0.25–.75
Birdseye	45 in.	.25 up
Bobinet	18–22 in.	1.00 piece
Brussels net	72 in.	.50–1.50
Buckram — double-faced fabric	36 in.	.12½ up
Bunting	27 in.	.05 up
Burlap	42–57 in.	.35–1.00
Calico	27 in.	.08
Cambric	36 in.	.14–.25
Canton flannel	25–36 in.	.08–.25
Canvas, Java	18–36 in.	.25–.70
Challie	25–32 in.	.06–.25
Chambray	32 in.	.12–.45
Cheesecloth	36 in.	.03–.10
Corduroy	21–27 in.	.50–.85
Cotton batting		.05 roll
Crash	24–36 in.	.05–.15
Crêpe	27–44 in.	.18–1.00
Cretonne	30 in.	.25 up
Crinoline	19–36 in.	.12½ up
Damask	1 yd.–2 yd.	.25 up
Dimity	30–32 in.	.10 up
Drilling	24 in.	.15 up
Duck	27 in.	.12½
Flaxon	32–36 in.	.18–.30
Galatea	27 in.	.15
Gingham	32–36 in.	.12–.50
Grenadine	30 in.	.08–.10
Handkerchief lawn	29 in.	.15–.25
Huckaback	18 in.	.10
Indian Head	36 in.	.16
Jean	28–30 in.	.15
Khaki	36 in.	.18–.50
Lawn	32–40 in.	.08–.25
Linon	30–36 in.	.12½–.40
Longcloth	36–42 in.	1.25–3.00 piece
Madras	32 in.	.25–.50
Marquisette	45 in.	.50–.75
Moreen	18 in.	.50
Mull	30 in.	.18–.20

COTTON MATERIALS—*Continued*

	Width	Price
Muslin, unbleached	36 in.	$.05–.15
Muslin, bleached	36 in.	.08–.15
Nainsook	36–45 in.	1.50–3.00 piece
Nearsilk	36 in.	.18–.26
Organdie	68 in.	.30–.90
Outing flannel	27–36 in.	.08 up
Percale	36 in.	.12½ up
Percaline	36 in.	.20 up
Persian lawn	32 in.	.25–.50
Piqué	27–40 in.	.18–1.25
Poplin	27–36 in.	.18–.25
Ratine	27–54 in.	.18–3.00
Sateen	32–36 in.	.18–.40
Scrim	24 in.	.20 up
Seersucker	27 in.	.12½ up
Silesia	36 in.	.10 up
Silkaline	27 in.	.15
Swiss muslin	27–31 in.	.12½–.25
Tarleton	48 in.	.12½ up
Ticking	36 in.	.12½ up
Velour	36–42 in.	1.50 up
Velveteen	22–27 in.	.50–1.25
Voile	27–40 in.	.12½–1.00

CHAPTER VIII

SILK

The filament which is obtained from the cocoons of the cultivated silkworm makes the costliest and most beautiful textile fabric. A variety of materials are made from it, ranging from filmy chiffon and lace to the heaviest plushes and grosgrains, and from soft, dull finishes to the most crisp and glossy ones. For those who can really afford it the properties of pure, well manufactured silk justify the expense, for beauty, cleanliness, and endurance are combined. The popularity and demand for the fabric at a low price have caused adulterations of it and substitutions of other fibers for it, whereby the natural qualities are altered and we can no longer rely on it or know, even when paying a good price, whether it will wear well or not. The issue is not against low priced silk which looks like the best, for this has distinct advantages, but in the fact that there is generally little certainty when a high price is paid for a supposedly enduring material that the silk will wear. Honest guarantees exist, but the term "guarantee" has been used so carelessly that it has largely lost its significance. The economical consumer who is a judge of textiles has two needs or desires, one of which is to gain temporary effects at a small expense, which she can have by purchasing silk combined with other fibers. For such purposes as millinery, hair ribbons, sashes, and neckties, for passing fashions to be used for one season only, for light colored garments in which change is better than cleansing and for the outgrowing of clothing the cheaper silks are a boon. The consumer, however, has a second need for which she is perfectly willing to pay if she can be assured that she is obtaining what she wishes, *i.e.*, pure silk materials which will endure for a long time for upholstery, hangings, umbrella covers, underwear, petticoats, and serviceable gowns.

It is distressing to the woman who knows the limitations of the cheaper textiles and desires to buy the best, to have so little assurance that her money is being wisely spent. The most careful experiments in the laboratory are the only satisfactory tests by which even the expert can be sure that a piece of silk having the feel and the look of the best will endure. The manufacturer who made the goods is the only one who can tell the content, and, if adulterants have been used, even he is likely to be much in the dark as to the exact percentage of the weighting. Every woman should know the present ways of treating silk and the prices which should be paid for pure silk, that she may be on her guard. She should ascertain the names of reliable manufacturing companies, and try in her own shopping to distinguish between silks she wishes for temporary use and those she wishes to endure. The manufacturers state that they are only too glad to provide good guaranteed stock, if women honestly wish it and will pay for it. The consumer should make it possible to do this without loss to the manufacturers. Women's lack of knowledge is a large factor in the unreliability of the purchased materials. Fabrics indeed are in the shops which are not enduring, being defective in the weave as well as from treatment, for they are made at a low price for effect alone. There are also light, gossamer-like silks which are very strong, and heavy silks are made for temporary appearance as well as for endurance. Stiff, shiny, luster silks are for sale which are strong, yet many varieties of this class of goods are so unreliable that consumers fear to buy. Some manufacturing firms have tried to provide the market with an honest guaranteed article, but have not had the encouragement they should have had, on account of the ignorance existing and the fact that fashion changes so rapidly that many women no longer wish the old enduring silks. The economical consumer, however, is awakening to her responsibility and is beginning to study the entire subject. She will soon demand a knowledge of conditions and what she can do to be assured that her money is well spent.

Properties. — The properties of cultivated silk give it preeminence among textiles when it is pure and well manufactured, for such silk combines strength, lightness, cleanliness, durability, high luster, and beauty. The characteristics of wild silk differ somewhat from the cultivated.

Softness. — Silk, especially after the gum is removed, has an unusual degree of softness, which is of value in the manufacture of some of the most exquisite materials.

Fineness. — The diameter of the filament ranges from .013 mm. to .026 mm., or .0005 to .0010 inch, while cotton ranges from .0005 to .0009 inch, and linen from .0015 to .006 inch.

Specific Gravity. — The weight of silk is the lowest among textile fibers after the gum is removed, consequently light weight fabrics can be made from it.

Endurance. — Pure silk will last for years, even though given hard wear.

Strength. — It is the strongest of all the fibers in relation to its size when the gum has not been removed. On account of this quality it is used in scientific experiments of a delicate nature. Weighting (Chap. XII) decreases this quality.

Tenacity. — The tensile strength is about one third that of the best iron wire, or about 64,000 lbs. per square inch. It loses some of this quality when the gum is removed.

Elasticity and Ductility. — These qualities are high in silk which has not been boiled off, and a thread may be stretched from one seventh to one fourth of its original length. Weighting decreases elasticity and ductility.

Electricity. — It is a poor conductor of electricity, but a good generator. This quality makes it difficult to manipulate in a hot, dry atmosphere. Humidifiers are used in mills to overcome it, and lessen breakages.

Heat Conductivity. — It is not a good conductor of heat, consequently even when it is wet it feels warm in contact with the body.

Cleanliness. — Silk sheds dust, and experiment has shown that germ life does not increase as rapidly on it as on some of the other textiles.

Transparency. — The transparency of some of the woven material lends attraction.

Luster. — This quality in silk is in excess of other textiles. It can be increased by treatment, and the removal of the gum increases the glossiness. Mordanting and weighting in the dyeing decrease it. The gloss of silk is easily destroyed by careless washing. Hard rubbing breaks the filament, weakens the material, and takes away the luster. Silk is easily scorched.

Scroop. — The crisp, crunching sound associated with silk is a quality natural with some silks; it is lost under some treatments and restored by a bath in dilute acetic acid and drying without washing.

Hygroscopicity. — The power of absorbing water, dye, or other substances in solution is very great. In dry weather the content of moisture is about ten per cent, but three per cent more may be taken in wet weather. The weight may be still further increased through artificial means as much as thirty per cent; therefore, according to expert statement, the amount may become ten plus three plus thirty per cent, or forty-three per cent. The universal standard of eleven per cent is added to the absolute dry weight to represent the usual absorption of moisture from the normal atmosphere.[1] The moisture in thrown silk is about the same. Raw silk contains slightly more moisture than boiled-off silk, as the sericin is more hygroscopic. Because silk has a great absorptive capacity, it takes dyestuffs more readily, perhaps, than any other fiber, but the technical difficulties connected with the process are

[1] *The Value of Conditioning*, 1908. Issued by the United States Silk Conditioning Co.

greater than with wool. Its avidity for moisture and its quick absorption of metallic salts have caused the practice of restoring the weight lost in boiling off by adding more or less foreign substance.

Life History. — The silkworm has been cultivated for many centuries on account of the filament which it spins. Roughly speaking, there are two general varieties of silk, the cultivated, produced by the *Bombyx mori*, and wild silk from uncultivated moths such as the Tussah. The name *Bombyx mori* comes from the family to which the silkworm belongs, the *Bombycidæ* (spinners), and *mori*, from the *Morus multicaulis* or mulberry tree, on the leaves of which it feeds. The species *Sericaria mori*, or silkworms of the mulberry, belongs to the class *Lepidoptera* or scaly-winged insects. The *Bombyx mori* is divided into other groups according to the method of reproduction. The annuals reproduce once a year, and sixty per cent of the silkworms belong to this class. The bivoltines reproduce twice a year, and the polyvoltines several times during the year, the first crop after cold weather being the best. Silkworms are cultivated by large breeders, or by small farmers, who with all of their families work together in the silkworm nurseries. The eggs are bought from growers who devote their time especially to reproduction, the best cocoons being kept for this purpose. In some countries there is strict government inspection to prevent the spread of disease. The manner of cultivation and the fertilization and growth of the mulberry are important factors in successful rearing. In 1908 Japan had one half a million families who were giving their entire time to silk culture. The yield that year was 300,000,000 pounds of undried cocoons. In temperate climates the silk is apt to be strong and even. In the tropics it is soft and bright. Bengal silk is excellent, but some of the tropical silk is lacking in strength. The silkworm which breeds once a year in temperate climates is considered the best.

The cultivated silkworm passes through four changes in its life of a couple of months, *i.e.*, egg, larva, chrysalis or pupa, and adult, — a cream-white moth which is about one inch in length (Fig. 105). Mating follows; the female lays several hundred eggs. She scarcely moves three inches during the three days of life, the entire life of male and female being devoted to producing

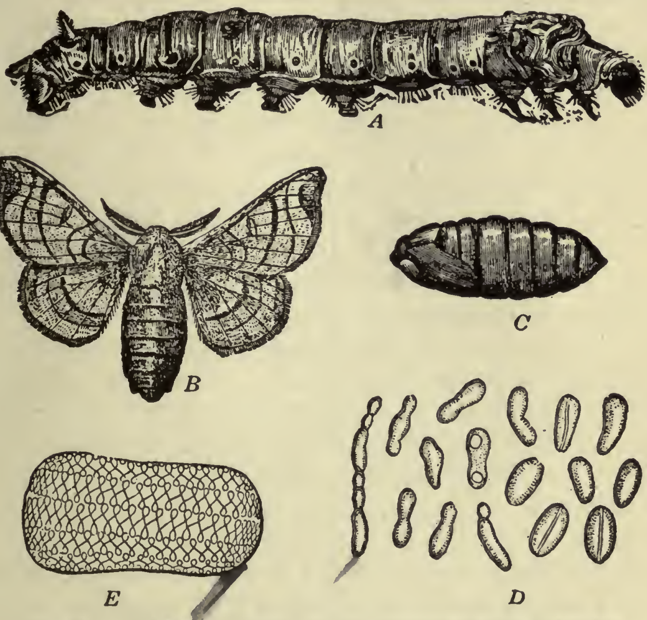


FIG. 105.—DIFFERENT STAGES IN THE GROWTH OF THE SILKWORM.
A, Full Size. *B*, Moth. *C*, Chrysalis or pupa. *D*, Eggs. *E*, Diagram showing cocoon and method of spinning.

From Matthews' *Textile Fibres*, by courtesy of John Wiley & Sons.

eggs. The eggs are laid on sheets of paper or pieces of muslin provided for that purpose. A slightly gummy liquid comes from the moth and holds the eggs fast. The sheets are gathered, hung for a few days in a damp atmosphere, and then placed in cold storage for about six months, the period of cold being advantageous for later hatching, which is done by heat. The worm sheds its skin four times; the times between the molts, or ages, as they are called, are as follows: (1) birth to first molt five or six days; (2) first to second molt four days; (3) second to third molt four to five days; (4) third to fourth molt five to seven days; (5) fourth molt to maturity seven to twelve days. The time between ages varies with different silkworms. Trays are provided to hold the different ages of worms and there are open shelves on which the trays can be placed that the worm can be watched. The cocooneries where the silkworm is best cultivated are quiet, spacious, well-ventilated rooms or buildings where an even temperature is maintained. Each worm is kept absolutely clean and has plenty of room, as overcrowding brings disease. Mild fumigation is resorted to at intervals. Heavy odors such as garlic or tobacco smoke are not allowed, being disturbing to the worms. The best food for the *Bombyx mori* is the perfect leaves of the white mulberry, which must be young, fresh, and dry, but never withered. They are chopped fine during the early ages of the worm. The tree is cultivated especially to provide food for the silkworm. Three varieties are found, the early, medium, and late-budding mulberry. The leaves, therefore, can be found in condition for the various stages of growth of the worm. The late-budding tree is cultivated in greater numbers, as the worms are larger and consume more leaves. The soil is important, and one which is rich in certain minerals has been found to provide leaves which keep the worm in better physical condition. A cold winter followed by a warm spring develops the leaf well. Two prime requisites for good silk are the state of the leaves and the choice of the eggs. When the leaves of the early mulberry are almost ready, the eggs are brought out from cold storage and subjected to heat for a month or less before they hatch out. The eggs are small, dark, flat, and round. The worm, when hatched, is about the diameter of a hair and less than three fourths of an inch long. It gnaws a hole in the end of the egg from which it issues. Showing under the magnifying glass are long hairs, many legs, and a shiny nose.

At first they merely suck the sap of the leaves provided for them, but later they gnaw the edges with their semi-circular jaws which move sideways. The noise of many full-grown worms eating is like the sound of rain. About thirty meals a day are eaten in the first age, for the worms are gluttons and eat their own weight daily. The development is very rapid, and during the next few weeks, as has been stated, the skin has to be changed four times. After the first molt the worm is lighter in color and requires more room; after the second, the spinning organs are more marked; after the third, the leaves do not need to be chopped. After the fourth molt the worm is full sized, about three inches long, white and velvety, and the spinning glands are full of transparent liquid. Hunger lessens, restlessness grows, and the lifting of the fore part of the body indicates the desire to climb and to spin. Brush or twigs are provided and the worm climbs into them and begins to inclose itself in its silken shell by expelling, from two openings underneath the mouth, two delicate threads which form a single one on issuing. They come from the internal glands, and the liquid hardens as it comes to the air. At first the silk is rough and is thrown out like guy lines on the twigs by the motion of the body. Gradually the worm incloses itself in the interior as it forms the cocoon. The method of spinning is by a movement of the head as if making a figure 8, weaving back and forth. (See Fig. 105.) The silk is a continuous double thread fastened together by the gum, the length varying from three hundred to fourteen hundred yards. The worm can be seen for a day, but gradually disappears, though it can be heard working within. It takes three days to complete the cocoon. The silkworm wastes away as the silk is exhausted, and gradually changes into a chrysalis. From fifteen to twenty days are spent in this state, and then the chrysalis changes into a moth which moistens the end of the cocoon and breaks its way out. The female cocoon is oval and the male cocoon is peanut shaped. The silk consists of two parts: fibroin (the silk fiber), and sericin (the gum). On the outside of each cocoon is coarse, tangled silk unsuitable for reeling, which is used as a material for making spun silk, being known as floss. The remainder of the silk on the cocoon can be reeled, but the filament of the inner layers is so attenuated that it does not pay to reel it, and it becomes a waste material used also in spun silk. Cocoons are white, yellow, or greenish in color. The color of the *Bombyx mori* silk, after its gum has been removed by boiling off, is creamy white, no matter what the color of the cocoons has been. The cocoons which are not intended for reproduction are subjected to heat, that the chrysalids may be stifled, since if the moth is allowed to issue, it cuts and spoils much of the fiber.

It is said that a silkworm during its life eats about thirty thousand times its initial weight, and increases in weight from ten thousand to fourteen thousand times. The mulberry is the best food, but osage, lettuce, oak, and other leaves are used. There are silkworms other than the *Bombyx mori* that provide useful silk, and the industry is growing in importance. This product is called wild silk because the worms are hatched in the open and not in nurseries under standard conditions. The leading varieties are the Tussah silk of India and China and the Japanese wild silk. A large amount of these silks is used in the United States. The cocoons are larger and the products coarser and harsher than those of the *Bombyx mori*. The color is brown.

Various diseases and parasites attack silkworms, and large sums of money were lost in that way until the absolute need of care in the following matters was learned: the importance of eggs from perfectly healthy moths, of flawless leaves of the mulberry for food, of ample room in the cocooneries with cleanliness; regularity in feeding and attention to temperature and ventilation. In good nurseries the most careful records are kept of food, temperature, and humidity. In Italy, France, and Japan the government provides schools of sericulture that the best results may attend the national industry.

Countries Cultivating the Silkworm. — The culture of silk began in China in 2700 B.C., says tradition. The emperor

Justinian introduced the silkworm into the Levant in 555 A.D., and from the ninth to the sixteenth century the production spread from the south to the north of Europe. Silk raising is still a national industry in these countries, though the north of Europe is engaged in manufacturing silk rather than producing it. The culture was started in America as early as 1622, in Virginia, and has been attempted many times since, but economically the United States cannot compete with the cheap labor of the Orient or of the south of Europe.

The principal silk-rearing countries at the present time are China, Japan, Italy, France, Spain, Austria-Hungary, Russia, India, and the Levant, the first four being the most important (Fig. 106). China is perhaps the leader, with Japan a close second. Both countries are noted for their rearing, reeling, and weaving. Three methods of reeling are found — the primitive, by which silks such as the Tsatlees are produced, from which the raw silk comes of irregular size and in irregular skeins; the rereels, by which system the silks reeled in the primitive manner are re-reeled into skeins of a more regular character, which gives a reliable product; and the steam filatures or filandas, equipped with modern machinery and improvements, from which the silk comes in good condition for the throwster. Steam filatures are found throughout Europe and Japan, and to a certain extent in the north of China and in Canton in south China. The name "steam filature" is used for certain China silks to differentiate them from Tsatlees.

The real pongee silk comes from the Shantung Province of China. The worms are fed on leaves of the scrub oak. Each lot of silk is woven into a piece, and varies from another in quality, weight, fineness, and color. It is an undyed silk. The United States takes 10 per cent of the product.

In the Canton districts of south China there are six or seven crops of silkworms annually; the cocoons are very small; much of the reeling is on primitive reels. The bales of reeled silk weigh about 106⅔ lbs. and the highest price per bale in 1911 was \$409.[1] In 1909 China exported raw silk to the amount of \$6,500,000, and piece goods valued at almost \$5,000,000.[1]

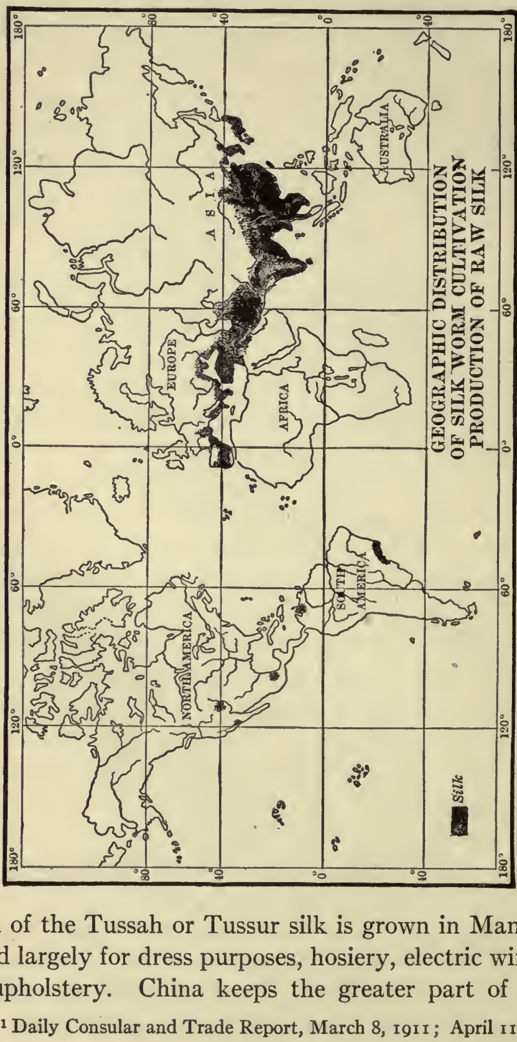


Fig. 106. — Raw Silk-Producing Sections of the World.

From Tarr & McMurry's *New Geographies*, Second Book, 1910, by courtesy of the Macmillan Company.

Much of the Tussah or Tussur silk is grown in Manchuria. It is used largely for dress purposes, hosiery, electric wire covering, and upholstery. China keeps the greater part of its silk for

[1] Daily Consular and Trade Report, March 8, 1911; April 11, 1912.

home consumption. There are many different races of silkworms utilized.

In Japan improved methods of cultivating and reeling have increased the export of silk. The steam filature and the rereel systems are used. Three crops of silkworms are grown annually by feeding them with mulberry leaves which are sometimes kept in cold storage. In 1909 the total export of silk from Japan, reeled and woven, was $66,229,794. Wild silk is also grown, the Yama Mai being celebrated. The United States consumes much of its raw and good waste silk. The quality is good and the range wide. The bales contain about 133⅓ lbs.

India produces much silk, but the industry has been poorly organized. The Bengal district has many filatures, and much of the output is used in Burma. The woven fabrics are for the "saris" worn by the native women, for handkerchiefs and dress goods. India offers opportunity for good silk rearing, as food for the worms abounds. The multivoltines are the most common variety of worm. The silk is reeled in 10/14 and 16/20 deniers. (See Counts below.) Tussah and other grades of wild silk are common.

European Silks. — The best raw silk comes from Italy and France. In both countries the cocoons from the highlands are better than those from the lowlands. In Italy, the important silk-raising districts are Piedmont, in which Turin is the principal silk center, noted for its even, regular silk, and Lombardy with Milan as its center. About 8,000,000 lbs. are produced annually. France grows the bulk of her silk in the south and southeast departments. The best silk in the world is said to come from the Granite Mountains in that country. France produces about 10,000,000 lbs. annually. The European silks are more carefully reeled than those from the East. Spain and Austria-Hungary grow a good quality of silk. Syria produces much which goes principally to France. The size of the bales of European silks, including the Syrian, is 100 Kg., or 220½ lbs. The Levant (Greece and Turkey in Europe and Asia), and the Caucasus produce much silk of good quality.

Silk in the United States. — New York City receives the bulk of the European imports of reeled and manufactured silks, and San Francisco most of the silks from the East *en route* to New York. The principal mills are in New Jersey, New York, Pennsylvania, and New England. The trains which bring the precious freight across the country from the Pacific Coast are dirt- and moisture-proof and thoroughly insured, as the value of one train may be from one to two million dollars. No stops are made except to exchange engines. In 1911 the United States spent on silk importations: Cocoons, $74,261; raw silk, $72,713,984; silk waste, $2,210,020; bolting cloth, $237,783; clothing and wearing apparel, $5,597,915; dress and piece goods, $2,478,413; artificial silk, $3,299,559; bandings and belting, $598,860; laces and embroideries, $3,679,748; ribbons, $685,585; spun or schappe yarn, $5,108,804; pile fabrics, $2,174,437; miscellaneous, $1,041,801, — with a grand total of $107,136,102.[1] The United States produced silk goods to the value of $196,911,667 plus $1,218,101 made in factories not listed as dress industries.

In 1910 and 1911 the world's product of raw silk was 51,850,000 lbs.

Classification of Raw Silk. — The silk from the various countries shows characteristics which fit it for different purposes. Chinese and Japanese silks are packed in bales covered with matting. The weight is supposed to be 133⅓ lbs. (one Picul), but is not constant. The value of a bale is $400 to $600, more or less. It is made up of a number of bundles called books, which weigh four and one half pounds upward, and contain about thirty rolls of raw silk. Those which have been reeled in steam filatures are generally put up in rolls of two skeins each, of a size convenient for winding, and with the ends fastened so that they can be easily found. The skeins from native reels are apt to be too great in circumference, and give much trouble to the throwsters. The length of Asiatic raw silk skeins is largely

[1] Consular and Trade Reports, April 11, 1912.

limited by the length of the working day, the skeins being started in the morning and finished in the evening. "Native reeled" skeins are often full of flaws. The ends of such skeins are hard to find. The various Asiatic reelers have trade-marks. Some of these have a high standard of excellence, even though climatic and other causes affect the product from year to year. The buyers and manufacturers know the classes of silk from the various filatures, and order from previous experience. The best raw silk is even, clean, elastic, strong, and lustrous. In a general way it may be said that the raw silk from North China is noted for its whiteness, brilliancy, and snap, but Cantons are creamier in color and much softer. Japan silk is creamy white, clean, and of good strength and nature. Sicilian silk is yellow in color, suitable for soft satins, such as the Liberty satins. Southern France produces excellent silk, brilliant and suitable for black satins. The trade-marks from China and Japan, known as chop tickets, are very numerous, for they include those of the filatures and the rereels. The market terms as adopted by the silk association of America June 15, 1908,[1] were: —

EUROPEAN SILKS

Grand Extra	Best No. 1
Extra Classical	No. 1
Best Classical	Realina
Classical	

JAPAN SILKS

Filatures	*Rereels*	*Kakeda*
Double Extra	Extra	Best Extra
Extra	No. 1	Extra
Sinshiu Extra	No. 1–1½	No. 1
Best No. 1 to Extra	No. 1½	No. 2
Best No. 1	No. 1½–2	No. 3
Hard Nature No. 1	No. 2	
No. 1 [of the grade of Sinshiu Okaya (Chicken)] summer reeling season 1907–1908	No. 2–2½	
No. 1–1½ No. 1½–2	No. 2½	
No. 1½ No. 2	No. 3	

[1] *The Value of Conditioning*, 1908. Issued by the United States Silk Conditioning Co.

Silk Reeling. — The greater part of the silk on the cultivated cocoons, and most of the Tussah silk cocoons are reeled, and the waste and unreelable parts are laid aside to be spun. When the cocoons are brought to the reeling establishments, they are first sorted and classified by color, size, shape, wrinkles, and condition (moldy, defective, or perfect). The fiber varies in thickness in the cocoon, tapering down in size towards the interior. In reeling several cocoon filaments are united, and they must be overlapped in such a way as to produce the evenness in size that is so essential. Reeling is therefore an important and tedious process. Uneven and careless reeling is common, especially among the primitive reelers, and gives much trouble later to the throwsters.

The filament should come off evenly in one long, smooth thread. The method of doing this is to float the cocoons in specially constructed basins in boiling water, then brush them until the filaments which will unwind to the center of the cocoons are found, and wind them into hanks on the reels which are connected with the basin. Hand reeling is a very simple process, but steam filatures are in general use, in which the heat of the water can be regulated, and the reels are run by power instead of by the feet. One reeler can thus attend to a couple of basins. A revolving brush is used to catch the ends of the silk. The work begins by removing the loose silk from the outside of a number of cocoons. This is laid to one side with defective cocoons and other waste to be used later for spun silk. The threads are caught by the fingers and drawn off the cocoons until the filaments run smoothly. The silk from several cocoons is now united, twisted slightly in the fingers, and passed through an agate or smooth glass eye and attached to the swift or reel. For 13/15 denier silk, which is the standard raw silk sent from Japan to the United States, the threads from about six cocoons are united; for finer counts, such as 10/12 denier, fewer cocoons are required, and for heavy sizes, such as 24/26 deniers, many more are united to make the thread. The regular method of reeling is to take the thread after it has come through the eye, and by a simple device twist it a number of times around itself to weld the filaments closer together. This is called the croissure (Fig. 107). The thread then passes to the reel, being wound in a transverse or lateral manner across its width, so as to make a cross reel, instead of piling up on itself. This helps later in unwinding the skein. By another method of reeling there are two

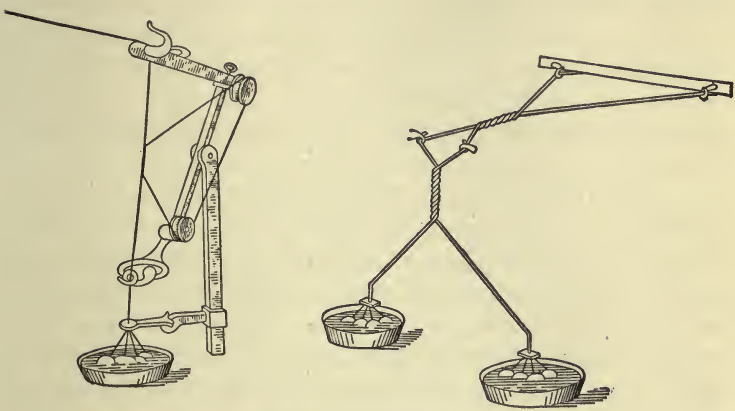


Fig. 107.—Croissures.

From Matthews' *Textile Fibres*, by courtesy of John Wiley & Sons.

threads, each made from a group of cocoons. Each thread passes through an eye, the two threads are twisted around each other, separated, twisted together again, and separated before passing to the swift. In some reeling machines a bell rings when a hank is complete and ready to be taken off. The product of reeling is called raw or reeled silk.

Fresh cocoons may cost about twenty-five cents per pound, but the dried ones, being much lighter in weight, run from eighty cents to one dollar per pound. Pierced cocoons (dry) from which the moth has issued are about fifty to sixty cents per pound. To make one pound of raw silk will take about eleven pounds of fresh cocoons and about four pounds of dry. There is in the

East sometimes as much waste as reeled silk from these cocoons. The price of reeled silk changes constantly, but runs approximately from three to five dollars per pound.

Conditioning. — The function of conditioning houses is to test the physical attributes of commercial fibers. They have been organized particularly for silk, but are extensively used for wool and cotton. These testing stations are found in silk centers such as Milan, St. Etienne, Basle, Zurich, St. Gall, Lyons, Krefeld, and New York. Conditioning is principally used for reeled and thrown silk. The elasticity and tenacity of silk are greatly affected by the moisture in it, and by other conditions. Silk, in commercial practice, is supposed to contain moisture equal to 11 per cent of its absolutely dry weight. It will carry 30 per cent without feeling appreciably damp, and can be made to absorb considerably more. The method of testing for moisture is as follows: Samples are taken from a number of books in one bale of silk and weighed carefully. They are then placed in ovens and dried perfectly. The samples are again weighed, and the difference noted, and the dry weight of the full bale is worked out by proportion. The conditioned weight of the bale is based on this dry weight of the silk plus the accepted commercial regain of moisture, 11 per cent. Tests by special apparatus are made of other points on which information is needed, such as the average size and regularity of size of the silk, its strength, elasticity, and boil off. Skeins are measured, bales weighed net, and like investigations are made.

Silk Throwing. — The term throwing is used for the series of processes by which reeled or raw silk is made into yarn for weaving. Silk direct from the reel is strong enough to stand the strain of weaving, but the threads would open up if dyed, so silk that is to be skein dyed has to be more or less twisted. When raw silk arrives at the throwing mills, the bales are opened, and, if necessary, the skeins are sorted as to size and color. Skeins that are to be thrown "bright," that is, without having been soaked, are taken directly to the winding machine. Those which are to be soaked are put in a bath of lukewarm water containing some olive or neatsfoot oil and some olive-oil soap. Silk usually stays in this bath overnight, the gum being thus softened. After soaking, the skeins are "whizzed" in a hydro-extractor and then dried. Winding the skeins follows to transfer the thread to bobbins. This process requires careful work. In the winding machine the skeins are stretched on a series of swifts or reels which are arranged side by side, and the end of each thread is passed through an eyelet to a bobbin and by means of a guide wire is wound without friction up and down the length of the bobbin. The attendant must piece all bad places and deliver a smooth thread. The threads are passed from one bobbin to another through a slot or between two parallel plates so set as to remove all irregularities on the silk. Winding prepares the silk for doubling and twisting, which are necessary to give to the filament sufficient coherence for boiling off and dyeing.

Doubling and Twisting. — These are usually separate processes. In the doubling machines the threads pass from as many bobbins as there are threads to be doubled together upon one bobbin. The doubled thread is now twisted on a second machine. In some American machines throwing, doubling, and twisting are combined, but such machines can only be profitably used with perfectly reeled silks of good strength. The amount of doubling and twisting depends upon the future use of the thread. There are many different ways of throwing silk, but the three following are in constant use: singles or no-throw, organzine, and tram.

Singles have little twisting, a single filament of reeled silk being used. Hard-twist singles are used for gauzes and chiffons.

Organzine (Fig. 108) is made from the better grades of silk, for it is generally used for the warp, and that must be strong. A single raw silk thread is twisted with a right-hand twist, perhaps sixteen turns to the inch. Two, sometimes three, or even more of these twisted threads are again twisted together, left-hand twist, perhaps fourteen turns to the inch. There are variations of the manner of twisting. In taffeta weaving the organzine is twisted sixteen or more times on the first twist. For soft satins, on the contrary, the twisting may be less, for the sheen or luster is greater if the silk is less twisted. For dull finishes for strong silks the organzine is twisted very closely. When two threads are finally twisted together the yarn is called two-thread organzine; when three are united, three-thread organzine.

Tram. — For tram silk, which is generally used for filling, two or more single, untwisted, reeled threads are united into one and

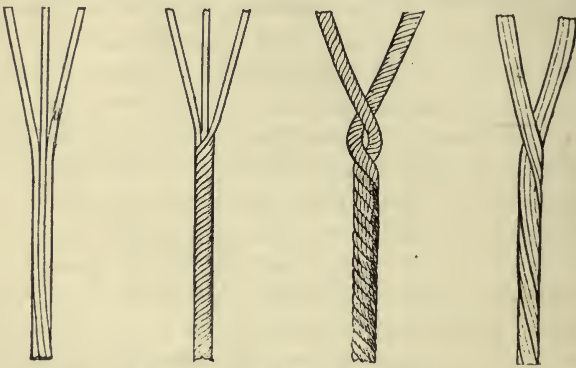


FIG. 108. — ORGANZINE AND TRAM.
From Barker's *Textiles*, by courtesy of Constable & Co., London.

twisted very slightly. The terms two-thread, three-thread, etc., are used to designate the number. A poorer quality of silk is used for tram than for organzine.

There are many special twists, of which sewing silk is an illustration. There may be as many as one hundred cocoon filaments in one thread of sewing silk, depending upon the size. From three to perhaps two dozen raw silk threads are united and twisted together, after which two, four, or six of these threads are again twisted together in the reverse twist while held at a tension. After the throwing, the silk is wound into skeins again for dyeing. When thrown silk is to be sold, the hanks of yarn are made into bundles. Thrown silk is sometimes called net silk.

Dyeing and Attendant Processes. — *Degumming and Stripping.* — Reeled silk is harsh and wiry, as it contains considerable gum or sericin, and it may also have much color in it. After the thread is thrown and before bleaching or dyeing it, the gum and color are boiled out. All silk does not require the same treatment, for the gum is more difficult to remove in some cases, and in some classes of silk the gum is only partially removed. Stripping or boiling off the gum greatly reduces the weight of the silk, for 25 per cent or more is often lost. The process is simple and not injurious. The natural luster and softness of the silk is enhanced by boiling off. If the silk is to be very lustrous, it is sometimes stretched in the gum before the stripping or boiling off occurs, and is again stretched and steamed after it. The boiling off, as usually practiced, consists of a boiling in a vat of soapy solution, the silk being placed on sticks and worked up and down until the gum is removed. This is a process of much delicacy, as the degumming must be complete but not overdone. For soft silk, about 20 or 30 per cent of the thrown weight is lost in stripping, leaving it soft and lustrous; for "souple" silk the loss is less, being from 5 to 12 per cent. The result is a duller appearance and a firmer touch, suitable for grosgrains. "Ecru" silk has still less gum removed, probably from 2 to 5 per cent. After stripping, a silk may need several washings. A bath of dilute acid is given if "scroop" (the crunching sound of silk) is required. Large dyeing establishments have given careful study to stripping, for carelessness in this process will prejudice the succeeding operations.

Weighting (see Chap. XII). — As silk is an expensive fiber and loses weight from the boiling off of the gum, harmless additions of plain sugar and sugar of lead were early used to make up the loss. The demand for less expensive silks has gradually brought about an exaggerated and injurious weighting. The silk to be weighted is immersed in a series of solutions, with thorough washings between each. A light weighting may be given which really seems to help the silk, or the silk may be charged heavily or "dynamited." The receptivity of the silk fiber for the substances used enables it to be loaded, in colors, to an extent equal to about double its boiled-off weight, and in blacks to three, four, and in extreme cases even five times its boiled-off weight. The result is the mechanical weakness of the filaments, on account of the stretching of their walls when taking in the metallic weighting. This later causes them to break; or crystallization of the tin takes place when exposed to the light, and its crystalline facets cut the silk from within; or oxidation occurs in the course of time, with a consequent weakening of the fibers; or if perspiration is present in the silk, chlorin is freed, which causes rotting, and pink spots appear on certain colors which later become tender. Even perspiring hands touching the silk will bring about this rotting of the fiber.

Dyeing (see Chap. XIII). — The dyeing of silk has great difficulties, even though the fiber takes the coloring matter readily. Silk is dyed in the yarn and in the piece, but the methods differ greatly. Overworked silk does not wind well. Silk cannot stand the boiling which may be given to cotton. Wringing, stretching, and lustering of many kinds come after dyeing to give gloss to the silk. When the dyeing process is without weighting of any kind, the manufacturer has to bear the expense of the loss of weight. The consumer is seldom willing to pay for this.

Further Processes. — *Bleaching* (see Chap. XIII). — Silks that are not perfectly white are hung in a sulphur chamber or they are bleached with peroxide when the color is difficult to remove, as in Tussah silk.

Stretching and Lustering (for silk thread). — Bringing out the gloss on silk thread may precede or follow dyeing, according to the character of the silk or the practice of the dyehouse. Both hand and machine methods are used. The dyer throws the skein over a strong peg in the wall, puts a smooth stick through it, and pulls the skein down hard, twisting it about from right to left until it is soft and glossy. By the machine method, bobbins of the twisted silk are placed in water and the silk is wound from them on a revolving copper roll. It then passes to another roll just above, which in revolving more rapidly stretches the silk. This stretching is usually done before dyeing. A high degree of luster is given by exposing the skein to steam in an oven, where the silk is stretched on highly polished rollers. The steam and friction, however, sometimes wear on the threads. Steam lustering often both precedes and follows dyeing, for the dyes, mordants, and weighting decrease the luster of the thread. A special olive-oil bath is given to some silks. "Scroop" as well as luster are given by soaking the silk in dilute acid. The boiled-off liquor containing the sericin or gum is frequently combined with the dye to increase the luster.

Winding after Dyeing. Weaving. — After dyeing, the skeins are wound in various ways on bobbins or quills according to the use to which they are to be put. Silks which are to be woven immediately are warped. Silk warping differs somewhat from that of other fibers, and requires the most delicate handling. There are several methods in use, the aim is the same as in all warping, and the weaving is also much like other weaving, though special silk looms are built. The fineness of the silk filament increases the difficulty. Silk does not have to be washed or scoured in the finishing process. The weave in silk is of paramount importance, and ranges through all kinds of designs from plain to the most intricate Jacquard patterns. The silk designer requires training, years of experience, and artistic taste. Standard silks found in the plain weaves are the China, India, and Japan silks; glacé silk, which is the name given to silk with contrasting colors of warp and filling; pongee and Shantung, taffeta and crêpe de chine. In twills there are the surah, and others such as serge and foulard. In ribs and cords there are the ottoman, grosgrain, bengaline, poplin, the cut and uncut Terry velvets, the faille française, and many others. These are often made with a wool or cotton filling, and the ribs are filling ways. In satin weaves there are the messaline, merveilleuse and satin de chine, satin duchesse, Liberty satin, and peau de cygne. In gauze weaving, the marquisette; in Jacquard, the brocades and tie silks, and in double cloth there are many kinds of double-faced ribbons and broad goods. Some silks are woven of singles or of two or more reeled threads, which are united and wound without throwing.

Finishing. — The general aim of finishing is to increase the luster and also to improve the cloth by giving "handle," strength, and body to poor, adulterated, or union materials. The kind of finish depends upon the aim to be attained. Finishes are of two kinds — mechanical, or by means of dressings. Some of these have already been mentioned. The main yarn finishes are: (1) Sizings to smooth certain hairy yarns and make them wear better; (2) soaking in dilute acid to give scroop and gloss; (3) gassing to burn off the fluff and to make the yarn smooth; (4) dressings and mechanical finishes to give gloss and to harden. Organzine (if it needs sizing, which it rarely will) is sized with gelatin.

Finishes for woven silk are also mechanical or by dressings. The first includes calendering, mangling, or pressings of various kinds by which the woven material is made smooth. The goods may come directly in contact with metal rollers or may be pressed between finishing paper, according to whether a glistening or a soft effect is needed; moiréing or embossing cylinders having designs etched upon them may press into the dressed material, leaving the design on the surface; special machines of many kinds, used to give such effects as panne and miroir velvet; polishing machines; steaming machines for velvets and other pile goods; gassing and shearing machines to eliminate fluff and ends in materials made of spun silk or any silk which is inclined to have too rough a surface; breaking machines which are used to soften up material made too stiff by dressing, the material passing over rollers on which the tension can be increased or decreased as needed. Flat spiral knives or rollers with brass knobs or buttons break the finish; printing either on the woven silk or on the warp threads, used extensively on foulards, crêpes, and ribbons, may be direct or by resist or discharge. (See Chap. XIII.) After printing, finishes are necessary, such as gumming the silk, calendering it, and breaking the surface to soften the handle and look.

Dressings are of many kinds; each mill has its own secret formulæ. The aim may be to soften, to stiffen or to harden, to glaze, to strengthen, to waterproof, so the material will not spot, to fireproof, as special treatments make silk inflammable, or to cover defects. The following dressings are in constant use, usually in combination with each other, dextrin being perhaps the only one used by itself: Rice water, isinglass, gelatin, dextrin, starch, glues, gums, and waxes. The waxes are made into an emulsion with alkali, and the gums are softened with castor oil. Resinous substances, such as amber and resin, are also used.

Pure silk requires no dressing, but is finished by pressing, mangling, or calendering, with or without friction. It is the poorer, cheaper silks and half silk materials which have dressings to add to their body. For them are used such finishes as gassing to remove fluff, gumming to give feel, calendering to improve gloss, breaking to remove stiffness and to give handle. Taffeta silk is finished in many ways. Gelatin water gives it stiffness; pressure and heat bring out gloss; waterproofing keeps it from spotting, so that it can be used for umbrellas and raincoats. For the latter purpose a special treatment is often given with melted rubber between two layers of silk. Light silk fabrics are stretched in a tenter frame and finished on the wrong side. Satin is often sized as well as calendered to increase its luster. Warp printed ribbons have a soft, uncertain pattern, on account of the plain filling passing over the printed warp. A surface print is made after the material is woven, consequently it is clear in outline.

Counts for Reeled and Thrown Silk. — There are several systems by which the counts of reeled and thrown silks are estimated, such as the metric and denier systems for raw and thrown silk, and for the latter, also, the Manchester dram system. The denier system for raw silk and the dram system for thrown silk are those customarily used in the United States. There are published tables[1] which show the relation of these systems to each other. The irregularity in the sizes of the raw silk makes it necessary to use an average figure when stating the count. The usual count of reeled silk used in the United States is 13/15 denier[1] (see Glossary). In the denier system, the higher the number, the coarser is the silk (this principle differs entirely from that for cotton or wool). The system generally used in the United States is the English. To quote from *A Short Description of Silk and Silk Manufacture*, issued by Cheney Brothers: —

> The hank is eight hundred forty yards, and the number of hanks in one pound avoirdupois is the count of the yarn. It is based on the finished yarn, and singles, two- and three-cord yarns of the same number all have the same yards per pound. Thus:
>
> No. 50 singles has 42,000 yds. per lb.
> No. 50–2 singles has 42,000 yds. per lb.
> No. 50–3 singles has 42,000 yds. per lb.

In the dram system the size of the silk is based on the weight of the thousand-yard skein in drams. A skein weighing five drams is called five-dram silk.

Counts for Spun Silk. — The usual method of counting spun silk in the United States is much like cotton. (See Chap. VII.) The number of yards in a hank is eight hundred forty, and the number of hanks in a pound gives the count, but silk is based upon the finished yarn, and the singles as well as the various two- or three-ply thread have all the same yards per pound, which thus differs from the cotton. For illustration: —

Silk	1/60s	50,400 yds. per lb.
Silk	2/60s	50,400 yds. per lb.
Cotton	1/60s	50,400 yds. per lb.
Cotton	2/60s	100,800 yds. per lb.

[1] See *Value of Silk Conditioning*.

Silk Manufacture. — The principal silk manufacturing countries of the western world are France, England, Germany, Switzerland, Italy, and the United States. France, Germany, the United States, and Switzerland produce about 80 per cent of the total. France makes the highest class of woven goods. Lyons is her chief manufacturing city, and has a water supply which is especially adapted for the successful dyeing of silk. This city is preëminent for its Jacquard weaves, velvets, embroidered tulle, gauzes, mousselines de soie, and chiffons. St. Étienne is noted for ribbons; Avignon, Nîmes, and Tours produce velvets, taffetas, and other classes of pure and mixed silks and silk knitted wear. Italy does a large business in silk reeling and throwing and also in woven materials, Milan ranking next to Lyons in silk production, while Naples and Como also have large silk industries. Palermo in Sicily manufactures mixed silk and cotton material. Switzerland does a large business in silk knitted and woven goods, Zurich making plain and fancy silks, Basle ribbons, and Berne knitted goods. Passementeries, embroideries on tulle, plain and drilled embroideries, netting and lace in imitation of the genuine Venetian, Brussels, and other kinds are made in Switzerland in the Appenzell and St. Gall districts, and in Bohemia near Carlsbad. Hand and shuttle work are both used. The work can be seen in various stages — all handwork, part handwork, and machine. The hand-embroidery machine is about five yards wide. The cloth on which the embroidery is to be done is stretched the length of the machine, and a carriage on either side of the stretched material carries in a double row from two hundred to four hundred double-pointed needles, each having an eye in the middle. The needles are pushed through by one carriage and taken up by the other, a stitch being taken with each operation. A pantograph is at the left side of the machine on which the design is six times enlarged. The operator with his left hand traces the pattern, which is reproduced in the correct size on the stretched material. If the cloth is to be an embroidered strip it is taken off after the work is completed and finished by hand. If it is to be made into passementerie, the same pattern has been repeated many times across the length of the strip. After the embroidery is finished, it is given to workers who cut out the designs, leaving a small rough edge around them. The background is made of vegetable fiber if the embroidery is to be an animal fiber such as silk, *i.e.*, a thin cotton fabric is stretched in the embroidery machine to receive the silk stitches. After the handworkers have cut out the designs, they carefully sew and embroider the many designs together to make the passementerie perfect, and the latter is sunk into a chemical bath which destroys the background, leaving the embroidery standing out clear, for the fraying edges have been eaten away. It is finally finished for sale by handworkers and pressers. Large amounts of the machine laces, embroideries, and passementeries are sent to America. Loop embroideries and nettings are also made by machine.

Germany has large silk industries and manufactures dress silks, satins, velvets, bindings, braids, and linings. Barmen, Elberfeld, and Krefeld are important centers, the last named having a water supply which is of especial value in silk dyeing. Germany is producing large quantities of mixed and cheaper qualities of dress goods and trimmings. Russia has factories, especially in Moscow. Belgium also has many silk mills. The United Kingdom manufactures dress goods, ribbons, laces, and embroideries. The production of material made of silk mixed with other fibers is increasing there. Leeds is noted for its sewing silks, and Coventry for its ribbons.

The United States makes all varieties of silk materials, but does less than France in the finest qualities and in velvets. Paterson and Passaic in New Jersey are the most noted silk manufacturing cities. Silk waste is used in all the countries where the silk industries are developed, Basle, Milan, Lyons, Paterson, and Passaic using large quantities of it.

Spun Silk. — The raw material of the spun silk industry is silk waste, and cocoons which are unfit for reeling or throwing. There are many qualities of silk waste, ranging from wastes of the highest class of reeled or thrown silk to a low class of waste silk used principally in the East. The lowest quality of Asiatic waste is not exported, but is used in the countries producing it for wadding, for interlining winter garments, and for other purposes. There is a large amount of waste in silk production: only about half of the total world's supply of silk spun by the worm comes into the market as raw silk. The principal sources of waste silk are the following: (1) From cocoons, such as the rough threads thrown out first from the silkworm; from the teasing brush; from broken cocoons; from parchment-like inner layers, too fine to reel; and from defective and pierced cocoons. (2) Reeling waste — poor reeling yields a large amount. Some Chinese silk is reeled solely for use as material for spun silk, as the Punjum. (3) Gum waste, *i.e.*, throwster's waste, being fine and coarse ends made in the various reeling and winding processes, as in piecings. (4) Weaving mill waste. (5) Various wild silk cocoons which will not reel.

The bales of waste are tightly packed and are difficult to open, an axe being sometimes used to break into the mass. There are several methods of removing the gum: (1) the English, or boiling off; (2) the French, or schapping; and (3) the alkaline or acid processes. In boiling off, the waste is put in bags made of open mesh material and pulled up and down in vats of hot soapy water kept just up to the boil, which softens the gum so that it passes out through the meshes of the bag. After several hours, the silk is taken out and dried. The silk is again soaked in another vat to rid it of more gum, and comes out soft, fluffy, and white, having lost from 18 per cent to over 50 per cent of its weight, the loss varying greatly according to the kind of waste. In the schapping system the waste is put in vats of tepid water for a week, until fermentation sets in and rids the silk of much of its gum. For some classes of goods, such as velvets, the schappe silk is preferred. The third process degums by soaking the silk in a solution of alkali, or in an acid solution.

The main processes after degumming the waste silk are, in general, the following, but considerable differences are found: (1) beating the fibers to open them and make them flexible; (2) winding them on a cylinder; (3) cutting them in short lengths for short spinning; (4) examining the material for foreign matter and imperfections; (5) combing the lengths through a hackle; (6) spinning by forming the threads of silk into slivers, then into rovings, and finally drawing out, spinning and twisting them into spun yarn on a frame or on a mule; (7) winding the spun yarn on bobbins for warping or on quills for the shuttle. There are many qualities of spun thread; the term bourette is used for a low and rough class. Spun silk yarn is frequently gassed to make it glossy by ridding it of short, fluffy ends.

The United States imports from the East large quantities of the best silk waste, or an average of 6,000,000 lbs. annually.

The best spun silk yarns are largely used for filling or woof for silk dress goods, and for warp velvets and half-silk goods. Lower grades of yarn are used for knitting yarns and poorer kinds of dress goods. Bourette yarn is used for coarse knitted goods, and for packing and insulating materials. Silk shoddy or recovered silk from cuttings and remnants is prepared like wool shoddy. (See Chap. XI.) It is employed in combination with silk waste and with other fibers. Silk wadding is made from the waste from bourette spinning.

Market Terms. — Silk wastes from the East and Europe are often known under the names of places from which they come. There are many kinds, and of different gradings; for instance, the Japanese curlies (Kikai Kibizzo) is a well-known waste. There is also a China curlies. Both of these are listed under three or four grades. Some few wastes are found under chop marks.

Abuses. Adulteration and Substitution. — The effort to cheapen silk has tended to develop numerous processes which give effects that pass for real qualities with the ordinary consumer. These may be reviewed as follows: —

In reeling, various soaps, oils, gums, glues, and chemicals are added to increase the weight yet escape detection, but such silks, it is said, do not often come to the United States.

In dyeing, an excessive amount of weighting may be added in mordanting or other processes. Salts of tin, iron, and lead are commonly used.

Substitutes. — These may be spun silk used in place of reeled silk, and Sea Island or other fine grades of American cotton.

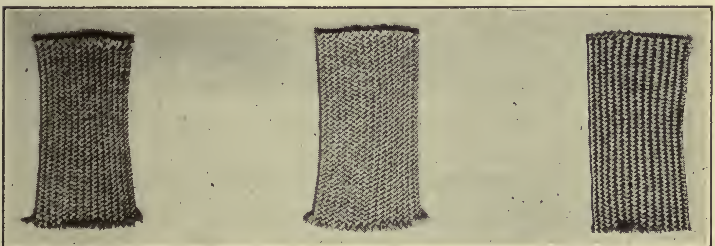


FIG. 109. — SILK SUBSTITUTES IN SKIRT BRAIDS.

1. Left-hand figure. Mercerized cotton braid sold as silk-finish. Price 10 cts. for 5 yd. bolt.
2. Middle figure. Mercerized cotton braid sold as silk braid. Price 15 cts. for 5 yd. bolt.
3. Right-hand figure. Artificial silk braid sold as silk braid. Price 10 cts. per yd.

Artificial Silks (see Chap. XII). — Artificial silks resemble silks in appearance, but differ completely in their properties. They are glossy and attractive, but they are frequently inflammable and become gummy in water, although treatment is lessening this. They are brittle and inelastic. For some purposes they are fairly satisfactory. They do not cover so well in the weaving as silk, therefore more picks per inch are required. The weight is greater; the price is lower. They are used in hosiery, neckties, drapery, and dress trimmings.

Silks weighted in order to cheapen them are usually weakened either directly by the treatment or by the additional weight.

The silk looks rich and feels heavy, but the walls of the fibers easily break down. This deterioration will occur while the material is being constructed into a gown, is lying on the shelves of stores, or hanging in the closet. An expensive silk gown had been worn but a short time when fraying splits appeared here and there where there was no strain on the material. The remainder of the gown was intact even where there was tension. Chemical tests showed that the entire silk was well weighted, but irregularly. The parts which were still good were carrying a weighting of 51 per cent, while those rapidly disintegrating were unable to endure 58 per cent. At the same time similar tests were made on an old-fashioned pink taffeta silk almost identical in color and weight. This gown had been in use for fifty years with almost no deterioration. It was found to contain so small a fraction of weighting that the silk was virtually pure.

The effect of poor or strong chemicals on silk is often noticeable in polka-dot or small sprigged materials which have been made by discharging the color from the solid ground. Careless or cheap treatment results soon in a rapid destruction of the textile as well as the color, and a perforated garment is the result.

Another common illustration of weakness where strength is needed is in the wide silk shoe laces sold at twenty-five cents a pair. While they are often "all silk," they are so heavily weighted to secure the look, feel, and weight of a better-class material that they are unenduring. A mercerized cotton product would wear better.

Black silk stockings were once considered luxuries, in which only the wealthy could indulge, but the demand for a cheap product has resulted in bringing them within the reach of every one. Heat and chemical tests on the silk show how this reduction in price has been made possible. Half hose, which were offered for sale at 35 cents a pair, as "a great bargain in 'pure silk' on account of changes in business," were tested. The general appearance of the stocking was of thin reeled silk, but the tests showed that the upper part was all cotton, that the toe was of cotton mixed with silk, the latter weighted 22 per cent, and the part between the toe and the upper part of the leg was of silk carrying a weighting of 63 per cent to give it body. For mere pleasing effect this pair of half hose was a success, the inserted cotton would add to its service, but the all-silk portion would soon go to pieces. It would be a bad investment for poor people, and rich ones could afford a better article. The greatest objection, however, is not to hosiery made in that way, but to the labels stating that the articles were "pure silk."

Sewing silks should be strong and enduring, but here, too, the demand by the consumer for cheap goods has its effect in lessening the economic value of the product. Sewing silk comes in various grades, A to E being the common numbers. The lowest priced spools have 100 yards of silk on them and sell for the same rate per spool, whether No. A or No. E. Yet the latter being much heavier thread should contain more silk in its hundred yards and should consequently sell for more. As the consumer expects to pay the same price for all grades of the same length, the manufacturer has been obliged to adjust his expenses in such a way that he will not lose.

SILK MATERIALS

	WIDTH	PRICE
Armure	40 in.	$1.50
Bengaline	21 in.	1.00–1.25
Brocade	36–42 in.	2.00–8.00
Chiffon	46 in.	.75–2.00
Corded silk	24 in.	1.00–1.50
China silk	27 in.	.50 up
Crêpe de chine	40–44 in.	1.50–5.00
Crêpe meteor	40–45 in.	2.00–5.00
Faille française	36 in.	1.50 up
Foulard	24–42 in.	.65 up
Gauze	45 in.	4.00–5.00
Glacé taffeta	36–40 in.	2.00–4.50

SILK MATERIALS — *Continued*

	Width	Price
Grenadine	44 in.	$1.00–6.50
Grosgrain	22 in.	1.25 up
Habutai	27 in.	.50–2.00
Japan silk	27 in.	.50 up
Liberty silk	36 in.	.50–1.00
Liberty satin	36 in.	1.50–2.00
Lining silk	27 in.	1.50
Louisine	36 in.	1.50–2.00
Malines	40 in.	.35–.75
Messaline	36 in.	.85–2.00
Moiré	22 in.	.85–1.50
Mousseline de soie	45 in.	.50 up
Mull	36 in.	1.00 up
Net	36 in.	1.00 up
Ottoman (similar to Bengaline)		
Panne velvet	21 in.	1.50 up
Panne velvet	40 in.	3.00 up
Peau de cygne	21 in.	.75
Peau de soie	21 in.	.75–1.25
Persian	20–36 in.	.75–5.50
Plush	24 in.	3.00
Pongee	27 in.	.65–1.50
Satin	21 in.	1.00–3.00
Satin brocade	36 in.	2.00 up
Satin duchesse	24–36 in.	1.00–3.00
Royal	45 in.	4.50
Shantung	33 in.	1.25–1.50
Skinner's satin	36 in.	1.25–1.50
Surah	24–36 in.	.75–1.50
Taffeta	21 in. up	.50–2.00

CHAPTER IX

THE LINEN INDUSTRY

Linen has been called the textile of luxury, as its expense in finer grades stands in the way of its common use. The fiber, however, has qualities which adapt it to special service. It is held that ramie, which most resembles it in appearance, has like properties and is cheaper, but as yet the latter is not common enough for comparison. Linen, therefore, at present is pre-eminent for surgical uses and for household purposes. No other textile is so free from lint, gives up its moisture so rapidly, is so quickly cleansed and so pure and hygienic for constant service. Fabrics woven from other fibers are adulterated and cheapened, yet are still acceptable with many consumers, as the appearance is all that is really required of them, but with linen, it is in general the properties that are sought, and as all adulterations decrease these, pure linen is demanded.

For higher grades, such as table damasks and fine linen, flax is neither grown nor manufactured in the United States. The difficulties of cleaning and manufacturing it, the expense of bringing it from other countries, and the tariff charges, make it expensive. When it is pure and well cared for, however, it has so much endurance that even the cost is justified when the quality can be secured. Each housekeeper must consider whether for her it pays to buy pure linen or not, or whether unions with cotton, plain or mercerized, will serve her as well. In order to judge wisely and to obtain the full value from a purchase, she should know the properties of flax, and the probable life of the towels or cloths made from it. She must also understand the care which will make them endure. The fact that this textile of ancient lineage can be laundered after lying four thousand five hundred years in the tomb of some Egyptian king shows that endurance is inherent in it.

The naturally sturdy linen unfortunately comes to us often in a weakened condition, on account of the careless and rapid preparatory steps, the poor and cheap chemicals employed in retting, bleaching, and dyeing, and the use of tow instead of the stronger line. When linen is combined with cotton, as is frequently the case, we lose the properties of the former, and the only gain is in cheapness.

For hygienic clothing, linen is to be commended. Its purchase, when pure, well manufactured, and enduring, may be justified even for the poor, but modern dress linen does not usually wear well, and methods common in the laundry hasten disintegration.

Linen is accorded a respect which we do not give to other textiles, for its long history, its old-time reliability, its exclusive command of many household needs, its purity and wholesomeness have given it a high record. We usually wish it to last, and will mend and repair old sheets and treasure old tablecloths and napkins when other textiles are discarded. Almost every household keeps its old-linen bundle in case of accidents.

Properties. — *Absorption.* — Linen absorbs water rapidly, the amount being 8 to 14 per cent according to some authorities. This is about equal to cotton, which is 10 to 12 per cent. Vegetable fibers are about equal in their absorbent qualities. Experiments have shown that linen does not absorb perspiration as well as cotton does. The moisture, however, seems to spread through the woven meshes of linen differently from cotton, but experiments do not indicate much difference between the two. Linen which has been sized does not in general absorb water as rapidly as the unsized linen. Smooth, damp linen adheres to the skin slightly more than will cotton.

Evaporation.— Water evaporates quickly from linen, which makes it valuable for toweling, handkerchiefs, and wash cloths.

The quality of rapid evaporation gives it a cold feeling next to the skin; this effect is lessened by weaving it with an open mesh. The natural smoothness of the material adds to the feeling of coolness. It is worn as winter underwear by Russian peasants on account of its cheapness and availability in that country, and by many others who believe in its hygienic qualities.

Cleanliness. — The property of cleanliness makes it valuable. When correctly laundered it easily gives up its dirt and continues to be white and clean even after long service. Its cleanliness has made it of value in surgical use, and experiments have shown that germs do not increase as rapidly on linen as on wool, silk, and cotton.

Endurance and Strength. — Linen thread is the strongest of the fine bast fibers. The wearing qualities are excellent when the fiber is pure. Chemical bleachings lessen the strength, although a dazzling whiteness can be obtained in a shorter time than in grass bleaching. The latter adds to the expense, but is justified in the longer endurance of the material. Unbleached linen is stronger than the bleached of the same weight. The length of the filament is a factor in the strength of linen. The material does not deteriorate quickly when laid away unless it is filled with sizings and dressings.

Tenacity. — When pure, linen is very tenacious, and is, therefore, used for the strongest twines and cordage. This quality is a factor in strength.

Weight. — Closely woven linen is heavy. Very much less air is held in the meshes than in cotton, so that equal volumes of the two textiles show linen to be 17 per cent heavier. Linen, however, is more penetrable by air than cotton, which adds to its feeling of coolness.

Fineness. — It is possible to spin the flax until it is almost like a hair, and the strength will still continue. The delicate linen threads for the finest lace are spun by hand in damp cellars, where the eye cannot see the gossamer filament, but the fingers can feel it.

Luster. — The luster of the finest linen is almost as high as silk. This quality is lost in overretted flax. Tow has less luster, for the short staple interferes with the reflection of light, but special treatment is given to it to make it glossy.

FIG. 110.—THE FLAX PLANT.

From Hooper's *Hand-loom Weaving*, by courtesy of John Hogg, London.

Affinity for Dyes. — Linen does not take or hold the dye well, therefore it is more apt to be found in the various bleaches than in color. Dress linens are, however, dyed in many colors, but are not always satisfactory.

Solidity and Toughness. — These qualities give it great value for canvas, twines, and cordage.

Suppleness. — When undressed and unsized, it can be bent sharply and yet not broken. Linen fabrics are less flexible than cotton of equal thickness, and retain their shape better if free from dressing. This quality recommends linen for shirt bosoms and table linen.

Botany and Growth. — Linen is made from the fiber contained in the stalk of the flax (Fig. 110). There are perhaps one hundred varieties of this plant known to botanists. The genus is *Linum*, and the best known of the cultivated species is *Linum usitatissimum*. Flax probably came from the East, but it grows easily in almost all climates and countries. In the ancient history of Egypt reference is frequently made to its cultivation and manufacture. It is grown in varying degrees for fiber in Great Britain and Ireland, Sweden, Denmark, Holland, Belgium, France, Russia, Germany, Austria, Spain, and Portugal. India and the United States cultivate it for seed rather than for fiber. Japan and Australia are experimenting with it.

The plant is an annual, and has an erect, slight, and willowy stem. It grows from twenty to forty inches in height, branching frequently in the upper part when not planted too closely, and having numerous small flowers which range from yellowish to bright blue. The seeds are small, flat, brownish, and smooth. The soil should be carefully selected, and the ground should be in a high state of cultivation for producing the best fiber, as is done in Belgium. The flax crop makes a heavy demand on the soil, which must be guarded against exhaustion; rotation of crops is practiced for this purpose, especially in Belgium. In the Courtrai district the interval varies from five to ten years between successive plantings of flax in a field.

The United States does little in the rotation of crops. A drill is used for planting, and the flax stalk is threshed for the seed, which is the principal crop. The straw is so broken and tangled after the threshing that it is useless for fine fiber. In the countries of Europe where flax is cultivated it is usually sowed broadcast by hand, with much regularity. If fine fiber is desired, the sowing is close so that there will be little branching of the stalk, consequently the filament is complete without break. The seeds should be carefully selected. The Riga seeds from Russia, or the Riga seeds which have been grown in Belgium, and the Dutch seeds are considered to give the best results.

Flax springs up with many weeds which must be removed. In Europe the weeding is done principally by women and children who go over the ground on their hands and knees when the plants are from one to two inches high. In the spring wherever flax is being grown, wavering lines of workers, side by side, can be seen moving across the fields, weeding as they go. Flax is in the best state for fiber when the leaves and stem of the lower part of the plant turn yellowish and the seed pods are becoming ripe. This may be any time between the last part of June and the end of August. Dry, clear weather is selected for the pulling. Men now go through the fields grasping a handful of flax at about the middle of the stems, and pulling the sheaf up by the roots (Fig. 111). The dirt is knocked off by hitting the root end against the boot. When the flax is cut instead of pulled, the sap runs out and the quality of the fibers is inferior and in addition there would be some waste of stalk, yet the pulling is a tedious operation. As yet, no satisfactory flax-pulling machine has been invented.

The drying of the flax before removing the seed is done in various ways. In some places each handful is laid diagonally across the former one. These sheaves are called beets. The root ends are together and the lengths are as nearly alike as possible. The flax is left to dry and is later stacked. In some countries it is hung in bunches on the fences or on racks, or it may be kiln dried. Still another way is to tie the sheaf together at one end and spread it open into a tent-shaped stack like the American Indian corn.

Rippling. — After the flax is dried, it is rippled, in which process the stalk with its dried seeds and leaves is drawn through a large comb which has teeth about eighteen inches long, placed a short distance apart. The comb is usually set in the middle of a bench; two workers facing each other sit astride the bench at either end. A handful of flax is taken by each and alternately thrown upon and drawn through the comb. The dried leaves and seed bolls fall off on a sheet spread under the bench. Rippling must be carefully done or the fiber is injured. The stalks are often kept until the following season before they are prepared further. They are tied in bundles and piled up ready for the next process or for storage. The term straw is now used for the flax.

The Seeds. — Flax seeds are commercially of great value. When the main aim is seed culture the bolls are allowed to

FIG. 111. — FLAX IN THE FIELD.

From Watson's *Textiles and Clothing*, by courtesy of the American School of Home Economics.

ripen completely, and special care is taken of them in the harvesting process. There is difference of opinion as to whether good, fine fiber and also good seed can be produced at the same time. Flax seeds are an important agricultural product in the United States. In 1911 the United States crop was 19,370,000 bushels,[1] comparatively little of which was exported. In the same year the greatest producers of flax seeds, in order of

FIG. 112.—RETTING AT COURTRAI.

importance, were Russia, Argentina, India, United States, and Canada. The seeds are used for linseed oil, which is required in paints, varnishes, linoleums, and oilcloths; linseed cake for feeding cattle; linseed powder for poultices; and linseed tea for an emollient.

Retting. — This is an important process in flax preparation. The object is to separate the filaments of flax from the bark and woody core. The straw is treated in such a way that fermentation is set up through the presence of bacteria. (See Chap. XII.) Retting may be done, *first*, by cold water, as in the running water of the river Lys in Belgium (Fig. 112); or in stagnant pools, as in Ireland, which gives a creamy white color to the fiber; or, *second*, by steam or chemical retting; and,

[1] Daily Consular and Trade Reports, April 25, 1912.

third, by dew retting, as in parts of Germany and Russia. The balance of favor is for the first method both for color and strength. The second methods are rapid, about sixty hours being taken, but they injure the fiber more. Dew retting is a weathering method, in which the sheaves of flax are spread in rows over a wet meadow and left, perhaps for the winter, exposed to rain, sun, and dew. The color is apt to be darker after this method than after the water retting, and sometimes is called silver gray or steel gray. The best flax is usually pale yellow white. Where there is no running water special vats or pools with steep sides are built and water is conducted into them. All impurities must be kept out of the water. In Ireland the soft water in numerous pools is excellent for fermentation, but the color is not so good as when the retting is done in running water.

The water of the river Lys, in Belgium, is especially adapted for retting the flax, which is remarkable for color, strength, and fineness. The region around Courtrai is given over to flax culture. Along the winding Lys at all seasons the flax is in various stages of preparation: growing and being weeded in the spring, covered with bloom in the early summer, and at all times of the year in stooks or stacks, or in crates retting in the water. Along canals and waterways passing into or out of medieval Courtrai come or go great barges of the flax to be retted or taken back to farms for further preparation. Scutching mills and great spinning and weaving factories are at hand to complete the preparation into cloth.

The method of retting in the Lys is in open crates of wood, with jute burlap around the four sides to keep the dirt out (Fig. 113). The bundles are stood on end alternately to keep the size equal, and are packed so that they cannot move. From two to three thousand pounds of straw are often in one crate. The crates are covered with fresh straw and floated into position in the Lys, and are then weighted down with stones and sod until they are a certain distance below the water, perhaps six inches. It takes about fourteen or fifteen days for the retting, depending on the temperature of the water or air and the color of the flax required. Coarse straw is retted more easily than fine. There are various indications of the completion of the fermentation, such as bubbles rising in the water and the crate lifting itself above the surface. When the process is complete, the crate is floated opposite a windlass and pulled

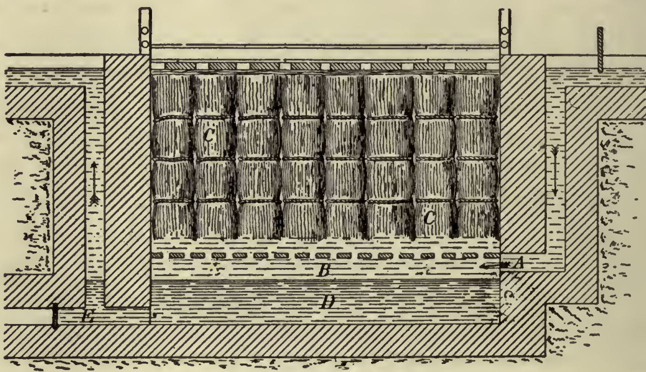


FIG. 113.—RETTING TANK.

on the bank. The bundles are taken out and stood in tent shape to dry. After a time, the bundle is turned wrong side out, that the inside may be also presented to the air. Fine fiber is usually immersed for about five days and taken out and dried for half a day, first on one side and then on the other, then put back for further retting.

The fall season for retting begins about September and continues until it is too cold. The retting begins again in March and continues until it is finished. Sometimes the year is not sufficiently long, and the remainder of the crop is carried into the next year. Overretting the straw causes the fibers to be brittle and weak. After the retting, in Belgium, the flax is spread on a grassy meadow to dry. This bleaches the fiber and helps in the separation of the bundles of filament. It is then stacked much like hay to be ready for the next process of breaking and scutching.

During the time of fermentation the odor from the flax is extremely disagreeable, and the water, unless carefully discharged, may poison fish and even cattle. After the flax is retted and dried, the straw should be bright and have a somewhat sweet odor. The fermentation separates the bark and woody pith from the fiber, but further cleaning is needed to remove the pieces of straw and the dirt which still cling, and to separate the bundles of fiber, which adhere closely. Several processes follow to accomplish this, of which the breaking and scutching are often conducted on the farms. Scutching mills, however, which also break the straw, are becoming frequent. The hackling and combing are done in spinning mills.

Breaking. — This process is done both by hand and machine, the purpose being to crack the inner wood all along its length. The chaff is then cast out from the fiber by shaking or hitting the sheaf. A very ordinary method of breaking is by a hand machine (Fig. 114). A series of long bars or knives are placed on a stand with a beater at one end, which can be raised and brought down again in contact with a sheaf of the flax straw as it is thrown across the bars. This breaks the wood into pieces and it drops out below, leaving the fiber. Breaking machines are in use in scutching mills which have several pairs of grooved rollers, through which the flax straw is passed. The pith is broken by the rollers, and much dirt falls out. After breaking, the flax is taken to the scutcher.

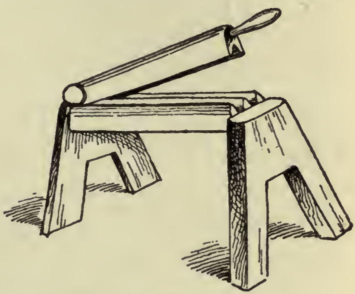


Fig. 114 — Flax Brake.

Scutching. — The flax must now be shaken or beaten to remove more of the coarse pieces of wood or bark which are clinging to it. Already the fiber begins to show itself more clearly, looking much like a switch of gray hair filled with straw. In early days flax was beaten against stands to clean it, or it was hung up and beaten or "swingled," as it was called. Still another method was to take a bunch of the fiber, place it in a cleft of an upright post, called a scutching post, and with a sort of flat beater to strike and clean the fiber (Fig. 115). Scutching mills are now common in all flax countries, and the process is very simple. A shaft runs through a long room, controlling a series of beaters of wood, which revolve rapidly. The workmen stand each in a separate compartment and present bunches of the flax fibers to the beaters through a hole in a board. The blades or beaters hit the flax and knock out the "shive" and dirt. When one end of the flax is clean the other end is presented. Short fibers break off during the process, which are called scutching tow. The latter are rescutched, spun like cotton, and used for coarse cloths. The long fibers are called the line. Scutching roughly divides line from tow. The process as used at present is not very satisfactory, for it frequently injures the fiber, and thoughtful flax workers say the less of it the better for fine thread. An improved scutcher is needed. During the scutching the worker roughly divides the cleaned flax into bundles of even lengths. These are tied up together and baled, two hundredweight or two hundred and twenty-four pounds being usually in one bale, although Russia also puts up bales weighing four to five hundred pounds as well as those of two hundredweight. The flax is now ready for market or for the spinning mills.

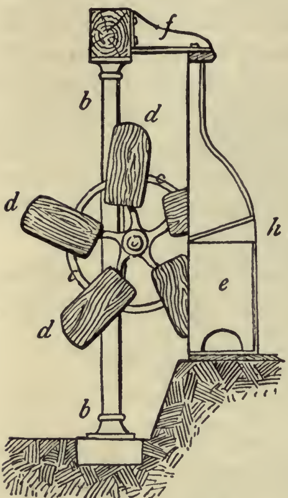


FIG. 115.—SCUTCHING DEVICE.
From Dodge's *Useful Fiber Plants.*

FIG. 116.—FLAX IN DIFFERENT STAGES.
Photograph by C. R. Dodge.

Line Spinning. — The baled flax arrives at the spinning mills, many of which are near the scutching mills, as is found in Courtrai in Belgium. The flax must now be opened, cleaned, and straightened before it is ready for spinning. The spinning of flax differs from that of the other fibers in such particulars as the clearing away of large amounts of dirt, the combing out of the tow from the line, the great length of the filaments of line, and the necessity for still further subdividing the fibers by combing them through increasingly fine wires. Flax preparation requires special machinery or hand methods, which are expensive.

The processes as seen in British and Belgium mills are usually the following: First, a preliminary cleaning, combing, or hackling called roughing (Fig. 117). The rough flax as it has come from the scutching mill is combed through coarse combs like the ripple or primitive hackle (Fig. 7). This removes broken pieces of tow and dirt. Roughing is a hand process. The roughing room has a series of benches, each containing usually two hackles, one coarser than the other, and also an upright, coarse, metal pin on which ends of flax can be broken by a quick pull. A rougher or worker presides over each bench. He spreads a lot of flax into divisions, called fingers, winds one of these around his hand, spreads the opposite end out into a fan shape, and throws it over the coarsest hackle. He draws the flax through first one way and then the other, until it begins to be smoother and finer and the dirt is removed. He casts the tow into the box at the back of the bench. Then he combs the line on a second comb, which is finer, in the same way. He lays the line in even piles with the root ends together. Three combs are sometimes used on a bench, coarse, intermediate, and fine. There is considerable art in hackling or roughing, and a poor rougher reduces all the flax to tow, but a good one has his line looking even and smooth, even after the first combing. The hackles or combs used in roughing are very similar to the old hand hackle of colonial days. For finer yarns hand hackling

FIG. 117.—HAND HACKLING.

From Watson's *Textiles and Clothing*, by courtesy of the American School of Home Economics is sometimes repeated many times in order to subdivide the flax bundles. Seemingly there is no limit to the amount of division the flax will stand, until the filament begins to look like a mere hair. In England and Russia the finest grades of flax are hand roughed before machine hackling, but in other countries machine methods are being used. The process of

FIG. 118. — MACHINE HACKLING.
Courtesy of the York Street Flax Spinning Co., Belfast.

hand roughing is expensive, and takes a longer time than the machine. It is claimed by many that coarser flax does not require the hand processes.

Machine Hackling. — The result of the roughing process is a fairly clean bunch of line, which is now subjected to a series of hackling machines which are much alike, except that the combs increase in fineness (Fig. 118). The object is the same as the hand hackling, to disentangle, clean, comb, and divide line from tow. Machine hackles are long upright machines.

The ends of a bunch or tress of line are placed in a plate in the upper part of one end of the machine and held by a clutch; a series of pins or teeth becoming gradually finer pass down through the flax as it moves slowly from one end of the machine to the other. The tow is left in the combs, and at the further end an attendant receives the line, turns it upside down that it may be combed through in the opposite direction, fastens it in another clutch, and it passes back by a second machine alongside the first one. The line, meanwhile, has become smooth, fine, and glossy; the tow is removed from the pins by a revolving brush or doffer.

Sorting and Cutting. — These two processes are sometimes used for fine yarns. Flax for coarse yarns goes directly to the spreadboard, but for fine yarn it is hackled by hand and assorted into different qualities before it is passed to the next machine. For very fine yarn the line after sorting is usually cut into three divisions by a blunt instrument, the middle cut being the best. The term "cut line" is used. The fiber is now ready for the spreadboard.

Spreadboard. — As the fiber is long, the bunches or strips are delivered to the spreadboard on an endless apron, each strip overlapping the former one by six or eight inches. It passes into the machine to be combed through by fine wires and made into a continuous ribbon or sliver.

Drawing and Roving. — The drawing is repeated, four times being customary. The slivers are doubled, it is said, as many as ten thousand times. The frames are much like those used for wool and cotton. Several machines are required, varying according to the fineness of the thread desired. (See Chap. II for description of these processes.)

Spinning. — The upright spinning frames (see Chap. II) for wet, dry, and semi-dry spinning are used for flax, and are like those for cotton or worsted, except for the trough of hot water through which the linen yarn at times passes before it is twisted. Wet spinning of flax and tow makes a fine thread which does not look as silky as that which is dry spun. It is twisted tighter, however, and the flax is more subdivided, which has its advantages for special classes of thread. Dry spun yarns have greater firmness than the wet spun, but the highest numbers are made with wet spinning. Warp yarns are usually made with the wet finish, as it adds to their strength. The use of too hot water is injurious to the flax, and the result is a frowsy, cheap looking yarn. Even in dry spinning, water is often dropped on the thread, or humidifiers are used to keep the air moist. It is necessary after wet spinning to have the yarn quickly dried, or mold will appear. Linen sewing threads are wet spun and then specially twisted and dressed much like cotton sewing threads.

Tow Spinning. — The tow, which is the short staple, coarse product, is treated differently from the line. It is beaten and shaken, carded, doubled, and spun much like cotton, and used for coarser counts of thread. The spinning frames for line and tow are much alike.

Winding, Warping, Sizing, and Drawing-in. — The processes for linen preparatory to weaving are much like those for other textiles. Sizing is used on the warp yarns to give strength, and yarns are frequently bleached wholly or partly before weaving. The dressing or sizing of linen yarns is important. Flour and farina paste are much used, and are applied to the yarn in the slasher.

Weaving. — Many linens, such as sheetings, lawns, and cambrics, are woven in the plain, tabby, or cotton weave. The twills and diaper patterns are found in towelings. The Jacquard loom is generally used for damask weaving. The damasks differ from the brocades in that both sides are alike and the cloth can be used on either side. The background is generally a plain or a broken twill. There are single and double damasks. The pattern shows more distinctly on the wrong side of the double, as there are more threads, which makes possible greater shading effects in the design, throwing it into relief. The threads of double damask are usually double in the filling. As the pattern is made by the way the warp and woof threads cross each other, an elaborate damask design requiring floats of six or nine threads is not as strong as a more closely woven pattern.

Method of Counting. — The method of counting linen yarns in England and America is by the number of leas in a pound, each lea representing three hundred yards. No. 1 lea yarn would therefore have three hundred yards in a pound; No. 2 lea would have six hundred yards. The method of numbering in France and Austria is different. The counts for jute, hemp, and ramie are also figured by the lea. Fine linen yarns for costly handmade laces run as high as 400s or even 600s. They are spun by hand. Belgian hand spinners often work in damp cellars. Such yarns are very expensive, being quoted at as much as $120 per pound. The hand can spin finer counts than the machine, three hundred being as high as the latter can spin, and that is unusual.

Finishing. — The finishing of linen materials is important to their appearance, but the processes are not unusual. The bleaching of the yarn or the fabric is perhaps the most important process. Dressings of various kinds are used, but the highest class of linens receives little, as the mangling, calendering, or pressing bring out the gloss. Beetling is often used to assist in giving luster both to dressed and undressed linens. A usual series of finishes in an Irish mill is, first, bleaching by chemicals; second, rub boards to wash the chemicals from the bleached linen; third, crofting or grass bleaching; fourth, bluing, starching, washing, and mangling; fifth, damping; sixth, beetling; seventh, calendering and pressing, which processes are often repeated a couple of times, and the material is finally finished by heavy pressure in the hydraulic press. Inspection, folding, marking, and packing complete the preparation for market.

Bleaching (see Chap. XIII). — The finest Irish table linen is usually woven of half-bleached yarn. It is then crofted from six weeks to two months. The following table gives the relative loss of weight in bleaching the various fibers: —

Flax, 12 to 30 cts. a lb. — loss in cleaning and bleaching, 20 per cent.
Cotton, 7 to 13 cts. a lb. — loss in cleaning and bleaching, 5 per cent.
Wool, 15 to 30 cts. a lb. — loss in scouring, 20 per cent to 60 per cent.
Silk, $7 to $10 a lb. — loss in boiling off, perhaps 30 per cent, made up in loading or weighting.

Experience proves that linen bleached by chemicals is not as strong as that bleached on the grass.

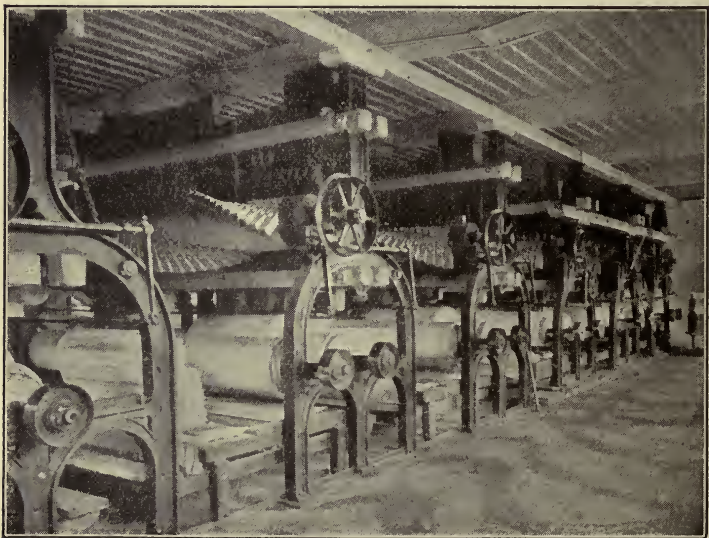


FIG. 119. — BEETLING.
Courtesy of the York Street Flax Spinning Co., Belfast.

Dressings. — Dressings for woven linen may be used to give strength and assist in bringing out the design, or to cover defects, as in poor qualities of linen or unions with cotton. (See Chap. XII.) Special finishes are used in table linen and damasks, for crash, for glossy linens, and for dark-colored goods. For black and dark sewing threads a very glossy dressing is applied to strengthen the yarn, which, without it, would wear rough.

Beetling (Fig. 119). — This process is frequently used to give gloss to the surface, and a supple, leathery feel to linens. It may be applied to dressed or undressed linen materials. Striking the woven cloth with wooden mallets after it was washed and dried was the original process. Hand-woven damasks are still finished at times by hand beetling. The power beetle is a large and heavy machine. The linen is dampened, wound on a roll, and placed in the machine; the roll is turned slowly and the cloth is hit by heavy hammers or stamps, which descend directly upon it, or stamps with square butts are set spirally on a cylinder and impress the entire surface of the cloth, leaving small faces close together which reflect the light. The beetling machine is somewhat similar to the stamping machines used in ore concentration mills. Some yarns are beetled, such as filling yarns for heavy sailcloths.

Statistics of Linen Manufacturing. — The estimate[1] of the number of flax spindles and of looms in operation in 1911 was:

		Spindles	Looms
France		500,000	18,700
Germany		330,000	20,000–25,000
Belgium		325,000	16,273
Ghent	235,600		8,773
Courtrai	24,900		5,000
Other cities	64,900		2,500
Austria		285,996	Probably 6000–7000 machine looms; 20,000–25,000 hand (Austria and Hungary)
Hungary		8,500	
Italy		113,452	
Russia:			
Spinning	367,670		Estimate of 1907: 12,380 power and hand looms
Twisting	333,760		
Great Britain:			
Ireland		935,000	
England		550,000	36,000 (Ireland, England and Scotland)
Scotland		160,000	

[1] Daily Consular and Trade Reports, June 14, 1911.

Great Britain's output of linen piece goods in 1907 was 220,722,000 yards, with a value of thirty million dollars. In addition, a number of mills were working on highly finished fabrics, of which there is no exact report, but at least several million dollars more was made.

The manufactures of flax, speaking generally, cover toweling and table linen, fine handkerchief linen and dress goods, shirtings, sheeting, canvas, ticking and tarpaulin, fine and coarse laces, and heavy yarns for carpets, sewing threads, embroidery threads and flosses, twines and cordage.

The world's annual production of linen fabrics is stated as 1,000,000,000 pounds. The weaving and finishing of fine table and dress linen are done in Great Britain and on the Continent of Europe, rather than in the United States. We have at least four million acres of land under flax cultivation, but for seed rather than for fiber. We import raw flax, linen yarn, and fabrics, for which we spend at least twenty million dollars annually. The flax straw which remains after the seeds are removed was at one time burned, although much protest was made against the waste. Within a few years, however, the weaving of coarse and medium grades of linen has increased in the United States. In 1890 there were but three establishments for weaving linen, but in 1900 there were eighteen, with a capital of $5,688,000 in round numbers. A number of these mills are in Massachusetts.

The development of machine methods for preparing the flax, in place of the usual hand methods of Europe, has made it possible for us to do more of the manufacturing business. Flax grows well in the United States. Michigan, Minnesota, North Dakota, and Oregon cultivate flax for fiber as well as for seed, but lack of persistent care of the soil has permitted the development of germ diseases which attack the flax plants and injure them for industrial service. The flax we have cultivated for fiber has produced mostly a rough, tow-like yarn, and not the kind required for fine linen. The cultivation of flax for the finest thread presents many difficulties for this country, and the returns in money do not attract the farmer, who has other crops which are less trouble and are more easily sold. Labor is much cheaper in Europe, and the women and children are willing to work in the fields weeding the crop. There is a great deal of waste in the crop at any time, and the returns per acre are small. The machinery required for preparing and spinning fine linen thread is very expensive and of a special kind. It is said that a flax-spinning mill costs four times as much as one for cotton. Tow can be spun on cotton machinery, and the medium grades of cloth made from tow have a large market. It takes a larger number of workers in fine linen manufacture than in cotton, the relation being from four to six times as many.

The value of the seed industry is great, and although it is possible to cultivate flax for both seed and fiber, the best results in both industries are not obtained. We are not, therefore, likely to enter fine linen manufacturing with much energy at present, as such linens are really a luxury and the sale comparatively small, whereas the market for cotton cloth is large. Each year there has been an increased acreage for the seed, and also a greater number of mills for the low grade of fiber, which has a good sale.

Irish linen has had and still holds a high reputation; the industry is mentioned in the history of the country as early as the thirteenth century. The linen is noted for its snowy whiteness, its reliable quality, its endurance. The climate is a factor in this, as sunshine and rain alternating give a moist climate good for the growth and manufacture of flax. The great center in Ireland for fine linens and damasks is Belfast and the northern part of the country. The trade goes calmly on with its own methods and does not make much effort toward doing new things to attract business. The old patterns are still used, being still greatly appreciated. Much of the linen in Ireland is grass bleached and in one noted old firm at least is still hand woven. Driving through the country outside of Belfast, the bleaching grounds can be seen covered with linen as in the old days. The linen is good and honest, but not always showy. Besides the toweling and table linen, there is quite a business in fine cambrics, lawns, and batistes. Ireland relies on Belgium for much of its fine fiber.

Scotch linen, especially from a few well-known houses, has a high reputation; much of it is sun and grass bleached. The color is silver white. Some consider it lighter in weight than the Irish. It sells particularly in the medium grades. The heaviest classes of sailcloths, canvas, tarpaulin, sacking, and carpeting are also manufactured in Scotland, Dundee being a center. Dumferline and Perth weave damasks. Much of the Scotch linen is of moderate price. The designs are generally more showy than the Irish.

French damask is noted for its exquisite designs and effective appearance; the thread is fine and round. Especial attention is given to the pattern and the beauty of finish. The most expensive materials are made as well as the plainer ones. France also provides many linen materials for dress goods.

Belgium in the Courtrai district has the finest variety of flax fiber in the world. Many other countries buy it after it has been scutched, to spin into fine counts, or they purchase the yarn and weave it into cloth. Belgium has also a large manufacturing trade. Materials of great beauty are woven in the region about Courtrai. Besides toweling and table linen, Belgium manufactures twilled linens, diapers, and drillings. It is said that more dressing is used on the linen in Belgium than in Ireland. In some respects Belgian linen is like that of Germany.

German linen is silver white. The highest grades of table linen are manufactured, but are not exported as much as the medium and lower grades. Those who have visited German cities, such as Dresden, well know the exquisite designs and the fineness of the table linens. Printed and dyed linens have also been manufactured for lunch cloths and napkins in Germany and are very attractive, but not as enduring as the white. Germany also produces a large amount of good unbleached cloths, which are bought by economical housekeepers and bleached by degrees. A foreign market is desired, and rather showy, inexpensive linen which reproduces the patterns of other nations and has much dressing has been exported. These are less satisfactory for service than the stronger old-fashioned German linens.

Austrian linens are much like those of Germany. Spain also manufactures linen. Russia not only grows large quantities of flax, but has manufacturing interests, crash being made there to a great extent.

England purchases her flax in Ireland, Scotland, or Belgium, and does some good work in dress and table linen and also in tickings, low class sheetings, and brown hollands. Leeds and Barnsley are noted as manufacturing cities. For the highest class of table damasks France, Ireland, and Scotland are perhaps preëminent, at least in the export trade.

Additional Fibers used in Textile Manufacture

There are many fibers of secondary importance to wool, cotton, silk, and linen which are used in Eastern countries for woven material. The United States grows or imports them to some extent for coarse baggings, floor coverings, and binding twine, for combining with other fibers to cheapen cloth, and, occasionally, for underwear, dress goods, millinery braids, and upholstery. Some of these secondary fibers are bast, *i.e.*, taken from the stem of the plant in a similar way to flax; while a large number are structural, in that the filament is in the leaves or fruit and not in the stalk. Ramie (Rhea), and China grass which are much the same, jute, true or common hemp, Ambari and Sunn hemp are well-known bast fibers. Piña, Sisal hemp or Henequen, Manila hemp or abaca, Bowstring hemp, New Zealand flax, and Maguey are structural fibers, and among a number of other varieties reach our market under the commercial name "hemp," as the structure and characteristics are similar to the common hemp.

Fig. 120.—Ramie Plant.
From Dodge's *Useful Fiber Plants.*

Cheap labor in the countries from which many of these fibers come has made it possible to prepare them by hand and sell them at a lower price than would be possible in the United States with its higher cost of labor; therefore we are not producing them to any large extent. The bast fibers in general are harvested, dew or water retted, and broken, scutched, hackled, and spun much like flax. The structural fibers are treated and prepared similarly to Manila hemp.

Ramie, often called China grass (Fig. 120), is a bast fiber with many valuable properties, of low price, and of future promise as a useful and attractive textile. It grows easily in the United States, but the difficulties of decortication and consequent expense have kept it from the development it deserves. Both ramie and China grass belong to the family of stingless nettles (*Urticaceæ*); the ramie, or Rhea, being of the species *Bœhmeria tenacissima*, and China grass, of the *Bœhmeria nivea*. They flourish in India, China, Japan, and in warm parts of Europe and of North and South America.

The plant grows very high and the woody stalks are cut as they mature. The bark, when green, is hand-stripped and scraped without retting. When the bark is dry it is dew or water retted like common hemp or flax. This process is repeated a couple of times if necessary. The fiber is usually hung in the sun after it has been relieved of the woody matter and at first looks much like coarse hemp. Degumming, combing, drawing, and spinning follow. It is more difficult to clean than flax. The degumming, a chemical process, is repeated, as a portion of the gum only is taken out by the first bath, and the remaining gummy matter is much harder to remove. Unless all of it is taken away, however, the material feels like haircloth as it touches the skin. After the final degumming the fiber is soft, white, silky, and glistening, and even more beautiful than flax. In the combing and drawing processes the long silky fiber, or line, is separated from the noils, or short fiber. Both are spun, the latter being used for coarser materials and for wadding.

Ramie is manufactured to an increasing extent in France, England, and the United States. It is frequently combined with silk and is made into materials to compete with linen, which it strongly resembles. Like linen, it is difficult to dye. It is brilliant, strong, and durable, not easily affected by moisture, though some of its luster is lost by a wet finish. It has more tenacity than other fibers, and its elasticity, though not great, equals cotton and is greater than flax. It is not very flexible, but endures wear and tear. For underwear it has much promise, for it is cheap, yet has the qualities of flax. There seems to be no limit to the possibilities of this fiber, for it has a range from the finest lace to the heaviest canvas, waddings, and cordage. It is found in the market of the United States in dress goods, upholstery, underwear, tablecloths, toweling, and lace.

Piña, or pineapple fiber, belongs to the family *Bromeliaceæ*, the species being *Ananas sativa*. It is native in tropical Asia, Africa, Southern Europe, and America, but in many countries the plant is grown for the fruit rather than for the fiber. The large fleshy leaves of the plant contain the fiber, which is usually extracted by hand. Piña is considered to be the most delicate and exquisite of vegetable filaments. The woven cloth is found in great perfection in the Philippine Islands and is often combined with silk in designs of great beauty. The weaving is usually done with the untwisted fibers. The appearance is white, soft, and lustrous and the material is flexible, durable, and unaffected by water. It is used much for coarse grass cloth as well as for fine transparent materials. The latter are for sale to some extent in the United States.

Jute, or Jew's Mallow, is used in cheaper classes of textile manufacturing. It belongs to the family *Tilaceæ*. The species are very numerous, but the best known are *Corchorus capsularis* and *Corchorus olitorius*. It is a bast fiber and is retted and separated by hand methods. It grows in the hottest parts of India; being cultivated especially in Bengal. China also is giving some attention to its growth. The plant grows very high, the fibers reaching thirteen to fourteen feet in length. It is a very cheap and unsatisfactory fiber, as it rapidly deteriorates when subjected to light, air, and moisture. It is perhaps the poorest of the textile fibers. The best grades are light brown or silver gray and fairly lustrous. It dyes easily but soon changes color. It is useful where cheapness is better than durability and is used for bagging, for covering cotton bales, and for cheap binding twines and cordage. Tapestry materials of jute and cotton are attractive in appearance but are not enduring. The fibers are combined with wool in cheap dress goods. Carpets, rugs, upholstery, and burlaps are also made of jute. It is spun in fine and coarse counts. The United States does not grow much of it, as hand methods are too expensive, but much fiber is imported and manufactured here into twines, cordage, and cheap materials.

Bast Hemps. — True or common hemp is a bast fiber of the species *Cannabis sativa* (family *Urticaceæ*). It is frequently named from places where it is grown — such as Kentucky hemp, Italian hemp, Russian hemp, and others. It grows from three to seven feet in height, and is harvested and treated much like flax. Dew retting is used extensively. The color of the fiber, like flax, is pearl gray or yellowish. It bleaches well, is very strong, is more hygroscopic than either flax or cotton, and is not easily rotted in water. The coarser fibers of hemp are used for sailcloth, canvas, carpets, cordage, and ropes, and the finer for fish nets and cordage, but it is not used for fabrics to any extent. Hemp is one of the principal export crops of Russia; it is produced in Poland; France cultivates a fine variety of it; Italian hemp is of the highest grade; Japan used it very early; India is growing it, but for its narcotic effect rather than for its fibers; and the United States at one time cultivated it largely, but has small crops at present, owing to the decline in the shipbuilding industry. When the stalk is fresh much of the outer bark and gum can be stripped off by hand. The yarn is sometimes twisted only slightly, and has a very glossy appearance.

The Ambari hemp of India is of the same family as the cotton plant — *Malvaceæ;* the species being *Hibiscus cannabinus.* It is a bast fiber and is used for very coarse textiles and for cordage.

The Sunn, Brown, or Madras hemp is another bast fiber of India. It belongs to the family *Leguminosæ;* the species is *Crotalaria juncea.* This fiber is also used for ropes and heavy textiles.

Hemps. — Manila hemp, or abaca, is a structural fiber. It is a plantain and belongs to the family *Musaceæ* and the species *Musa textilis.* It is cultivated largely in the Philippine Islands and has its best development on rich flat lands. Manila hemp is a more brittle fiber than the true hemp. The coarser varieties are used for binding twines, cordage, and heavy cloth; the finer for dress materials, veils, and shirtings. The cultivation is simple and the fiber is obtained by native methods. The leaves are cut before the flowering of the plant; they are slit down and the layers of fiber are removed, dried, and then scraped free of pulpy matter, leaving only the fiber. The latter is shaken, washed, dried, and spun. Fiber for weaving sheer materials is beaten to separate the filaments into finer threads. France manufactures Manila hemp into fine muslins.

Sisal hemp (henequen) is an agave and is cultivated in the West Indies and in parts of Mexico and Central America. It is a structural fiber from the leaf, like the Manila hemp. The fibers are not so strong as those of the latter. They are used largely for hammocks and sacking.

Cocoanut, coir, or coco fiber comes from the fruit of the coco palm (*Cocos nucifera*) and is also a structural filament taken from the inside of the husk of the cocoanut. It consists of bundles of stiff fiber which separate into finer threads after treatment. The palm grows extensively in India, the Malay Peninsula, Java, and Japan. The husk of the fruit is removed and the nuts are soaked in holes dug for them or in tanks. The best coir in the market is soaked in heated water in specially prepared tanks, for machinery is now being tried successfully. The fiber in general is beaten, cleaned by hand, and spun into a loose rove. The color is cinnamon brown; the fiber looks like horsehair and is very strong, light, and elastic. It is used for many purposes such as stuffing, upholstery, coarse mattings, sails, and cordage.

Linen Materials

	Width	Price
Butcher's linen	36–44 in.	$0.40–1.50
Cambric	36–44 in.	.50–1.50
Diaper	18, 20, 22, 24, 27 in.	2.00–5.00 piece
Dress linen	30, 36, 72, 90 in.	.25–2.00
Holland for shades	27–36 in.	.35–1.00
Linen lawn	36 in.	.50–2.00
Napkins	17–22, 23–27, 29–31 in.	1.25–25.00
Pillow cases	22½ by 36 in.	1.25–6.00
Sheeting	72–90 in.	.80 up
Sheets, hemstitched	Double	6.00–25.00 pr.
Sheets, hemstitched	Single	4.00–16.00 pr.
Table linen, damask	70–72 in.	.75–5.00
Toweling, huckaback	17–27 in.	.25–1.00
Toweling, crash	17–24 in.	.12½–.28
Toweling, glass	17–24 in.	.12½–.28
Towels, huckaback	14 × 20 to 24 × 45 in.	1.20–30.00 doz.
Velour	54 in.	1.00 up

CHAPTER X

CONSUMER'S JUDGMENT OF TEXTILES

Testing Materials. — Chemical and microscopical tests (see Chaps. XI, XII) are used to determine the content and value of materials, but these are at present hardly feasible for the rank and file of consumers. There are many simple physical tests, however, from which a housekeeper may gain fairly accurate information of standard materials and of those which are not up to this mark. It must be borne in mind that the wonders of cloth finishing at the present time make it difficult even for the expert to judge entirely by the appearance and feel, and that the only reliable tests are the scientific ones. The best cloth is made of good stock with strength in the yarn and woven of an enduring pattern. It should have a standard weight, the finish should be developed from the stock and not placed superficially upon the goods, it should have a good feel and appearance, should be capable of holding its color under definite conditions, and should be of good wearing quality. The physical tests aim to discover if these points are present or lacking, but will not indicate what the content is except in a general way.

The economical housekeeper should train herself to recognize the look and feel of the leading fibers, yarns, and woven goods and also the names and prices of the standard materials. The standards are fabrics which have long been known and regarded as representative and enduring. Variations in quality and price are found, as in serges of many values and kinds, but if a housekeeper learns the look, feel, weight, cost, and worth of one reliable variety she can grade others from that. Serge is found in all wool, in mixtures with cotton, or mixtures with re-manufactured wool, but still bears the same name. If a consumer knows the cloth in its best condition and what to expect of it, she can better judge the value of other varieties of the same fabric and know whether the price is sufficient for a good material and if the width and weight are satisfactory. She should also know the properties of fabrics that she may test a doubtful piece of cloth for such qualities. Each textile has special characteristics. It may be elastic, soft or harsh, firm, wiry or sleazy, cold or warm to the touch; it may look dull or lustrous or smooth; its weight may be heavy or light; it may absorb moisture and evaporate moisture. The consumer should know enough of the methods of manufacture (see Chaps. VI, VII, VIII, IX) to judge of difficulties and adulterations which may occur and affect these characteristics, and should distrust material which seems to be too good for the price asked. In order to know these points she must study the pure state of the four textiles as well as the adulterated. After such preparation she is ready to test doubtful materials.

Wearing Quality.—A good way of testing the endurance of any material is by pressing the two thumbs together on the cloth and then pulling the material straight out, first warp way and then filling way. If it tears or frays in either direction it shows a lack of strength. To discover if material will bear strain in the seams, the threads of the warp and woof should be tested to see if they move easily. If they can be pushed with the finger nails without difficulty and are soft and brittle, the material is not strong, and when strain is applied it will fray. Another way of testing such cloth is to weave a needle in and out of the double of the material as if making a tuck. The single cloth is then drawn away from each side of the needle and if a row of holes shows clearly alongside of the needle the material will not bear a strain. Soft silks which are good otherwise will sometimes draw in the seams and should be so made up into garments that there is as little strain as possible. Wool which is woven with a weak thin warp and heavy filling, as is found in some poplins, shows a decided lack of endurance wherever there is a strain or where there is apt to be the rubbing of one piece of cloth against another.

The Burning Test. — Animal and vegetable fibers burn differently; this can be noted when they are on fire. The rapidity of combustion, the residue afterward, and the odor while burning differ greatly. The animal fibers are wool and silk. Wool burns slowly, goes out quickly, leaves a gummy residue, and has a very disagreeable odor. Pure silk when burning has the characteristics of wool but to a less extent. Artificial silk burns quite differently, as much of it is cellulose. Cotton and linen are vegetable fibers. Cotton burns very quickly, and is difficult to blow out and often continues to smoulder until all is consumed. It sometimes happens that a piece of cloth woven with cotton in one direction and wool in the other will be consumed in the direction of the cotton, leaving the wool intact, or if cotton and wool are carefully mixed together in the yarn, by unraveling one strand and burning the different fibers in it, cotton will be indicated by the way in which one section will be consumed. Linen burns much like cotton but is not so inflammable, as it has less oil in the fiber and less air in the woven cloth, the long smooth fibers packing more closely together than the many short rough ones in the cotton cloth.

Tearing Test. — This test may be used at times to determine whether the material is pure or union goods. Linen quickly torn will leave straight, smooth threads along the edge of the tear, but cotton will curl up. The ear can accustom itself to the sound of the tearing of various materials. The noise accompanying the tearing of cotton is unlike that of linen. The warp has its voice and the filling quite another, the former being shrill while the latter is apt to be dull. Silk tears differently from wool. Some wools are very easily torn and others resist more.

Content, Quality, and Strength of Yarn. — To find the strength in warp and filling threads and to identify the content, it is well to have a small sample of the cloth which should be raveled both ways. The yarn can be examined for strength or weakness, for the manner in which it is twisted, for the length of the fibers, for their purity or inferiority, for the luster and whether one kind of fiber or mixed fibers have been used in it. The burning test is helpful here. The breaking strength of the yarn should be tried and the relation in size and strength between the warp and filling threads. A very fine, weak warp will soon be broken if a heavy filling thread is inserted across it. This condition is sometimes found in poplins, of all wool or silk and wool, even if the fabric is as high as $1.50 a yard. Cotton and linen mixtures in a yarn can often be told by raveling it and noticing whether its content is soft short fibers and also long strong ones; the former being cotton, the latter linen. Tow with its short ends looks much like cotton if it is combined with the long linen fibers or line, but is harsher in feel than cotton.

Weaving Test. — Close, even, firm weaves are usually enduring. Loose and open ones are apt to catch on small obstructions, to pull out of shape, and look shabby. The way the cloth has been woven often constitutes its strength or weakness. As explained in an earlier chapter, the surface of material is often finished by gigging to give it a soft look. This surface is apt to wear smooth or shiny wherever there is friction. Goods woven with long floats of warp or filling yarn on the face or even on the back are apt to wear poorly. Napped cotton goods will crush down and wear off as the fiber is soft and not elastic. Napping in wool goods sometimes covers imperfections. Simple tests and thoughtful observation guided by knowledge of the properties and processes described in preceding chapters will show many of these disadvantageous conditions.

Cloth may be wiry and enduring, or smooth, strong, and shiny but requiring much care, or soft and sometimes easily mussed. The varying qualities are adapted to different purposes. The first is for hard wear, the second for dressy suiting, the third for house or evening service. Raveling a sample will sometimes show the weave if it is not evident to the eye, or a weaver's glass can be used. Felted goods, like broadcloth, cannot be raveled but a very thin broadcloth is apt to lack endurance although beautiful to the eye. The demand among women at present is for very thin broadcloths, but when given rough wear they may slit at the hem as the felting is not sufficiently strong and the shearing has come close to the weave. By holding a sample of cloth to the light, imperfections of weave may become evident, threads that have been repaired can be detected, and any undue openness of the texture can be seen.

Standard Weight. — Each fabric, according to its use, should have weight sufficient for endurance. This quality is tested by the appearance to the eye and the feel of it as raised in the hand. Linen is purchased by the weight, and there are a standard number of threads in the different linens. A good test of linen is to count the threads either way in an inch, and see if they conform to the requirement. A consumer is helped in her judgment if she learns the usual weight of such materials in their best condition.

Finish and Weighting. — Goods may be poor, yet after dressing and finishing may look rich and strong. Closely woven cottons and linens are often filled with sizing or clay and are unsatisfactory after a few launderings. Luster and stiffness are often a matter of treatment. The housekeeper must learn to detect the difference in appearance and feel between pure and treated goods. The tongue can often detect sizing, or the nail can remove it, showing the coarse texture below. Another means of discovering sizing is by rubbing the material between the hands to see if the surface dressing will come out. Sizing can be removed usually by a very thorough boiling, although this is not always easy to accomplish. Mineral weighting in silk can be detected by placing the sample on a small dish and leaving it in a hot oven (about 400° F. or 200° C.) for about an hour; the pure silk will be consumed and the weighting will, until disturbed, remain in the form of the fabric. This experiment is more satisfactory when performed in a laboratory furnace but may be done in an ordinary oven.

Color Changes, Spotting, Weathering, and Crushing. — Cottons and linens are apt to fade, shrink, and tear in the laundry, and if they contain sizing will look coarse as this passes away. Colors are frequently ruined by strong soaps, by careless drying in the sun, or by pressing with too hot an iron. The endurance of wash materials depends greatly on careful treatment in the laundry. A doubtful material should be tested for these points by taking a small sample, noting its color to see if it fades and its size to see if it shrinks and then washing, ironing, and exposing it to hot sunlight. A piece of white cloth rubbed on dyed goods will sometimes show if the dye is permanent or the material crocks even without moisture and heat. If material is to be exposed to sun and air, its endurance can be tested by placing a sample for a couple of weeks on a window ledge or roof and covering one half of the sample with a card. The sun, air, rain, and changing atmosphere will affect the part which is not covered and will indicate the result to be expected from continued use. (See Chap. XIV.)

In general it may be said that bleached materials do not wear as well as unbleached, as in bleaching at the present time chloride of lime, or other strong chemicals, whiten but weaken the fiber. The old time housekeeper used unbleached and undressed muslins for underclothes and sheeting and unbleached tablecloths and toweling. Gradually these materials were whitened through the laundry and by spreading on the grass.

Some materials are finished in such a way that they easily spot with water and must be sponged or washed before making up. These should be tested by dropping water on a sample before purchasing the cloth. Those who have worn pongees know what is apt to happen when caught in a slight shower.

It must be remembered that no one material is dyed fast to all influences; some are made fast to laundering, others to sunlight, others to dust, mud, and general wear. It is impossible to expect them to stand all bad conditions. Perspiration will often change the color of cloth; a sample can be tested by dipping it in a little warm acetic acid and drying between parchment papers, without rinsing, and noting results. Elasticity is inherent in some fibers but is lost through adulteration and substitutes. A simple way of testing fiber which should have elasticity is by wrinkling the material in the hand and then trying to shake it out. If the wrinkles continue, the material will easily become lined and crushed.

Differentiation Tests. — Fabrics made of cotton and linen do not have the full properties of pure linen. Doubtful material can sometimes be tested by dropping water on it and noting the way the water spreads and the material dries. Moisture spreads rapidly on linen and soon dries, but a drop of water will often lie some time on the cotton before being absorbed, and the material will remain wet for some time afterward. Ink can also be used as a test. It must be remembered, however, that when cotton and linen goods are heavily dressed with sizing the water does not spread as easily. Glycerin is considered a more successful test than water. It causes linen to appear transparent but has not this effect on cotton. In general linen yarn is irregular in appearance but cotton yarn is more exact in twist. By breaking the yarn across quickly the cotton threads will usually curl up, while flax threads remain smooth. This test takes practice to do well. Singed ends of linen thread appear even and compact; cotton threads spread out like a paint brush.

Crushing in the hand will also indicate the difference between all cotton and all linen material and the unions. Silk and artificial silk, or mercerized cotton combinations, are difficult to test physically, but the burning test will sometimes show that the material is not pure silk. Artificial silk and mercerized cotton burn in a like manner, as they are cellulose.

In general soft finished silks are much better for wearing than stiff ones, but they must be tested for the possible inability to stand strain in the seams. Crêpe de chine or other silks woven of closely twisted threads wear better than the soft silks but do not have the characteristic gloss of silk, looking much like wool. Taffetas are stiff and crease easily; they are very apt to be heavily weighted and unreliable, especially in black. Cheap, heavily corded black silks are generally weighted. A good wearing silk should be closely and evenly woven and soft to the feel. If the threads are raveled out and broken, they should stand some strain. To some extent price is indicative of values in silk, for it is impossible to get good silks at low price, but this cannot be entirely relied upon, as even silks sold at $6.50 per yard have been found too heavily weighted to wear well.

The Purchase of Linen. — Linen should be pure, for then only has it the properties for which we buy it. Damasks as well as some other linens are bought by weight. Damask is made double as well as single. Double damask is more beautiful, and is usually made by having a double thread in the filling, and it is woven of well-twisted fiber. In double damask the pattern shows more distinctly on the wrong side of the cloth than in the single, and is, therefore, especially desirable for its beauty as table linen. The pattern in damask is in the warp lines, that is, the threads of design run lengthwise. When the cloth is held up, the vertical lines reflect the light and the cross lines look dark, hence the right and wrong sides can be determined by the way the pattern stands out in the light.

In order to judge table linen the following points should be remembered: Good linen in the hand is soft and yielding, yet elastic and tough like leather, and is not stiff and crackly. The medium range in price would be from $1.50 to $3 a yard. Hand woven, grass-bleached damask wears better than damask made by power looms and chemically bleached. In general, the grass-bleached linen comes to the United States about the first of January, having been bleached in the summer, and the housekeeper can find it on the counters at that time. Colored linens are not satisfactory, since flax does not hold dye well, and as a strong mordant has to be used to hold the color, the yarn is apt to be weakened. If one has some knowledge of the best linens, it is well to buy them at a time in the year when the stock is low and the price reduced, before the new stock comes in. Linen should always be bought at a reliable house, and of a salesman who knows the quality. Some retail linen houses have their own patterns, which are used only when weaving for them. Table linen comes by the yard and in the bordered cloth. The cloth having a border around it is more attractive, but for the same weight linen it is generally cheaper to buy the material by the yard. Over-fine thread in damasks is not always a wise investment, but a strong, rounded thread is best. The best linen is sized very little, if at all. The sizing in the yarn or in the cloth is apt to make a break in the yarn when the cloth is folded, which will later become a hole. Highly sized or dressed linen should, therefore, be distrusted. A round thread of even weight in both warp and filling gives strength. It is true some hand-woven linens have the thread somewhat flattened by beetling, but it has been round and strong in the first place, and not being dressed is probably not injured by the beetling. The number of threads per inch in damask should be noted by the weaver's glass, both warp and woof or filling way. The correct amount for the warp in a good damask is for medium quality, 180 threads; for fine quality, 220 threads; and for the filling, of double damask, 280 threads; of single damask, 180 threads.

The weight of the linen is a factor in its value. When the number of threads per inch is satisfactory and there is no dressing, the cloth will wear well; when the cloth is coarsely woven and the weight is made of dressing, it will not wear, for after laundering the material will be coarse and flimsy. The minimum of weight is $4\frac{1}{2}$ oz. per square yard.

High grade linens are made from the line and the poorer grades from the rougher fibers. Good linen has a smooth surface; if when rubbed between the fingers it becomes fuzzy, it probably has much tow in it, or is a cotton mixture.

An all-over pattern in damask is generally more satisfactory than one with plain bands, for ironing is apt to twist the plain design, therefore the effect of the former is better after several washings.

At one time certain patterns were characteristic of different countries, as the snowdrop or shamrock of Ireland and the check of Germany. At the present time these patterns are used interchangeably, and cannot be depended upon as representing any special country. Excellent linens come from many parts of Europe. Those accustomed to any one kind and who rely on good firms are apt to feel that that particular linen is the best. Certain brands of table linen can always be relied upon, and a housekeeper should know these.

Hemstitched sheets are more apt to tear in the laundry than sheets with a hem made by sewing machine or hand; fringe is not enduring, and machine-scalloped edges soon become ragged. In sheeting that is not high priced, yarn made of tow is sometimes used, which will not wear satisfactorily nor even look well, as the tow is short in staple and soon has a rough look. Homespun sheets and towels are liked for their feel and texture. In the past the line was not so carefully separated from the tow as now, and therefore the spun yarn had a more irregular surface and was more artistic than the extremely smooth yarns of the present day.

Standardizing Textiles. — Our federal and municipal governments realize the necessity of providing reliable materials for the army, navy, and police service. Standards are set for judging the integrity of various suitings, linens, blankets, and other materials, which must meet the specifications or the cloth will be returned to the manufacturers. (See Chap. XIV.) Efforts are being made to secure some degree of standardization of textiles offered in general trade so that the nature and quality may be judged from the labels. An intelligent interest on the part of consumers will greatly strengthen this movement. A serious study of textiles in the schools and colleges, in women's clubs, and by individual consumers is necessary in order that the demand for "pure textiles," like that for "pure foods," may be supported by an alert and intelligent public opinion. In both cases "pure" should mean materials honestly standardized and labeled; it should not imply an unwillingness on the part of consumers to accept the honest products of new processes nor an unduly conservative attitude toward new materials.

Analysis of Cloth. — The analysis of cloth is finding its content, the nature of the weave, and the cost of manufacture. In the textile industries it is a very important and elaborate process leading into technical fields, and requiring information on many difficult branches of design, manufacture, and methods of dressing and finishing. To know the make-up of the yarn often necessitates both chemical and microscopical investigations. The final report must be absolutely exact, must give methods and expenses of reproduction, with kinds, sizes, and amounts of yarn, colors, dyeing costs, and methods and details of warping, weaving, and finishing. In plain weaves or simple twills with unfinished materials it is usually not difficult to judge the nature of the weave. Weavers' glasses are easily obtained at a slight cost, and show a small field magnified perhaps ten times. The ends and picks are then easy to count. The investigation becomes more difficult in felted and sheared goods, in double and backed materials, or in those finished in such a way that the condition is changed. Such special trade analyses are not needed by the student of economic consumption, but she should gain standards by some experience with the dissection of cloth. The following points might be a basis for the study of standard materials: —

I. *The name of the material*, with a statement of the fiber or fibers comprising it; the general character, such as worsted or wool, single, double, or backed cloth; and the use of it with its price and width. New names are constantly appearing for common materials, and a little study will enable the student to classify such fabrics under standard kinds.

II. *Analysis of weaves.* The weaver's glass or a magnifying glass will aid in the dissection. A small square of the material can be fringed a little both warp and filling way. If there is no selvage, the greater strength and straightness of the threads in one direction will indicate the warp. The filling can be pushed up slightly and the intersections with the warp and the number until a repeat comes can be noted. Several picks in succession should be tested in this way until the pattern is revealed. The color of the warp or filling can be seen on the threads of the fringe. The weave will fall under plain, twill or broken twill, or pattern. (See discussions of weaving in earlier chapters.) The glass will indicate the number of ends or picks in its field, which then can be multiplied to gain the full number in the width or in a given distance of the length of cloth. It is well to have squared paper at hand, and when the weave is discovered to plot it out on the paper, as is done by textile designers. Double, stitched, and basket cloths having two systems of threads are more difficult to analyze than single weaves.

III. *Yarn analysis*. The points to be considered are: The number of ends in the width of cloth; the number of picks in an inch of cloth; the character of the ends or picks, *i.e.*, the fiber or fibers used, the color or combination of colors in the yarns, the sizing present, and the breaking strain of both warp and filling. Regular machines called dynamometers are used in the trade for determining the breaking strain. In addition, the quality and kind of twist in the ends and picks is noted and the relation of size and strength of the warp to the filling. It is well to draw threads one after another from the little piece and lay them down in perfect order after examining each one, as often they vary greatly.

IV. *Finishing*. Analysis of finishes is also a subject of technical difficulties for the common consumer, and is concerned with the amount of shrinkage in the length and width, changes in weight, special dressings, formulæ for dyeing, and mechanical treatment.

For the beginner who knows little of weaving, it is well to begin to study the weaves of canvas or mattings, or the simple rather coarse cloths, such as worsted serges, until the methods of weaving become clear. In some cloth it is difficult to tell the right or wrong side, but by slipping the hand along both sides one side will be found to be smoother than the other, or "draws," while the wrong side "bites" or resists. The difference in printed warp goods and in printed materials should be considered. The methods of disposing of threads in an elaborate pattern when a color is not in use on the face should be noted. It may be by long floats on the back or by weaving the thread in. Various crêpe weaves, leno and swivel, embossing and moiréing, should be likewise studied. A student should keep a card catalogue with data of her investigations and results.

Such simple analyses will result soon in realization of the ignorance of the general purchaser of even common fabrics, of the differences between textiles, of characteristics of fiber, of the false effect of artificial finish, of the strain of uneven weight of warp and filling, of goods that are effective but not strong, of poorly prepared yarn, which often breaks under the strain of weaving, of spots and flaws in cloth, and of the relation of beauty, as well as strength, to weave. All this tends to a better judgment of cloth which endures.

Additional Considerations. — As has already been pointed out, the suggestions given in this chapter will be much more effective when applied in the light of a knowledge of the properties of the textiles and the typical manufacturing processes as described in the special chapters devoted to wool, cotton, silk, and linen (Chaps. V–IX). The consumer should also be acquainted with the possibilities of the microscopical and chemical methods of testing (Chaps. XI, XII) which are of increasing importance in trade and some of which are simple enough for everyday household use. The selection of textiles and clothing should also be influenced by a knowledge of their properties as regards dyeing and laundry processes (Chaps. XIII, XIV) and the hygienic, economic, and social considerations discussed in Chapters XV–XVII.

CHAPTER XI

MICROSCOPIC STUDY OF TEXTILE FIBERS

THE microscope is a most valuable aid in the study of textile fibers. Each fiber has its peculiar structure and characteristic markings, which are revealed by the microscope alone, and which furnish the best and often the only certain means of identification. Chemical tests fail, for instance, in distinguishing between wool and hair fibers, or between different grades and qualities of wool, cotton, or linen. Familiarity with the microscope, therefore, and with the appearance of the more important textile fibers, must be the basis of their analytical study.

A compound microscope of 250 to 500 magnification is necessary. The following directions for its use are given to aid beginners: —

Parts of the Microscope. — The essential parts of the compound microscope are those belonging to the microscope stand, and the optical parts. The microscope stand includes: —

1. The base.
2. An upright or pillar.
3. A stage for holding the mount.
4. A mirror, having a straight and a concave side. The concave side is used in poor light. The mirror is manipulated till a shaft of light is sent through the hole in the stage and so through the center of objective, tube, and ocular.
5. The arm, which supports the tube.
6. The tube, which in turn holds the draw tube. In focusing an object, the tube is moved up and down by the rack and pinion, or coarse adjustment. A finer adjustment is secured by a slight turning of the small wheel at the top of the pillar.

The optical parts include: —

1. The eyepiece or ocular, which fits into the draw tube, and may be taken out and used as a single microscope.
2. The objective. There are usually two objectives, which swing around on the nosepiece. A click tells when one is swung in position. The low power objective is generally short and stout; the high power long and slender.

To Use Low Power

1. Swing the low power objective into the optical axis, about one inch from stage.
2. Place mount on stage, so that a fiber lies over the center of the hole.
3. Looking at the objective from the side, turn the screw on the tube until the distance between objective and cover glass is about $\frac{1}{8}$ inch.
4. Look through the tube, and manipulate the mirror to get a clear white light.
5. Lift objective until object focuses.

To Use High Power

1. Using low power, see that the part of the field to be observed is in the optical axis.
2. Raise objective one inch from stage, and swing high power objective into place.
3. Looking from the side, lower the high power objective until about $\frac{1}{100}$ inch separates it from the slide. Do not let it touch the slide.
4. Lift objective until object focuses.
5. After using the high power objective, always turn the nosepiece before removing the slide from the stage.

Preparation of the Mount or Slide

1. With a pipette, put a drop of water on the middle of the microscope slide.
2. Lay not more than two or three individual fibers in the water.
3. Lay a clean cover glass on the fibers and water, bringing it down gradually from one side in order to exclude air bubbles.
4. See that the mount is clean and dry above and beneath. The space between cover glass and slide should be filled with water, with no floating, however.

Permanent mounts can be made with Canada balsam. Clean the cover glass and slide with alcohol, place the dry material on the slide, and add a drop of Canada balsam, just sufficient to fill the space between slide and cover glass. Carefully press down the cover.

Cross sectioning may be done by embedding in paraffin [1] or in glycerin gum,[2] and cutting with a microtome or razor.

Wool and Hair Fibers. — Wool and hair fibers are alike in origin and growth, and so similar in appearance that no sharp distinctions can be made between them. For purposes of classi-

[1] Chamberlain's *Methods of Plant Histology.*

[2] Glycerin gum: 10 gms. gum arabic, 10 cc. water, and 40–50 drops of glycerin. (Hanausek and Winton, *Microscopy of Technical Products.*)

fication, the fleece of sheep is called wool, but it varies from the long, hairlike covering of the Lincoln, Leicester, and Cotswold varieties to the soft, crimpy merino. The so-called hair fibers come principally from the alpaca, cashmere, angora, and Thibet varieties of goats. (See Chap. V.) However, both forms are usually produced on the same animal. The long hairs of the cashmere goat cover a soft, wooly coat, and mixed with the fleeces of most sheep are long, stiff fibers called beard hairs.

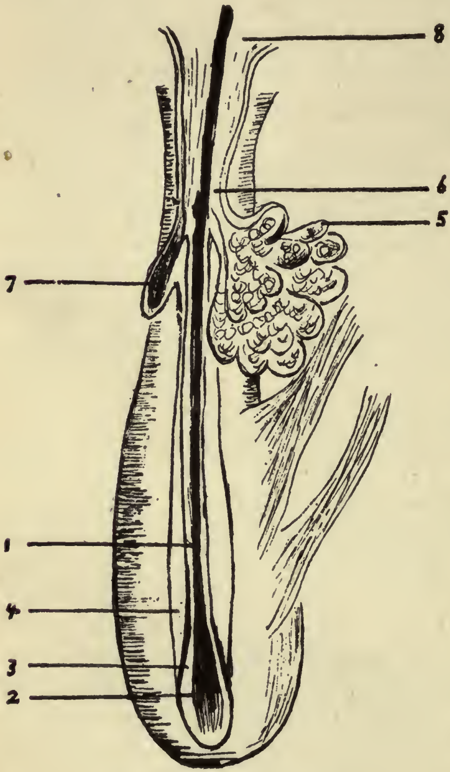


FIG. 121.—HAIR FOLLICLE.

1. Hair root. 2. Bulb of the hair. 3. Internal sheath of root. 4. External sheath of root. 5. Multilobular sebaceous gland. 6. Excretory duct of sebaceous gland. 7. Simple sebaceous gland. 8. Mouth of hair follicle.

Physiology and Structure. — The root of the wool or hair fiber is in the follicle (Fig. 121) situated in the dermis. Both wool and hair show a common structure :—

1. *The epidermal covering*, consisting of flattened, overlapping cells like the scales of a fish. These give the appearance of serrations or saw teeth to the fiber edges. Occasionally in fine wools, single scales encircle the fiber like a series of funnels; more often two or more make up

the circumference. Coarse wools may show a covering of irregular, depressed scales like heavy plates. The scales of true hair fibers are often difficult to see except under high magnification, as they are fastened firmly throughout their length to the cortical region, and are only slightly serrated at the fiber edge, while wool

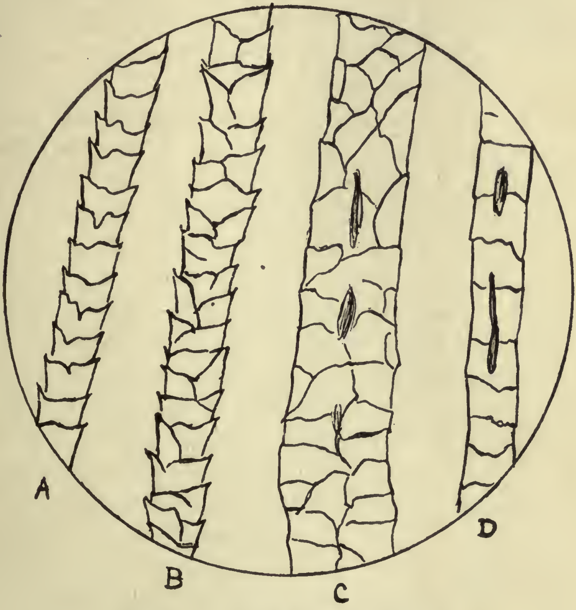


FIG. 122.—WOOL AND HAIR FIBERS.
A, fine. *B*, medium. *C*, coarse. *D*, hair fiber.

fibers, which have the scales set more loosely, show marked serrations (Fig. 122). Due to these differences, wool fibers felt more readily than do hair fibers (see Chap. XIV), because the loosely set scales of the wool give softness and pliability which tend to make the fibers mat together, and in so doing their serrated edges interlock. The firm, horny covering of hair, on the other hand, gives spring and wiriness to the individual fibers, and the lack of distinct serrations prevents any interlocking. The luster of wool or hair is dependent upon the kind and arrangement of the epidermal scales. When these are smooth and horny, and set firmly as in hair fibers, a lustrous effect is given, which is lacking when the scales are coarse and irregular, or damaged.

2. *The cortical region*, made up of narrow, elongated cells, giving strength and elasticity to the fiber. By focusing deeply, small striations can be seen, which are the lumens of the tiny cells. The waviness of wool is supposed to be due to differences in size and development of the cortical cells.

3. *The medulla or central canal*, composed of cells, generally rounded in form. The medullary canal may be broad and plainly visible; it may appear as a continuous or broken line, or it may not be seen at all in some fine, transparent wools. Granular fragments and often pigment matter may appear in the contents. Hair fibers commonly show the medulla, wool fibers often do not. By its capillary action, the medullary canal has much to do with the absorptive capacity of wool, and is an important factor in the dyeing of the fiber.

Two important secretions adhere to the wool or hair fiber. The sebaceous glands pour their contents into the hair follicle, the sebum being known as wool grease. The chief constituents of this substance are cholesterin, a waxlike alcohol, and its compounds with two or more fatty acids. Wool grease is insoluble in water, therefore a coating of it makes the fleece waterproof, besides keeping it soft, pliant, and resistant to matting and felting. The second secretion is from the sweat glands (Fig. 123) and consists largely of water-soluble compounds of potassium with oleic and stearic acid, forming soaps, and of potassium

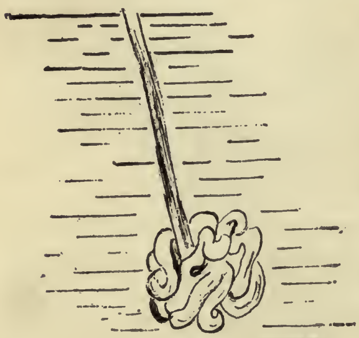


FIG. 123.—DIAGRAM OF SWEAT GLAND.

chloride, sulphate, etc. As generally accepted commercially, all the extraneous matter on the wool fiber is known as yolk or suint, although according to its French meaning the latter term is limited to the sweat secretion. The removal of the yolk is important, first, to enable the wool to take dyestuffs, and second, because the lanolin extracted from the wool grease, and the potash salts from the sweat, are of great commercial value. (See Chap. V.)

Tabular Comparison :—

	Diameter Inches	Length Inches	Serrations per Inch
Wool :—			
Fine, Merino	0.0005	2 to 5	2800
Medium, Southdown, etc. . .	0.0008	3 to 8	2000
Coarse, Lincoln, etc.	0.0010	5 to 8	600 to 1400
Hair :—			
Angora	0.0010	5 to 10	——

Regenerated Wool. — This is wool recovered from old garments or other sources and used again as textile material. Three principal kinds are recognized :—

1. *Shoddy.* The best grade of recovered wool. It comes from materials which have not been felted, hence the scales are in better condition than those that have undergone the felting operation.

2. *Mungo.* Obtained from fulled or felted goods. In tearing the firm material apart, the fibers are broken into short lengths and the scales damaged or removed entirely.

3. *Extract.* Recovered from wool and cotton mixtures by treatment with sulphuric acid or other carbonizing agent. The cotton fibers are destroyed, while the wool is left, with scales often missing or corroded.

These fibers, collectively called shoddy, cannot always be determined under the microscope even with care and practice (Fig. 124). Uneven sizes and damaged scales may or may not indicate shoddy, but the presence of cotton fibers now and then is an indication of wool obtained from mixed

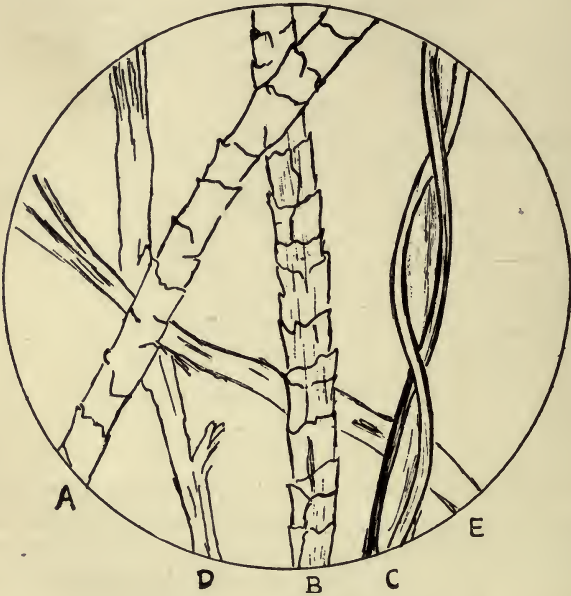


FIG. 124.—SHODDY FIBERS.

A, *B*, fibers differing in color and kind. *C*, cotton fiber. *D*, *E*, fibers with frayed ends, torn places, and damaged scales.

weaves by the carbonizing process, and other probable identifying marks are the presence of many frayed ends, together with a lack of uniformity in the size and appearance of the fibers, and of fibers of various dyes, due to their various sources.

Kemps are fibers which through disease or other causes have the medullary canal undeveloped or closed. Consequently they do not absorb dyestuffs, and give a streaky appearance to the yarn or cloth. In addition to the absence of dye, diseased wool often shows swellings or other irregularities under the microscope.

Pulled wool is removed from the pelts of slaughtered animals. Lime is used to aid in the removal, and as it is apt to penetrate the medulla and close it with insoluble particles, such wool also takes dyes unsatisfactorily.

Fibers with close, thick scales resist dyes more than those with small, open scales, hence different tones of color may appear in a fabric containing different kinds of wool.

FIG. 125. — RAW SILK.

Silk. — Silk differs from all other natural fibers in that it shows no cellular structure. The fluids secreted by the two spinnerets of the silkworm unite on issuing to form the double continuous thread of the raw silk. Under the microscope these two threads of protein material, called fibroin, are seen to be held together by an external gum or silk glue, the sericin, which appears in raw silk as irregular masses on the surface of the fiber (Fig. 125). After being freed from the sericin by boiling off, the individual fibrils look smooth, cylindrical, structureless, lustrous, and transparent. Occasional constrictions or humps may appear. Cross sections of silk from the middle layers of the cocoon are rounded; those from the outer and inmost layers may be flattened or triangular.

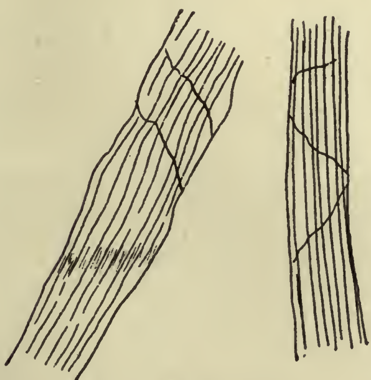


FIG. 126. — WILD SILK.

Wild Silk. Under the microscope the wild silk fiber is broader and coarser than the cultivated silk, and shows numerous longitudinal striations (Fig. 126). The cross section is flattened or sometimes wedge-shaped. The diagonal lines often seen in Tussah or other wild silks taken from woven material have been attributed to pressure of other fibers on the filaments.

Artificial Silk. — This shows regular cylindrical rods having the appearance of glass (Fig. 127). Most varieties, the gelatin

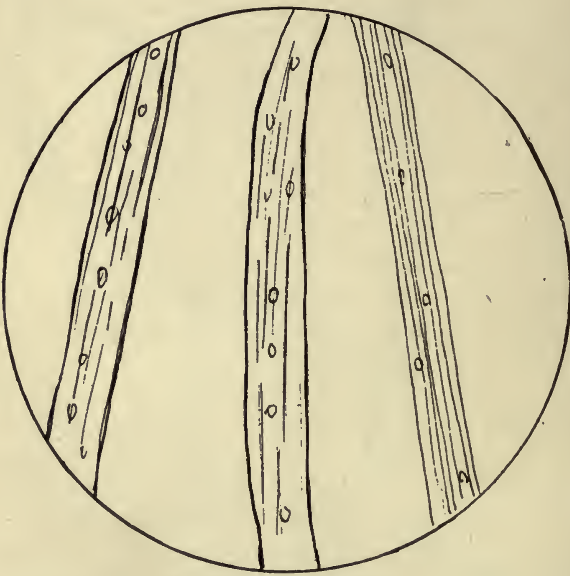


FIG. 127.—ARTIFICIAL SILK.

silks excepted, have their surfaces marked by grooves or flutings running lengthwise of the fiber, and minute air bubbles are sometimes seen, especially with the Chardonnet silk.

Cotton. — Cotton is a unicellular seed hair, which grows as a modification of the epidermis of the cotton seed. Its length varies from less than one inch to about two inches, and it has an average diameter of about 0.0007 of an inch. Being a part of the epidermis, the seed hair or cell is covered with a thin, structureless cuticle. The walls are strong and thick, and an interior canal or lumen is present which is filled with protoplasm until the cotton is nearly ripe, when it gradually dries and the cell collapses. The typical appearance of a ripe cotton fiber under the microscope is that of a smooth, flat band with thick-

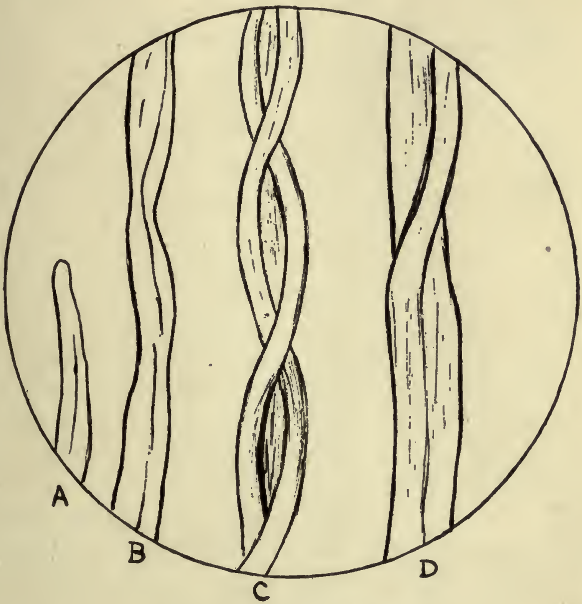


FIG. 128.—COTTON FIBERS.
A, end of fiber. *B*, dead or unripe fiber. *C*, ripe cotton. *D*, mercerized cotton.

ened edges — the cell walls — which make up about one third of the diameter of the fiber (Fig. 128). The lumen is generally visible, its breadth being usually greater than that of the walls. The most characteristic mark is the twisting which occurs at intervals. The stronger and more uniform the twist, the greater the elasticity of the fiber, and the better it is adapted to spinning. Dead or unripe cotton fibers show little or no twist, and a less strongly developed cell wall. In general, the cotton fiber is larger in the middle than at the base, and tapers gradually to the point, which is rounded or blunt, with thick walls. The lower end of the fiber, which has been torn from the seed coat, is open. While the twist is a distinguishing mark of cotton, the presence of a cuticle can also be made to differentiate it from bast fibers, unless it has been removed by treatment, as is the case in mercerized cotton, and often in well-bleached yarn or weave. When cotton is placed in cuprammonia the cuticle is not affected, but the walls of the fiber become greatly swollen and break out in places through the cuticle, which is left hanging in constricting rings or shreds on the fiber (Fig. 129). The lumen becomes like a coiled thread as the fiber shortens and swells.

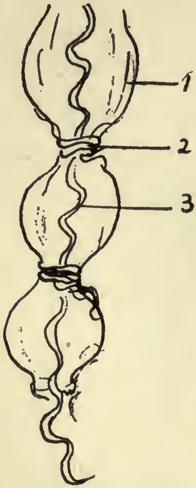


FIG. 129.—COTTON FIBER IN CUPRAMMONIA.

1. Swollen cell wall. 2. Constricting rings of cuticle. 3. Lumen.

Cross sections of ripe cotton fibers show elliptical, reniform or crescent shapes, with a central line representing the lumen (Fig. 130). The fibers of unripe cotton have not fully collapsed, therefore their cross section shows a more rounded appearance and a more regular outline than the ripe cotton.

Mercerized Cotton. — In the mercerizing process (Chap. XII) the strong alkali used removes the cuticle of the cotton fiber and swells the cell walls, while the tension employed takes out the natural twist more or less completely. Under the microscope the modified fiber is seen to be straight, smooth, lustrous, and cylindrical (Fig. 128). Characteristic markings are occasional slight twistings, if the merceriza-

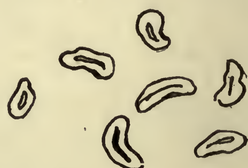


FIG. 130.—CROSS SECTIONS OF COTTON FIBERS.

tion has not been perfect, and especially a lumen which appears and disappears in irregular widths, noticeable if the fiber is examined along its entire length. As the cuticle has been removed, there is an even swelling of the fiber in cuprammonia with no constrictions. The lumen now plainly appears, and granular

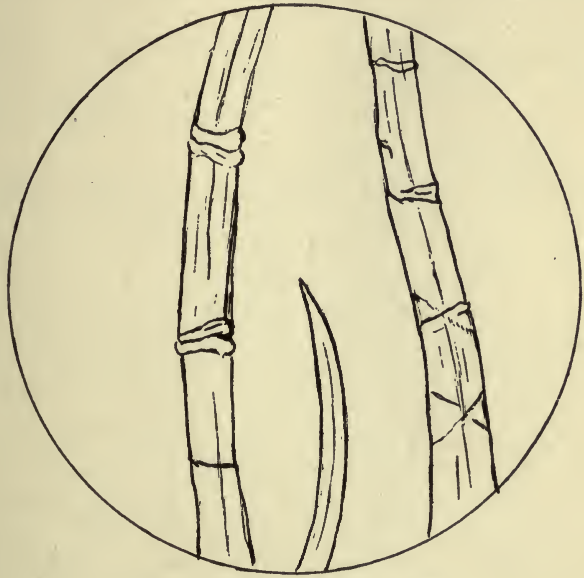


FIG. 131.—FLAX FIBERS AND END.

fragments may be seen in it. In cross section the mercerized fiber is rounded.

Linen. — Flax fibers, the source of linen, are the bast fibers which lie under the outer layer of bark in the flax stalk. The individual fiber may vary from twelve to thirty-six inches in length, the whole made up of cells ranging from a fraction of an inch to two inches in length, and having an average diameter of .001 of an inch. Under the microscope flax fibers show certain variations according to their quality or source, but the long fibers for linen yarn have the following characteristics in common: The shape is cylindrical, tapering to a sharp point. The cell wall is so thick that the lumen appears as a narrow, often thread-like, line. A distinguishing feature is fine cross lines at intervals, giving the appearance of joints or nodes, strikingly like those on the sugar cane or bamboo. Sometimes these intersect like the letter X (Fig. 131).

In cuprammonia the walls dissolve with irregular swellings, but with no appearance of constricting cuticular rings, as with cotton. The lumen resembles a coiled thread.

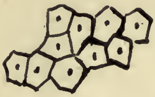


FIG. 132.—CROSS SECTIONS OF FLAX FIBERS.

Cross sections of flax are characteristic. They are polygonal, made up of groups of five- or six-sided cells, with a small lumen (Fig. 132).

Fibers from the base of the stem and the root of the plant are flattened, broad, and stratified, with wide lumens. In cross section the lumen shows its considerable size. These fibers are one source of tow yarn.

Other Vegetable Fibers. — *Ramie* is a bast fiber, obtained from the nettle *Boehmeria tenacissima*. A very similar fiber, and one generally called ramie, comes from the *Boehmeria nivea*, or China grass. The fiber has a silky luster, is smooth, stiff, and inelastic. The bast cells are unusually large, being much longer than linen fibers and on an average three times as wide. Like linen, the cell walls are well thickened. The lumen varies, but is generally plainly visible, and sometimes equals one third or one half the diameter of the fiber. Characteristic appearances are a folding over of the cell wall at times, heavy transverse markings or nodes, and frequent striations along the fiber. The ends of the fiber are thick walled and rounded (Fig. 133).

Jute is the bast fiber from different species of the *Corchorus*, grown principally in India. The fiber is fine, long, lustrous, and soft, but deficient in strength. This is due in part to irregularities in the thickness of the cell walls, which show in the microscopic examination, as frequently the inner and outer cell walls do not lie in parallel lines. The fibers have a smooth appearance, without the transverse markings of linen and ramie.

Hemp is derived from many plants. For a discussion of different varieties see Chapter IX, and Matthews' *Textile*

FIG. 133. — RAMIE.

Fibers. In general hemp resembles flax, with the difference that the ends of the fiber are frequently forked.

Pineapple fiber, incorrectly known as silk grass, is obtained from the leaves of the pineapple plant. The elements of its bast fiber are extremely fine and lustrous; the lumen is thread-like. Woven with silk, the product is called Jusi cloth; alone, it forms the Piña cloth of the Philippines.

Coir. — The shell of the cocoanut furnishes a fiber known as coir. It is about ten inches long, but the fiber elements may be less than one millimeter in length. Under the microscope, the fiber shows irregularities in the cell wall, and a correspondingly irregular lumen, so that the latter may seem to have serrated edges. Pore openings are frequent.

Microscopic Analysis of Fabrics. — The purpose of the microscopic examination of a material is usually fourfold: to determine the method of construction, the nature of the fibers used, the relative amounts, if of different kinds, and their quality. A measured square of the fabric is cut out, large enough to contain all of the different threads which may appear in the weave. It is then separated into warp and filling threads, which are carefully placed in different piles. The threads in each pile are individually examined. If different fibers have been used, the microscope will show whether they appear separately in warp and filling, or are combined either by twisting together or by making one a core around which the other is veneered. Other methods of combination may also be found. If possible, the different varieties of fibers are separated and weighed, which will give a quantitative estimate of the makeup of the fabric. When the various points in question have been settled and the weave has been analyzed, the microscopic examination is complete. There may yet remain questions which can be settled only by chemical tests, such as more accurate quantitative analysis, and an estimation of sizings or weightings.

CHAPTER XII

CHEMICAL STUDY OF TEXTILE FIBERS

WITH a few exceptions, the tests given in this chapter are designed for classes beginning the study of textile chemistry. Only simple apparatus is required, and many of the experiments can be performed in the home. Until the law shall require the proper labeling of goods, the buyer's protection lies in more knowledge of the character of materials used, and the processes to which they are subjected, and to this end these practical chemical tests will be found of value.

Classification of Textile Fibers. — Arranged according to their origin, the principal textile fibers are grouped as follows: —

ANIMAL	VEGETABLE	MINERAL	ARTIFICIAL
Wool and hair fibers Silk	Cotton Flax Hemp Jute Ramie Coir Piña	Asbestos	Lustra-celluloses Gelatin silk Metallic threads Spun glass

According to chemical composition, **animal fibers** are protein in nature, and therefore contain the elements carbon, nitrogen, hydrogen, and oxygen in common. In addition, they may or may not contain sulphur, and on this basis they are subdivided as follows: —

Sulphur-bearing (keratinic) fibers: Wool and hair.
Containing no sulphur: Cultivated and wild silks.

Vegetable fibers contain the elements found in cellulose: carbon, hydrogen, and oxygen. An altered form of cellulose, lignocellulose or bastose, which is a compound of pure cellulose with lignin or woody tissue, is sometimes present. The principal vegetable fibers fall therefore into the following groups: —

True celluloses: Cotton, flax, ramie.

Lignocelluloses: Jute, hemp, New Zealand flax, coir, raffia, vegetable silk.

Mineral fibers are best represented by asbestos, a silicate of magnesium and calcium, which separates easily into straight metallic threads, capable of being spun into fabrics which have a well-known value as fireproof material.

Artificial fibers are of mineral, animal, or vegetable origin. The application of the mineral fibers is limited mostly to trimming effects in non-washable materials, such as gold and silver threads in embroideries, brocades, tapestries, etc. Artificial silks, which are principally of vegetable origin, will be considered later.

Ultimate Composition. — The ultimate composition of the principal fibers can be easily determined by the following experiments, and the method further serves as a ready means of identifying certain fibers.

Experiment 1. Burn a sample of woolen material in a dry test tube. Notice the odor like burning hair or feathers, and the condensation of hydrogen and oxygen as water on the sides of the tube. Test by odor and red litmus paper for nitrogen and hydrogen combined as ammonia. The paper turns blue if ammonia is present. Hold in the mouth of the tube a roll of filter paper moistened in lead acetate. In the presence of sulphur the paper is colored black. The carbon content appears in the charred residue.

2. Repeat with silk No sulphur is found, unless sulphates have been used in the weighting. Other reactions are the same as with wool.

3. Repeat with cotton. Notice odor like burning wood. Hold a strip of moistened blue litmus paper in the fumes. It turns red, due to a combination of carbon, hydrogen, and oxygen in the form of a volatile acid, impure acetic. Try to find ammonia and sulphur as before.

Ordinarily, animal and vegetable fabrics may be distinguished by the characteristic odor on burning, and the manner in which each burns. Vegetable fibers flash quickly into flame; animal fibers burn slowly. Frequent peculiarities of weave and treatment often make this test of uncertain value, however.

Action of Acids and Alkalies. — The chemical nature of animal fibers is both acid and basic, like that of proteins; the reactions of vegetable fibers cannot be so definitely stated, although cotton has been observed to show the characteristics of both an acid and a weak base (Vignon). Wool absorbs both acids and alkalies, due to its double nature, but neutralizes only the former. Hydrochloric acid is absorbed by wool to a less extent than is sulphuric; the absorption of dilute sulphuric produces an increased affinity for acid dyes. In general, animal fibers are attacked more strongly by alkalies, vegetable fibers by acids. However, cold dilute acids, either mineral or organic, have little action on cotton or linen unless allowed to dry and concentrate on the fiber. Acetic acid, being volatile, has no action. Silk is less rapidly destroyed by alkalies than wool, but is attacked by acids more strongly, and is dissolved in a few moments by strong sulphuric or hydrochloric acid. Acids of suitable strength, with the time of action under control, have the effect of contracting cultivated silk strongly, with not so much effect on tussah silk. This fact is applied to the manufacture of crêpe from a mixture of these two silks.

The important differences in the action of acids and alkalies on various fibers can best be learned by experiment.

Experiment 1. Immerse samples of cotton and of woolen material in concentrated sulphuric acid and in a 10 per cent solution of caustic soda. After fifteen minutes remove any residue, wash, and examine condition of material.

2. In separate dishes, immerse samples of silk and wool in hydrochloric acid and in sulphuric acid for two minutes. Remove and wash, and observe the comparative action of these acids on the two materials.

The following tables sum up the usual reactions of acids and alkalies upon textile fibers: —

REACTIONS WITH ALKALIES

	WOOL	SILK	LINEN	COTTON
Strong caustic alkalies	Destroyed	Destroyed less rapidly	Fiber swells, becomes brownish yellow	Fiber swells, pale yellow
Boiling 5 per cent NaOH or KOH	Destroyed in 5 min.	Destroyed less rapidly	Little effect if air is excluded	Same as linen
Na_2CO_3 or K_2CO_3	Becomes tender in boiling solution or on long action	Same as wool; yellowed by strong solution	Dilute solutions have no effect	Same as linen
Cold 10 per cent NH_4OH or $(NH_4)_2CO_3$	Little effect	Same	No effect	Same
Neutral soap or borax	Little effect	No effect except on long boiling	No effect	Same

REACTIONS WITH ACIDS

	WOOL	SILK	LINEN	COTTON
Conc. H_2SO_4	Succumbs slowly on heating or drying on fiber	Destroyed with yellow color in 2 min.	Soon dissolves	Dissolves more quickly than linen
Strong HNO_3	Becomes yellow (xanthoproteic reaction). Dissolves slowly	Same color effect as wool; dissolves quickly	Not colored; dissolves slowly in hot solution; nitrates in cold	Same as linen

REACTIONS WITH ACIDS—*Continued*

	Wool	Silk	Linen	Cotton
Strong HCl	Hardly affected	25 per cent solution contracts fiber; 30 per cent dissolves in 10 min.; 40 per cent dissolves in 20 min.	Dissolved very slowly by conc.	Action quicker than with linen
Picric	Yellow	Yellow	——	——
Organic acids, oxalic, etc.	Absorbs readily; no injurious effect	Absorbs readily; increased luster	Not injurious unless dried on fiber. No action with acetic	Same as linen
Tannic	Does not absorb readily	Greatest affinity for of all fibers	Absorbed to some extent	Same

Suggested work: The student may perform experiments based on these tables, making the experiments identification tests for the different fibers. A few household tests should be worked out, using the acids and alkalies of the home; for instance, solutions of the lye used in soap making, strong solutions of washing powder, etc.

Qualitative and Quantitative Analysis of Fabrics. — In general materials should be freed from dressing before conclusive tests can be made, but this is not necessary for the qualitative tests which follow.

In all color determinations, fringe out a square of the material to the depth of about one inch, exposing both warp and weft threads. Differing fibers will thus show the expected color differentiations more plainly.

The microscope should always supplement the chemical test, as it alone shows the quality of the fiber. Weaves should be examined as to variety and wearing quality. All these factors, including price and width, should enter into the analysis and estimate of a given material.

Differentiation Tests

Wool-Cotton. — The following color tests easily distinguish between wool and cotton in white or light-colored mixtures. The point should be borne in mind, however, that a thread may have a cotton core with a veneering of wool. The test will disclose this if the yarn is first untwisted.

Millon's Reagent.[1] Fringe a sample, exposing both warp and weft. Moisten with Millon's reagent, and apply gentle heat. Animal fibers, being protein, turn red; vegetable fibers are uncolored.

Nitric Acid. Immerse the fringed sample in 50 per cent nitric acid. Animal fibers are colored yellow; vegetable fibers, except hemp, are uncolored. Wash in one change of water and touch with ammonia. The yellow color becomes deep orange.

Fuchsin. Make a 1 per cent solution of fuchsin, neutralize carefully with caustic soda to the point of precipitation. Filter. Bring a fringed sample of cotton wool material to the boiling point in the filtrate. Wash, lay in acetified water. Animal fibers colored pink; vegetable fibers remain uncolored.

Acid Dyes in General, e.g., *Phloxin.* Bring sample slowly to boiling point in a solution of phloxin, to which may be added a few drops of 10 per cent sulphuric acid and a little Glauber's salt. Remove, wash. Wool fibers are colored red; cotton or linen hardly colored.

Mikado Yellow. Dye the fringed sample in a bath of Mikado yellow to which Glauber's salt and a small amount of soda ash have been added. Keep for half an hour at a temperature of about 50° C. Wool is scarcely affected; cotton is dyed yellow.

For the analysis of dyed fabrics, the following method of separation of animal and vegetable fibers will give a fairly correct estimation of the percentage composition of the material, and will be found the best test to apply to such mixtures: —

Caustic Potash Method. Weigh the air-dry sample, boil for fifteen minutes in a 5 per cent solution of caustic potash, keeping the solution at constant

[1] Millon's Reagent: Dissolve 100 gms. of mercury in 71.5 cc. of nitric acid of sp. gr. 1.4 in the cold. When action ceases, add twice the volume of cold water.

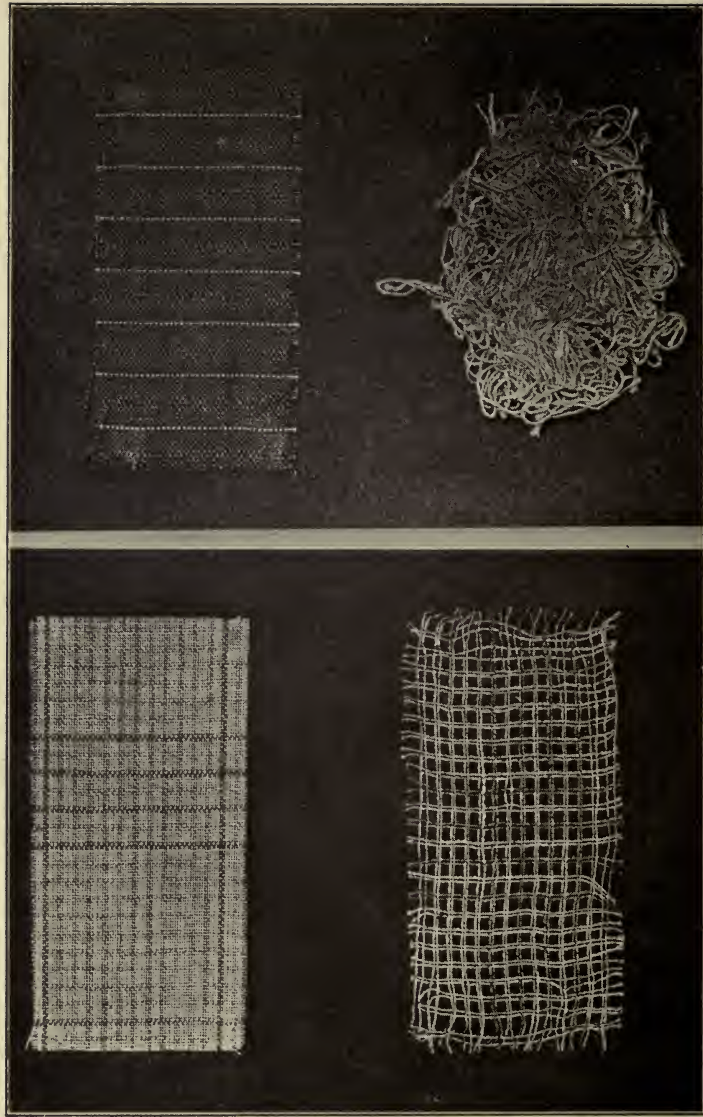
strength by replacing the water lost by evaporation, or by using a reflux condenser. (A long piece of glass tubing rising vertically through the cork of the flask will answer.) Wool is destroyed; cotton remains (Figs. 134, 135). Remove the cotton residue, wash thoroughly, restore to air-dry condition, and weigh. It is estimated that the cotton loses from 3 to 5 per cent of its weight through the action of the alkali. Five per cent of the weight of the cotton residue is therefore added to it to correct this loss. Subtract this weight from the wool, and express composition in per cent. Example: —

Weight of air-dry sample	2.500 gms.
Weight of cotton residue	1.700 gms.
Difference (approximately wool)	.800 gms.
Correction (5 per cent of 1.7 gms.)	.085 gms.
Weight of cotton (1.7 + .085)	1.785 gms.
Weight of wool (.800–.085)	.715 gms.
Cotton	71 per cent
Wool	29 per cent

To be more accurate, the above analysis must first take into account the weight of the finishing materials in the fabric. A method of removing these, recommended by Matthews, is as follows: —

Weigh the air-dry material, boil in a 1 per cent solution of hydrochloric acid, then in a very dilute solution of sodium carbonate (about one twentieth per cent), and lastly in water. Air dry and weigh. The loss is finishing material and coloring matter. Dry in an air bath at 100° C. to constant weight, to remove the natural moisture of the fabric. Record weight of moisture-free material, and treat with the solution of caustic potash as above. Make the correction for loss of cotton. Finally, since the amount of wool and cotton in a mixed weave is not based on dry weights, estimate the natural amount of moisture in cotton at 8 per cent, and in wool at 16 per cent. On this basis the cotton found represents 92 per cent of the true amount, and the wool 84 per cent.

In large classes beginning textile chemistry, it may be convenient to omit the quantitative work, and make the above test approximate. In the household, lye can be used in place of the caustic potash. Wool and silk will be destroyed by heating in a solution of Babbitt's lye, in the proportion of one tablespoonful to a cup of water.



FIGS. 134, 135.—MIXED WOOL AND COTTON FABRICS TREATED WITH CAUSTIC POTASH. THE ORIGINAL MATERIAL AND THE COTTON RESIDUE ARE SHOWN.

Wool-Silk. — 1. True silk is destroyed by boiling in a 5 per cent solution of caustic potash as above. To distinguish between silk and wool with this test, apply the following: —

	Wool	Silk
To the alkali solution of the fiber add: —		
Sodium nitroprusside (2 per cent solution)	Violet	No color change
Lead acetate (5 per cent solution) . . .	Black	No color change
Copper sulphate (5 per cent solution) . .	Brown	Violet

Although sulphates may be present in the weighting of the silk, these will give no color response; the test depends upon sulphides yielded by the sulphur of the wool.

2. Immerse in 40 per cent HCl. Silk is destroyed in two minutes. If the test is made quantitative, finishing materials and moisture are removed by the method given above, and a correction of 0.5 per cent is made for loss of wool.

3. To a 5 per cent solution of caustic soda add sufficient lead acetate to form a heavy white precipitate. Mix well. Heat a white or light-colored sample in the mixture until a brown or black color is developed on the wool fiber. Silk is uncolored. Remove and wash.

4. Wool is dissolved by treatment with cold 10 per cent caustic soda; silk is undissolved.

Wool-Silk-Cotton. — A solution of either ammoniacal nickel oxide[1] or basic zinc chloride[1] dissolves silk with little loss of either cotton or wool.

Heat a weighed air-dry sample for five minutes in basic zinc chloride, remove, wash thoroughly in acidulated and fresh water, air dry, and weigh. Make a correction of 1.5 per cent for loss of cotton; for loss of wool, 2 per cent (Matthews). Separate wool and cotton residue by the 5 per cent caustic potash method.

If ammoniacal nickel oxide is used, the silk in ordinary fabrics will dissolve in two minutes, in a cold solution. Correction for loss of wool, 0.33 per cent; for cotton, 0.45 per cent.

See Matthews' *Textile Fibers* for analysis of shoddy, plush, etc.

[1] Matthews (*Textile Fibers*) gives the following directions for the preparation of these reagents: —

Ammoniacal nickel oxide. Dissolve 25 gms. of crystallized nickel sulphate in 80 cc. of water, add 36 cc. of a 20 per cent solution of caustic soda, carefully neutralizing any excess of alkali with dilute sulphuric acid. The precipitate of nickel hydroxide is then dissolved in 125 cc. of strong ammonia, and the solution diluted to 250 cc. with water.

Basic zinc chloride. Heat together 1000 parts of zinc chloride, 850 parts of water, and 40 parts of zinc oxide until complete solution is effected.

Silk-Cotton. — The color tests under wool answer very well for silk-cotton differentiation, or a mixture of silk and cotton may be analyzed quantitatively by using the 5 per cent solution of caustic potash as given above. As the standard of moisture in silk is 11 per cent, the silk found by the exact method will represent 89 per cent of the original weight.

An alkaline solution of copper containing glycerol[1] dissolves silk, with little effect upon cotton. Cotton may be separated from silk in plush mixtures by heating the material in the solution for twenty minutes. The cotton residue should be considered to have lost 1.5 per cent in weight.

A rapid but inaccurate method of separation is by immersing the sample in 40 per cent hydrochloric acid. Silk is dissolved in two minutes, cotton is attacked to the extent of 4 per cent of its weight (Matthews).

Silk and Wild (Tussah) Silk. — Hot 10 per cent caustic soda dissolves cultivated silk in about ten minutes, tussah silk in about one hour.

Cold 40 per cent hydrochloric acid dissolves cultivated silk rapidly, but has little effect upon tussah silk.

True and Artificial Silk. — Artificial silks have a tendency to become weakened or dissolved by boiling water.

True silks turn red with Millon's reagent and yellow with nitric acid; artificial silks are not affected.

Artificial silks gelatinize with cold caustic soda (10 per cent) in two minutes; true silks do not succumb so quickly.

Artificial silk burns rapidly with no odor; and with the exception of gelatin silk, the fumes turn blue litmus paper red; true silk burns slowly with a characteristic odor, and an alkaline reaction of the fumes on litmus paper.

True silk dissolves in two minutes in an alkaline solution of copper sulphate; lustracelluloses are not affected. This test may be made quantitative.

To distinguish between the three principal varieties of lustracelluloses, — nitrocelluloses, cuprammonium, and viscose silks, — the following test is made: —

Immerse fibers in concentrated sulphuric acid. In the case of the nitrocelluloses no coloration appears for nearly an hour, then a pale yellow color shows. Cuprate silks show a yellow color at once, which deepens on standing, and viscose silks turn reddish brown immediately. Dyed silks must have their color removed before this test is made.

Cotton-Linen. — The microscope is the only final test for cotton or linen fibers. All color or other tests fail at times, es-

[1] *Copper glycerol solution.* Dissolve 16 gms. of copper sulphate in 150 cc. of water, with the addition of 10 gms. of glycerol; then gradually add a solution of caustic soda until the precipitate of copper hydroxide which is at first formed just redissolves.

pecially in distinguishing cotton from fine bleached linen, which by the processes of retting and bleaching has become chemically identical with cotton.[1] The tests which follow are the most satisfactory of those found in textile chemistries, and work sufficiently well with the coarser linen and cotton weaves, such as union towelings, where either the bleach is not perfect, or epidermal fragments adhering to the linen cause it to respond differently to the color tests. With practice, however, the sulphuric acid test may be made to give good results, even when the fabric under analysis is a fine quality handkerchief weave. Before conclusive tests of any kind are made, the fabric should be freed from dressing by boiling in water, or by the oxalic acid method which follows. The latter is the most convenient method for heavily dressed damask, where the purpose is to discover the real quality of the weave and material.

Five Per Cent Oxalic Acid. Using a reflux condenser, boil the sample about fifteen minutes in a 5 per cent solution of oxalic acid. This hydrolyzes the starch to glucose, soluble in water. Remove, wash thoroughly, and test with iodine. If starch is still present, as it may be in heavily dressed table linen, continue the boiling in plain water till starch-free. A longer boiling in acid would have a tendency to weaken the fiber; boiling for fifteen minutes does not show under the microscope any deleterious action. An approximation of the amount of starchy dressing in a fabric can be reached by making this test quantitative. This method requires only one tenth the time of the method of boiling out the starch in water.

Sulphuric Acid. Immerse the sample in concentrated sulphuric acid for one and one-half to two minutes, according to the texture of the material.

[1] The object of retting is to separate the bast fibers themselves, and to free them from the other parts of the flax stalk — the bark, woody tissue, and pith or marrow. Certain substances known as pectin bodies bind the bast fibers to each other and to the surrounding stalk, but in the process of fermentation, while the flax is immersed in water, these are more or less completely removed. This is effected principally by microörganisms which in the absence of air will attack moist pectose and break it down into simpler compounds. These are, as a rule, soluble and wash away, leaving the bast fibers free. Some pectic acid may be formed, which being insoluble in water remains on the fiber. Full bleaching still further purifies the flax fiber, however, making it nearly pure cellulose.

Remove, wash thoroughly with water, followed by weak ammonia. Cotton fibers are destroyed; linen fibers less affected (Fig. 136).

Fifty Per Cent Caustic Potash. Heat a fringed sample of union material in 50 per cent caustic potash for two minutes. Remove and dry between filter paper. Linen becomes brownish-yellow; cotton white or straw color.

Fig. 136. — Mixed Linen and Cotton Toweling treated with Sulphuric Acid. The Linen remains in the Fringe.

Fuchsin. Immerse a fringed sample in a 1 per cent solution of fuchsin in alcohol. Wash thoroughly, lay in ammonia, then in strong caustic soda. Cotton is slightly colored; linen becomes rose-red.

Cyanin. Warm a fringed sample for about three minutes in a 1 per cent alcoholic solution of cyanin. Wash in water to which only a drop or two of sulphuric acid has been added. Linen fiber is colored blue; cotton not colored. The color may be intensified by further treatment with ammonia water.

Madder Tincture. Linen orange-red; cotton lighter.

Cochineal Tincture. Linen dull red; cotton bright red. Heat the sample for fifteen minutes in either of these tinctures, using a water bath or a reflux condenser, to lessen danger from fire. Remove and rinse in a strong solution of sodium chloride. A variation of the ordinary tincture may be made by dissolving 20 gms. of cochineal or madder in 500 cc. of alcohol and 500 cc. of water, and adding 2 gms. of aluminium acetate.

Rosolic Acid. Warm the fringed material for five minutes in an alcoholic solution of rosolic acid, wash and dip for a second in strong caustic soda. Wash thoroughly. Linen becomes rose-red; cotton remains colorless.

For tests to distinguish the minor vegetable fibers, see Dodge, *Useful Fiber Plants*, Bulletin No. 9 of the U. S. Dept. of Agriculture, and Matthews, *Textile Fibers*.

Mercerization. — In the process of mercerization, cotton is made to undergo certain changes by treatment with strong caustic alkalies. John Mercer, an English cotton printer, was the first to show that cellulose, treated under given conditions with alkalies, contracted, gained in strength, and in affinity for dyes. His investigations are described under the English patents of 1850. Owing to several reasons, chiefly the high price of caustic soda, the discovery had little commercial value for thirty years. Since 1880 the process has grown to be vastly important, especially since the patent taken out by Lowe in 1889, which covers a method of employing tension for preventing shrinkage and producing a lustrous material. There have been several modifications and improvements of the method, credit for some of which is due to Thomas and Prevost of Germany, but the essential process consists in immersing the cotton yarn or piece under tension in strong cold caustic soda or potash solutions, and subsequently washing it.

To obtain a high degree of luster, the best quality of cotton is required. Sea Island or Egyptian cotton is therefore preferred, and the fiber is generally combed and gassed to remove protruding ends and render it more silky. The yarn or piece may be bleached before or after mercerizing, depending upon the purpose for which it is intended. The mercerizing process leaves it brown. The material, suitably prepared, is carried under tension on rollers through the mercerizing solution. This may be caustic soda of a specific gravity of 1.11 to 1.2, at a temperature not exceeding 20° C. (68° F.). Under different methods, various chemicals are added to this bath for the sake of better penetration or increased luster. After a few minutes in the alkali solution, the material, still under tension, is washed in fresh and acidified waters. It has been found that the brilliancy and durability of the luster is increased by alternately releasing and taking up the tension on the material while it is in the alkali solution.

The chemical change involved consists in the probable formation of an alkali cellulose, which breaks up during the washing process, and the cellulose unites with water to form a cellulose hydrate to which the composition $(C_6H_{10}O_5)_nH_2O$ has been assigned.

In addition to the chemical change, the cotton fiber undergoes structural modifications. The cell walls are thickened, the lumen is consequently decreased in size, and with complete mercerization under tension the natural twist disappears, giving place to a smooth, rodlike appearance. Owing to the fact that the outer and inner fibers of the yarn are not equally influenced by the alkali, some twisting is commonly found in mercerized fiber. The acquired luster is due partly to the better surface for light reflection given by the smooth, rounded fiber, partly to removal of the cuticle, and partly to the translucent effect produced by strong alkalies on cellulose.

The mercerized material is found to have gained in weight, in tensile strength, and in affinity for dyestuffs, especially for the direct cotton colors. (See Chap. XIII.) It will also take up mordants more readily, as its absorptive capacity is practically doubled.

Cotton may be made to appear mercerized by giving it the Schreiner finish. (See Chap. VII.)

Tests for Mercerization. — The microscope is fairly useful in determining not only the presence but the degree of mercerization; but if the tension has not been sufficient, or the fiber imperfectly mercerized, the twist which persists may make a definite conclusion impossible. The best chemical test is the Hubner method of treatment with a solution of iodine in potassium iodide.[1] The material is moistened with water, placed in the solution for a few seconds, then washed thoroughly and laid

[1] Iodine in potassium iodide: Dissolve 20 gms. of iodine in 100 cc. of a saturated solution of potassium iodide.

in water. Mercerized cotton remains blue or black; ordinary cotton fades to brown or yellowish. The absolute prerequisite for this test is that the material shall have been boiled free from starchy dressing before testing, otherwise all fibers will give the blue reaction.

Mercerized Wool. — By a method somewhat similar to the mercerization of cotton, German experimenters have produced a "mercerized" wool — a product with luster, handle, fair strength, and no felting power. The wool enters a bath of sodium bisulphite, where it is kept under tension for some minutes at a high temperature. Boiling in a weak mineral acid solution, rinsing and drying complete the process, which has not gone far beyond the experimental stage.

Unshrinkable Wool. — When wool is treated under certain conditions with bleaching powder, the fiber loses its felting quality, due to a fusing of the epidermal scales with the cortical region. The luster is increased, and it is claimed that the tensile strength is greater also. Since the power of felting is gone, wool so treated cannot shrink, and is being much used for underwear.

Fireproofing of Cotton. — The Non-Flam Process, an English process patented in the United States in 1907, is a method of permanently fireproofing cotton, resulting from the investigations of William Henry Perkin. It can be applied to any cotton fabric, but is especially valuable in the case of flannelette, which because of its nap and treatment in finishing is exceedingly inflammable. The process, as described by the originator, is as follows: "The material is run through a solution of sodium stannate of approximately 1.22 sp. gr., in such a manner that it becomes thoroughly impregnated. It is then squeezed to remove the excess of the solution, and passes over heated copper drums in order to thoroughly dry it, after which it is run through a solution of ammonium sulphate of about 1.75 sp. gr., and again squeezed and dried. Apart from the precipitated stannic oxide, the material now contains sodium sulphate, and this is removed by passage through water. The material is then dried and subjected to the ordinary processes of finishing." It is probable that the more or less soluble salts used are combined with the fiber in some undisclosed way. The additional cost per yard is trifling, and as the material becomes better known in this country it will probably be much in demand.

Artificial Silks. — Nearly all artificial silks are made by treating cellulose of some kind in a way to produce filaments of great luster and beauty, capable of giving brilliant hues with dyestuffs, and of sufficient tensile strength to allow for spinning into textile material. These filaments, however, lack the softness and elasticity of true silk, and are liable to disintegrate on washing. They are coarser than true silk in the approximate ratio of 15 filaments to 100 in a given area, and their tensile strength is as 30 to 100 in favor of natural silk. This comparative weakness of the artificial silk becomes even more serious on wetting. The principal artificial silks on the market are the nitrocellulose, cuprate, and viscose silks. They are known as lustracelluloses, from their cellulose origin.

Nitrocellulose, or pyroxylin, silks are produced by various methods, the best known, perhaps, being Chardonnet's, Du Vivier's, and Lehner's. The idea in each process is the same, — the production of guncotton or nitrated cellulose, which is dissolved, forced through capillary tubes, and coagulated into a filament. Chardonnet's method consists essentially in nitrating the cellulose by treatment with a mixture of fifteen parts fuming nitric acid and eighty-five parts concentrated sulphuric acid. The nitrated cellulose is washed and dissolved in a mixture of alcohol and ether. The clear, filtered, viscous solution, collodion, is then forced through glass capillary tubes of 0.01 to 0.08 mm. in diameter. The outcoming filament rapidly hardens in the air. Three or four threads are combined into a single filament, which is passed through a denitrating bath of ammonium hydrosulphide. Treatment with a mixture called "antiphlogin" corrects the inflammable nature of the fiber. The material is then washed and dried.

Cuprate or cuprammonium silks are prepared from cellulose dissolved in Schweitzer's reagent (ammoniacal copper oxide). The cellulose is mercerized, dissolved in the copper oxide solution, filtered, and pressed through capillary tubes. The filament is coagulated by passing directly through a dilute acetic acid bath. These filaments are known commercially as the Glanzstoff or Elberfeld silks. Cuprammonium silks are manufactured to some extent in the United States.

Viscose silk is prepared by grinding wood pulp, or other forms of cellulose, often linters, with solid caustic soda, and mixing the product, alkali-cellulose, with carbon disulphide. This gives a gelatinous, viscous substance known as viscose. It is dissolved in water, filtered, pressed through platinum capillary tubes under great pressure, and hardened by passing at once into ammonium sulphate and sodium bisulphate. After some further treatment the filament is bleached by calcium hypochlorite, and the finished silk shows a luster and strength equal or superior to the other lustracelluloses. It is generally produced in rather coarse filaments. Viscose silk is manufactured in the United States.

Gelatin or Vanduara silks are made by forcing gelatin in water solution through capillary tubes, drying the filament, and treating it with formaldehyde vapor, which renders it insoluble in water. These silks have not had a wide use in textile manufacture, due to high price and lack of strength.

A filament of animal origin which may be classed with the artificial silks is spun by a Mediterranean shellfish. It is used in Sicily for the manufacture of wearing apparel.

An adaptation of the process of making an artificial silk filament is now applied to the production of artificial tulle, or maline. Instead of being forced through capillary tubes, the solution is pressed upon an engraved cylinder, and at the same time receives the hardening or coagulating treatment. It is then drawn off as a continuous web having the structural appearance of the tulle weave, and with pattern effects produced by the various designs with which the cylinders may be engraved. The fabric is not strong, having the properties of artificial silk, but it can be employed for hat trimmings and such uses.

Another artificial fiber is the spinning material "textilose," said to be made from paper, wood pulp, and wool waste. It is manufactured in Germany and Austria, and lately in New England. It is stronger than jute and cheaper, and has been used for sacking, upholstery, and curtain materials, and even for toweling and coarse clothing.

Dressing and Weighting. — The question of dressing or weighting is an important one from the consumer's standpoint, especially in the purchasing of table linen or silk dress goods. Materials of very inferior fiber or weave may be so loaded with starchy or other dressing as to appear of fine quality and firm texture. Simply boiling out a sample of toweling or table damask will often reveal an apparently different fabric from the purchased one.

A certain amount of dressing or sizing is legitimate and necessary, in order to make the filaments in a spinning yarn more homogeneous, and better able to stand the strain and friction of weaving, especially in the case of warp threads. In cotton or linen goods the sizing is commonly compounded of flours — wheat, rice, potato, etc. — to which glue, dextrin or other gums are frequently added. Mineral substances, principally kaolin or China clay, and chlorides of magnesium and zinc contribute to the weighting. The chloride of magnesium prevents the drying out of the size on the warp threads, keeps them soft and in good condition for the loom, and makes possible an increased amount of dressing. Zinc chloride is useful in preventing the growth of mildew, to which linen is particularly subject.

Dannerth (*Methods of Textile Chemistry*) recommends the following method of determining the amount of organic finishing material in a cotton fabric: —

1. The percentage of filling materials. A weighed sample of the fabric is boiled consecutively in distilled water, 1 per cent caustic soda solution,

and 1 per cent hydrochloric acid; each operation should be continued for about one hour. If the sample be finally washed and dried to constant weight at 105° C., the result will give the amount of absolutely dry fiber present. Add 8 per cent to obtain the "normal" air-dry weight.

2. The percentage of moisture in the air-dry fabric is determined by drying to constant weight at 105° C.

3. The percentage of fats and waxes is determined by extraction with ether in the Soxhlet apparatus.

4. The percentage of starch, etc., is determined by difference as shown in the illustration below: —

Total filling materials		22 per cent
Moisture	12 per cent	17 per cent
Fats, etc.	5 per cent	
Starch, etc.		5 per cent

The qualitative test for mineral matter in the fabric is the ash which remains after ignition of the fabric in a crucible. The filling material may be soluble in water, *e.g.*, the chlorides of zinc, calcium, magnesium, and sodium. The insoluble portion may consist of China clay, barites, gypsum, chalk, talc, lime, or aluminium soaps. These latter compounds will, of course, be decomposed on heating.

Weighting of Silk. — The practice of weighting silk may begin with the raw material before it reaches us. Hygroscopic mineral salts and fatty and petroleum oils are sometimes used in the process of reeling, in connection with or in place of the weak soap solution which is the only necessary aid in softening the cocoon. Conditioning tests do much to reveal the state of the silk, but adulterations go undetected many times through lack of chemical analysis.

In the stripping of silk, the removal of the sericin or silk gum involves a loss of weight. This averages 25 per cent; therefore one hundred pounds of raw material will yield about seventy-five pounds of boiled-off silk. As the price of raw silk may be about $5 per pound, the loss in these processes is evident. The throwster and especially the dyer plan to make this good by allowing the silk to take up weighting from the baths used. The throwster may leave an excess of soaps and oils in the silk, but the chief addition to its weight comes in the dyeing operations.

Silk readily absorbs the tannic acid and iron, tin, or other salts used in the baths. When properly carried out, this absorption, up to a certain amount, cannot be considered an adulteration, for it is a necessary accompaniment of the mordanting and dyeing operations, and it adds to the quality and attractive appearance of the silk. (See Chap. VIII.) A weighting of over 25 per cent, however, is often a strain on the fiber, yet organzine may be weighted to the extent of 18 oz. for colors and 30 oz. for blacks, and the tram up to 24 oz. or 26 oz. for colors and to 40 or even 60 oz. for blacks.[1]

The substances used in dyeing which give weight to silks vary according to the color and the quality desired. White or light-colored silks do not always contain heavy metallic weighting. When they do, it is often in the form of a tin-phosphate-silicate. Successive baths of stannic chloride, sodium phosphate, and sodium silicate are used, and the amount of weighting is accurately regulated by the number of dips and the time allowed in each bath. Aluminium sulphate is sometimes added to save tin and also give a heavier thread. Sugar is often used as a weighting agent, and is applied after the silk is dyed. Each dip in the sugar solution may add 10 per cent in weight. Lead acetate, or more often "pink salt," which is the double salt of stannic and ammonium chlorides, is also used. Black silks may be "pure dye," with iron tannate as the mordant, or they may be "dynamited," that is, especially heavily loaded. Logwood is still preferred to coal-tar colors for black silks. A method for dyeing organzine with logwood is as follows: After boiling off, the silk is steeped in a bath of iron nitrate, and passes into a soap and iron bath, which adds a given weight of iron soap. The skein is then placed in a bath of potassium ferrocyanide, which with the iron present produces Prussian blue, and this is followed

[1] Weighting is generally calculated as ounces per pound of raw silk. If raw silk loses 25 per cent in boiling off, a pound will yield about 12 oz. (generally figured as 12.4 oz.) of stripped silk. A 24-oz. tram, for example, means that 12.4 oz. have been brought up to 24 oz., the equivalent of 16 oz. of raw silk, which is a weighting of 93 per cent. See Matthews, *Textile Fibers*.

by a bath of cutch or catechu. Tannin absorbed from the catechu increases the weight 35 per cent to 40 per cent, and here stannous chloride may be added to bring it up to any desired weight. The silk is now mordanted in an iron bath, and the dyeing finished in a logwood solution. Black tram weighting is in part tin-phosphate-silicate and in part tannin.

Piece-dyed goods, such as liberty silks, foulards, chiffons, and Shantungs, were formerly little weighted in this country, but the practice of adding some weighting to these is increasing here.

Estimation of Weighting. — Mineral matter may be estimated approximately by burning a sample in a crucible until the organic matter is entirely consumed. The ash residue roughly represents the mineral weighting (Fig. 137), and if the fibers have been coated to excess, the form of the fabric will persist after the animal matter has been burned. This is a guide to the wearing value of a silk, and is the only method of investigation possible in the home. The sample may simply be held by forceps in the flame until nothing but mineral matter remains.

Fig. 137. — Weighting of Silk. The Bottle contains the Mineral Weighting left after burning a Piece of Silk like the Sample Shown.

The quantitative estimation of weighting is a difficult matter, because of the many different substances used. The most accurate method of finding total weighting seems to be the determination by the Kjeldahl process of the actual silk present in a given sample. As nitrogenous bodies — gelatin or glue, ammonium phosphate, and Prussian blue — may be in the weighting, these must first be removed. Matthews gives the following method for this: —

"Boil a weighed quantity of silk (about 2 gms.) in a 2 per cent solution of sodium carbonate for thirty minutes. Wash, heat to 60° C. for thirty minutes in water containing 1 per cent of hydrochloric acid, and afterwards wash well in hot water. Repeat the treatment with alkali and acid until the sample no longer has a blue color."

The Kjeldahl process consists in converting the nitrogenous matter of the silk, by the aid of sulphuric acid, into ammonium sulphate. Ammonia is liberated from this on addition of caustic soda, is distilled into a known amount of sulphuric acid, and the amount of nitrogen calculated. Matthews gives the nitrogen content of silk with 11 per cent hygroscopicity as 17.6 per cent, therefore the amount of true silk in the sample is determined by multiplying the percentage of nitrogen found by 5.68.

The operation is conducted as follows: Place the silk, treated as above, for removal of nitrogenous weighting, in a Kjeldahl flask, add 20 cc. of concentrated sulphuric acid, 10 to 12 gms. of potassium sulphate, and 0.5 gm. of copper sulphate. Heat gently at first, then increase the heat, and boil till colorless. Cool, add about 250 cc. of distilled water, and after the solid matter has dissolved, 4 or 5 drops of rosolic acid. Put 100 cc. of tenth-normal sulphuric acid and 4 or 5 drops of Congo red in an Erlenmeyer receiving flask. Place small pieces of zinc and paraffin in the Kjeldahl flask to prevent bumping, add 80 cc. or more of strong caustic soda, and connect at once. At first distill over a low flame, later with increased heat, until about half the contents of the flask have been distilled over. If the color in the receiving flask becomes red, showing excess of ammonia, add a measured amount of the tenth-normal sulphuric acid. Titrate the excess of acid in the receiving flask against tenth-normal caustic soda. (A more detailed description of this process with discussion of precautions and modifications may be found in Sherman's *Methods of Organic Analysis*, Revised edition, Chap. XIV.)

Given the weight of the silk sample as 1.5 gms., the calculation may be as follows: —

100 cc. N/10 H_2SO_4 used.
7.9 cc. N/10 NaOH used to neutralize excess H_2SO_4.
100 cc. H_2SO_4 − 7.9 cc. = 92.1 cc. used to take up ammonia.
1 cc. N/10 H_2SO_4 = 0.0014 gm. nitrogen.
92.1 × 0.0014 gm. N = 0.12894 gm. N in sample.
5.68 × 0.12894 gm. N. = 0.73 gm. actual silk.
0.73 ÷ 1.5 = 48.7 per cent of actual silk in the sample.

Weighting is calculated in terms of percentage of the amount of pure silk present. Therefore a weighting of 0.77 gm. on 0.73 gm. silk (1.5 gms. − 0.73 gm. = 0.77 gm.) would be (0.77 × 100) divided by 0.73 = 105 per cent. This amount of weighting means that 16 oz. of raw silk have been brought up to 24 to 26 oz. in the dyeing and finishing operations. (See table, p. 403, Matthews' *Textile Fibers.*)

The hydrofluoric acid method, recommended by Matthews, gives results which agree fairly well with the above method. It is based on the fact that the acid destroys mineral weightings without injuring the silk fiber. The process is given as follows: "A portion (about 0.5 gm.) of the sample is placed in a weighing bottle and dried in an air bath at 105° C. to constant weight. It is then boiled in a 2 per cent solution of hydrofluoric acid for five minutes, rinsed with water, and boiled for five minutes in a 2 per cent solution of dry sodium carbonate and washed. This alternate treatment with the hydrofluoric acid and sodium carbonate solutions is repeated three times, after which the sample is finally rinsed, dried at 105° C., and reweighed. The loss in weight will represent weighting materials. The hydrofluoric acid may be prepared by diluting 11 cc. of commercial acid to 400 cc. with water, and the sodium carbonate solution by dissolving 2 gms. of sodium carbonate in 100 cc. of water. Three alternate treatments with these reagents will generally suffice to remove all weighting materials without appreciable injury to the silk fiber, though to be accurate the treatments should be repeated until no further loss in weight is observed." Hydrofluoric acid must be handled very carefully, as it is very corrosive, and serious poisoning has sometimes occurred even from exposure to the fumes of this acid.

Other processes, providing for a separation and identification of the different weightings used, may be found by referring to the works of Matthews, Herzfeld, and Mitchell and Prideaux. (See Bibliography.)

CHAPTER XIII

DYEING OF TEXTILE FIBERS

THE chemical nature of dyestuffs, and the technique of dyeing, are subjects much too extensive and technical to be treated at all fully in a few pages. The aim of this chapter is to indicate an introductory course in dyeing, which may be expanded according to the needs of the class. There are several good laboratory manuals of dyeing which may be used as supplementary textbooks. (See Bibliography.)

Preparatory Processes — Scouring and Bleaching. — These processes remove natural coloring matter, gums, waxes, oily substances, and the like, which would interfere with dyeing.

Cotton Bleaching. — The cotton fiber contains about 5 per cent of such impurities as pectic acid, brown coloring matter, fatty acids, and waxes. As a result, the spun yarn has a dull, grayish appearance, which does not matter if it is to be dyed a dark color. In this case scouring is generally sufficient, a treatment which consists of removing waxy or fatty substances by boiling in solutions of either soap, sodium carbonate, or caustic soda, or mixtures of the three. For light colors, scouring is followed by bleaching with cold, dilute bleaching powder (calcium hypochlorite), followed by an acid bath and washing. When the yarn is to remain white, soap solution and bluing baths complete the process. If bleaching is to be done in the woven fabric, the process is more complicated, for additional matters, such as sizing added to the warp threads in the weaving, have to be considered, and the method varies according to the subsequent treatment of the cloth. Three processes are in general use — the market or white bleach; the Turkey red bleach; and the printer's bleach, which prepares the material for calico printing. This last process is essentially as follows: —

1. Singeing.

2. Gray wash. The material is allowed to remain in plain water long enough to remove soluble matters.

3. Lime boil. Boiling in limewater for several hours converts fatty matter into lime soaps, which deposit as insoluble matter on the fabric.

4. Washing. This removes excess of lime, and any soluble substances.

5. Lime or gray sour. The material is passed through dilute acid, generally hydrochloric, which breaks up the insoluble lime soaps and other salts of lime, forming soluble calcium compounds, and setting fatty acids free.

6. Washing.

7, 8. Lye boils. Boiling with soda ash and with resin soap and caustic soda changes the free fatty acid left in (5) and (6) to soluble soaps.

9. Washing. All impurities are now removed, other than natural coloring matter.

10. Bleaching proper, or chemicking. The material is passed through cold, dilute calcium hypochlorite.

11. White sour. After a hasty wash, the material passes into dilute hydrochloric, sulphuric, or acetic acid. This sets chlorine free from the bleaching solution, which in the presence of water liberates oxygen, and this removes the coloring matter. (See page 339.)

12. Washing.

Linen Bleaching. — Linen contains more coloring matter and natural impurities than cotton, which make its bleaching a longer and more complicated process. The method is similar to that of cotton, except that the chemicking and souring may be repeated several times, according to the perfection of bleach desired, and grass bleaching is often combined with the chemical treatment. There are four grades of linen bleaching — quarter, half, three quarter, and full. Other terms are sometimes used. Full-bleached flax is not as strong as the other grades, due to the severity of the process. In linen yarns the loss of strength is estimated at 20 per cent for full bleach, and 15 per cent for half bleach.

Wool Bleaching. — Before bleaching or dyeing, wool must be scoured to remove the oil and grease left on the fiber after spinning. The usual method of wool scouring employs a solution of soap and soda ash. If it is necessary to scour the skeins provided for laboratory dyeing, they may be treated as follows: —

Work a five-gram skein of wool for a half hour in a bath containing one liter of water, ten grams of soap, and two grams of soda ash, at a temperature of 60° C. Wash in fresh water till free from soap, and dry. Avoid using friction, which will felt the fiber.

Neither wool nor silk can be bleached by the method used for cotton, since the chlorine would yellow the animal fiber, and the alkalies destroy it. The agent generally used is sulphurous acid or sulphur dioxide gas. The wool or silk may be given the gas bleach, by subjecting the yarn or piece to the fumes of burning sulphur in a moist atmosphere, or they may be passed through sulphurous acid. Sodium bisulphite is sometimes used, which in solution gives sulphurous acid. These bleaches are not very permanent, and eventually the natural color returns, especially if the article is washed with soap. The hydrogen peroxide and sodium peroxide bleaches are expensive but effective, and are coming into greater commercial importance. (See page 340.)

Nature of the Dyeing Process. — Dyeing follows bleaching. It is the process by which coloring matter is permanently fixed upon or within a textile substance by means of immersion in the color solution. Textile printing is a process of applying color to certain portions only of the fabric, by means of a printing machine. Printed colors are not so fast as dyed colors. The two processes are sometimes combined in one material. The color solution, to be a dye, must possess not only color, but the power of combining with the chemical constituents of the fiber, with or without assistance, to form an insoluble compound. The changes taking place in the fiber are not clearly understood, but that they are of a chemical nature is indicated by the fact that wool and silk, which are both acid and basic by nature, are dyed directly by acid and basic dyestuffs, which is not true to any extent of the other fibers. According to Witt's theory, however, the dyed fiber is a solid solution of the dye. Many of the dyeing operations are now classified among the phenomena of "adsorption."

Materials and yarns for the market may be dyed in the following ways: —

1. *Dyeing in the wool.* — What is called raw stock dyeing corresponds to the "dyeing in the wool" of early days. The wool is dyed after washing and scouring, and before drying. It is recommended for its permanence, and is used principally for dark goods which must stand much wear and friction, and still hold their color. Equal parts of black and white wool, so dyed, and mixed in the yarn, make the Oxford mixture.

2. *Dyeing in the slub.* — Wool is dyed after being carded and combed, but not twisted; cotton is twisted. The dye sinks in, and later spinning conceals any irregularities. Vigoureux yarns are yarns that have been printed on the slub or top by a special machine with regular or irregular designs of color, generally black and white, covering spaces of one quarter inch to several inches. The colors are set by steam. When the printed slub is later drawn and twisted, a more perfectly mixed effect is obtained than if colored wools had been blended.

3. *Skein dyeing.* — Spun yarn, usually two-ply, is dyed in the skein. This penetrates fairly well into the yarn. Skein-dyed yarns are used for ginghams, and in wool for plaid and novelty effects.

4. *Piece dyeing.* — The fabric is dyed after weaving in the natural color, which produces a single uniform color.

5. *Cross dyeing.* — This is piece dyeing of mixed cotton and wool. Cotton will not take wool dyes, consequently when dipped in a wool bath it is merely tinged with a fugitive color easily washed out. Plain colored materials, such as mohairs and alpacas, are woven with a cotton warp. The cotton yarn is dyed first in the color desired, and then woven with the worsted filling. The cloth is cross dyed by placing it in a wool bath, in which the cotton is unchanged. Cloths are woven

with white or colored hair lines in the warp. When cross dyed in a wool bath and washed, the wool is colored and the cotton hairlines remain as they were. The reduction in price in thus inserting cotton for wool is quite an item. Cheap shepherd plaids and other fancy dress goods are woven with cotton for the white effects and with wool for the colored.

6. *Resist dyeing.* — Resist dyeing and cross dyeing are virtually the same process. In resist dyeing some of the woolen or worsted yarn is treated to remain unchanged in the bath which colors the untreated part. For example, a thread of red or green woven into a material to be dyed dark blue or black keeps its original color. Resist dyeing is used in the interesting Batik work, which originated in Java. In this work all of the material which is not to take the dye in the first dip is brushed over with wax. The wax may be removed and again applied to parts which are to resist a second dye, and so on, until the desired pattern is worked out.

7. *Discharge dyeing.* — By this process the material is piece dyed and the color afterwards removed in certain places by the action of chemicals. Flannels with polka dot effects are often dyed in this way.

Necessary Equipment for Dyeing. — For each student, the minimum apparatus required is an agate kettle holding a gallon or more; two glass rods at least eight inches long and three eighths of an inch in diameter; one agate pint cup; a tablespoon; a thermometer; a 100 cc. graduated cylinder and some kind of heating apparatus, such as a small gas stove. The laboratory should be equipped with one or two clothes wringers and a clotheshorse or drying rods.

Use of Glass Rods — Handling of Skeins. — The glass rods obviate any handling of the skeins and staining of the hands. Holding a rod in each hand, the dyer keeps the skein revolving in the dye bath. When the dyeing is accomplished, the skein is looped evenly on one rod, and with the aid of the other inserted in the loop is twisted and wrung out. Subsequent washing, wringing, and hanging up to dry are accomplished also by using the rods.

Preparation of Dye Solutions. — Skeins to be dyed are generally in five-gm. weights for wool, ten gms. for cotton, and two gms. for silk. Five gms. of wool require sixty times that amount of dye solution, or about 300 cc.; ten gms. of cotton require also 300 cc., and two gms. of silk need 125 cc. of solution. It is the common practice to measure the necessary dyestuffs and chemicals in percentage relation to the weight of the material. A recipe for acid dye which calls for 5 gms. of woolen yarn, 250 cc. of dyebath, 10 per cent Glauber's salt, 5 per cent sulphuric acid, and 3 per cent Benzyl Violet 6 B would use the following amounts: —

10 per cent of 5 gms. = 0.5 gm. Glauber's salt.
3 per cent of 5 gms. = 0.15 gm. dyestuff.
5 per cent of 5 gms. = 0.25 gm. sulphuric acid.

In order to obviate individual weighing of these small amounts, solutions may be prepared of such a strength that 10 cc. will contain the proper amount of each ingredient for a skein of wool. For example, 0.5 gm. of Glauber's salt are required; 10 cc. of solution must contain 0.5 gm., therefore dissolve 50 gms. of Glauber's salt in about 500 cc. of water and make up to 1000 cc. Of dyestuff, 0.15 gm. are required; therefore one liter is made up in a similar way to contain 15 gms. Of sulphuric acid, 0.25 gm. in 10 cc. would equal 25 gms. in 1000 cc., but as the specific gravity of concentrated sulphuric acid is 1.84, the number of cubic centimeters measured out would be 25 divided by 1.84, or 13 cc.[1]

[1] These technicalities are introduced to teach the student how to interpret dye recipes, if necessary. The recipes which are occasionally given in the text may or may not be used. They are given simply with the idea of suggesting possible dye baths, and providing for uniform experimental work in large classes. Dyeing formulæ are in no sense fixed, but most varied, and the instructor, if he wishes, may readily substitute or add recipes from the larger manuals of dyeing. As soon as the student has studied the properties of a class of dyestuffs, recipes and the dyeing of skeins may be discarded for the working out of experiments in mixing color and in dyeing piece goods.

Mixing, Blending, Topping. — The primary mixing colors — blue, red, and yellow — are sufficient for the production of other colors, shades, and hues. The student measures out the dyestuff in small quantity, dissolves it in a little hot water in a cup, and experiments through different proportions and combinations for the desired shade. Some knowledge of the laws of color blending is necessary. For instance, equal parts of blue and red produce violet, but three parts blue to one red make violet-blue; two parts blue to one red make blue-violet; two parts red to one blue make red-violet; three parts red to one blue make violet-red. Yellow and blue make green, and the shades of green may be worked out as above, but a softer shade, approaching olive, is produced by a slight addition of red. Red is the opposite of green; the opposite of any color grays that color. While the addition of the third color is almost always desirable, on account of its softening effect, the amount added must be gauged with care. Topping often gives better results than mixing two or three colors in one bath. A clear, bright orange, for example, may be produced by dyeing a skein in a bath of yellow and immediately dipping it in a red bath, called "topping."

Classification of Dyes. — Dyestuffs may be classified as: —

I. *Artificial.*

Coal-tar dyes (aniline dyes and others).

II. *Natural.*

1. Vegetable, — logwood, fustic, cutch, madder, indigo.
2. Animal, — cochineal.
3. Mineral, — Prussian blue, iron buff, chrome yellow.

The artificial dyestuffs are by far the most important. Since 1856, when the first coal-tar dye, mauveine or mauve, was discovered by Perkin, the number has increased enormously, and the natural dyes are for the most part falling into disuse. In fact, many of these can be produced synthetically. Alizarin is the chemical equivalent of madder, and synthetic indigo is a strong commercial competitor of the natural product. Logwood, however, holds its own. It is much used for producing a good black shade in silk fabrics, often in connection with cutch or fustic. Cutch is still employed in cotton dyeing to produce certain shades of brown.

Based on their nature or properties, dyes fall into certain classes, of which the more important are: —

(1) Acid Dyes, (2) Basic Dyes, (3) Substantive Dyes, (4) Sulphur Dyes, (5) Adjective or Mordant Dyes.

I. **Acid Dyes.** — These are direct dyes for silk and wool, feathers, leather, and other substances of a protein nature. They do not color vegetable fibers to any extent, but may be used in staining wood and straw, where the color does not need to be fast to washing.

The following experiment is given to show the comparative action of acid dyes on wool and cotton: —

Prepare a dye bath of 300 cc. water, 1 per cent Naphthol Red E. B., 20 per cent Glauber's salt, and 4 per cent sulphuric acid. Thoroughly wet a five-gm. skein of wool in water, immerse it in the bath at a low temperature, and heat gradually until a good color is obtained. Remove, rinse, and dry. Dye a skein of cotton in the same manner.

Acid dyes are salts of color acids. When an acid, in this case sulphuric, is added to the dye bath, the salt is broken up, the color acid is liberated, and this dyes the wool fiber more readily than the salt itself. The sulphuric acid also unites chemically with the wool and increases its affinity for the dye. Glauber's salt is generally added to the acid bath with these dyes. Its main function is to hold back the dye from too rapid absorption by the fiber, so that a more even, level shade is produced. Such substances as Glauber's salt, sodium chloride, and sulphuric acid, which aid in the dyeing operation, are called assistants.

Generally speaking, acid dyes are cheap, easily applied, and give even shades on wool and silk which are fairly fast to light. A few selected colors can be obtained which are entirely satisfactory in this respect. They are not so fast to washing, and the dyed material should be well washed after dyeing, else there may be an effect of "bleeding" or "crocking." Wool and silk are almost always dyed with these colors, unless fastness to washing is necessary.

In the following experiments, students may work out color combinations with acid dyes and apply to skeins or piece goods: —

Dyeing Directions. — For Wool. Dissolve the dyestuff in a bath containing about a tablespoonful of 30 per cent sulphuric acid and two or three tablespoonfuls of Glauber's salt to a gallon of water. Immerse the thoroughly wetted wool in the cold or lukewarm bath, and heat it slowly until the desired shade is reached, turning it cautiously so as to give the dye a chance for even penetration. The bath should not boil if the wool is to be kept from felting, and for the same reason the skein should be turned carefully on the rods. Finish by rinsing thoroughly in two or three waters, to remove the last traces of acid. Wring out by hand or machine, and let dry in the air.

For Silk. Dissolve the dyestuff in a soap bath, containing 2 per cent of good neutral soap; then add dilute sulphuric acid, drop by drop, until the bath "breaks" and becomes faintly acid. Immerse the wetted silk, stir it well, keeping it on the dye sticks, and warm the bath till the desired shade is reached. Rinse well, wring out between folds of blotting paper in the wringer, straighten, and dry.

For Feathers. If necessary, cleanse the feather by washing with water and olive-oil soap, and carefully rinsing. Soften by soaking for a short time in hot water and dye in a bath slightly acidified with oxalic acid. Begin in a cold bath and warm very gently, keeping the butt immersed in preference to the tip, till the desired shade is reached. For good, even dyeing, the time allowed for each feather should be from half to three quarters of an hour. Rinse in two or three waters, partly dry, and then work in a thick milk made by stirring finely powdered starch with cold water. Take the feathers out and pass through the wringer between blotting paper, and dry carefully over a radiator, taking care not to cook the starch. When thoroughly dry, shake out the dry starch granules.

II. **Basic Dyes.** — These are direct dyes for wool and silk; vegetable fibers must be mordanted.

Experiment. Dye a skein of wool and one of cotton in a 1 per cent solution of fuchsin, boiling fifteen minutes. Remove and wash. The dye is easily washed out of the cotton.

Basic dyes are salts of color bases. The color base unites with the acidic groups of the wool or silk fiber to form an insoluble dye. Silk especially has a great affinity for basic dyes, and care must be taken that the color is not taken up so fast that uneven dyeing results. Artificial silks of the nitrocellulose class take these dyes well. Basic dyes have greater tinctorial power than acid dyes, and give more brilliant colors. They are used to some extent for silk, but not so generally for wool, being largely superseded with both by the acid dyes. They are useful, however, in staining straw and raffia. Their defects are a want of fastness to light, and a tendency to crock. With hard water the dye precipitates more or less from solution, and dye spots appear.

Application to Wool. — Wool is dyed in a neutral bath, or in one slightly acidified with acetic acid, especially if the water is hard. The acetic acid aids in softening the water by breaking up its carbonates, and also causes the dye to fix on the fiber more slowly and evenly. Glauber's salt is used as an assistant. The dye must be carefully dissolved and filtered into the bath through a cloth.

Experiment. Prepare a dye bath containing 300 cc. of water, 2 per cent of acetic acid, 10 per cent of Glauber's salt, and 1 per cent of Methylene Blue. Thoroughly wet a 5-gm. skein, place it in the lukewarm bath, raise the temperature slowly, and dye for half an hour at about 80° C.

Application to Silk. — Silk is dyed in a neutral, alkaline, or slightly acidified bath, to which in practice soap and boiled-off liquor are usually added. An after treatment with a tannic acid bath, followed by rinsing in a solution of tartar emetic, improves the fastness of the color.

Experiment. Immerse a 2-gm. skein of silk in a bath containing 150 cc. of water and 5 per cent olive-oil soap, and after working with the rods for a time at lukewarm heat, add gradually 2 per cent of Methylene Blue. Dye for fifteen minutes at 80° C., carefully acidulate the bath with acetic acid, and dye fifteen minutes longer. Remove, rinse, and dry.

Dye another skein in a similar manner, wash well, pass into a bath containing 100 cc. of water and 1 gm. of tannic acid. Work for twenty minutes at 80° C., then let remain immersed in the cooling bath for a half hour. Squeeze out, pass into a fresh bath containing 100 cc. of water and 0.5 gm. of tartar emetic, and work at 60° C., for twenty minutes. Wash well and dry.

Application to Straw. Cleanse the piece of straw braid, loosely bound together, or the hat, in soap and water, and thoroughly rinse. Prepare the bath by straining a solution of the dye through muslin into sufficient water to well cover the material, and slightly acidify with acetic acid. Immerse the wet straw and gently heat until the right shade is obtained. Remove and rinse.

Topping with Basic Colors. Dye a skein of cotton or linen with a direct or salt color, or a sulphur color (as described beyond), and top by passing into a basic dye bath. The direct and sulphur dyes serve as mordants with the basic dyes.

Dyeing Cotton with Basic Colors. — Mordants. — In dyeing cotton with basic colors, a mordant, generally tannic acid, must be used to make the fiber take the dye. Mordants are substances which in the dyeing operation unite with both fiber and dye, and fix the dye on the fiber. For the application of mordants see Adjective or Mordant Dyes below.

Experiment. Thoroughly wet a skein of cotton and immerse in a lukewarm bath of a dilute solution of tannic acid; slowly raise the temperature to nearly boiling, then let the skein remain in the cooling bath. Remove, wash lightly, squeeze, and dye in a one per cent solution of fuchsin, together with a skein of unmordanted cotton, observing the same temperature regulations and dyeing for about one half hour at the maximum temperature. Remove, wash, dry. Observe the effect of the mordant in fixing the dye.

In practice, tannic acid is more effective if combined with certain salts of metals. The metallic tannates formed unite with the dye to produce compounds of greater insolubility. This process, called fixing, follows the tannic acid mordanting. Salts of tin, iron, chromium, antimony, etc., are used as fixing agents. Applied to the last experiment, the cotton skein is passed from the tannic acid bath into one containing about two grams of tartar emetic in a liter of water. Work the skein five minutes, and let remain in the solution while the dye bath is being prepared. Then place in the dye and proceed as before.

III. **Substantive Dyes.** — This class of dyes bears several names. They dye vegetable fibers directly, requiring no mordant, so are called direct cotton colors. As common salt is usually used in the bath, they are also known as salt colors. The term diamine dyes refers to their chemical constitution. The first direct or substantive dye was discovered in 1884, and named Congo red; the dyes belonging to this group are therefore sometimes called Congo colors.

Experiment. Thoroughly wet a 10-gram skein of cotton and immerse in a bath of 2 per cent Congo red to which 2 per cent sodium carbonate and 20 per cent Glauber's salt have been added. Heat to boiling point and boil a few minutes; remove and rinse.

Vegetable fibers take more brilliant colors than wool. To show this, dye a skein of wool in the same manner. Note any differences in the degree of color and in the exhaustion of the bath.

Certain of the substantive dyes, Congo red, for example, have their color changed by the action of acids. If a strand of the skein just dyed be dipped in dilute sulphuric acid, the color will be changed to blue, and the red returns when the acid is replaced by an alkaline reaction. Congo red is often used as an indicator, with a reaction opposite to that of litmus. The acids present in the air may be sufficient to dull material dyed with some of these colors. Treatment with an alkali, such as sodium carbonate, aids in restoring the original shade. The sodium carbonate used in the above experiment remains to some extent in the fiber and protects the material from color change.

Substantive dyes furnish bright, clear colors which are fairly fast to light, and with wool and silk withstand washing, especially with the latter when dyed in a boiling bath. They have the disadvantage, with vegetable fibers, of "bleeding" when washed, unless the color is thoroughly boiled into the fabric, and often unless a treatment of copper sulphate and potassium bichromate is given. If even tones are desired which do not have to be particularly fast to washing, these dyes give them quickly and easily. They are also useful for dyeing evenly mixtures of cotton and wool or cotton and silk. The lower the temperature of the bath, the stronger the affinity of the cotton for the dye, and the more the bath is boiled, the deeper the color produced on animal fibers. In dyeing mixed goods, therefore, the material is first dyed cold until the desired shade is nearly reached in the cotton material, then heated until the wool or silk takes the color. With practice, the same shade can be produced in this way on different fibers. Substantive dyes are very soluble in water, and salt has the effect of making them insoluble. Used in the bath, it prevents too thorough a solution, and therefore causes more of the dye to go on the fiber. Glauber's salt is used for the same purpose.

Dyeing Directions. — Cotton and Linen. Fill the kettle half full of hot water, and bring to boiling point on the fire. Mix the dyestuff with a little hot water in a cup, and stir into the kettle. When thoroughly dissolved, add a tablespoonful of salt. Thoroughly wet the material, place it in the dye bath, and boil for about thirty minutes.

Artificial Silk. Fill the dye kettle half full of lukewarm water, and in this thoroughly wet skeins of artificial silk. Wrap in cheesecloth and put through the wringer. Dissolve dyestuff in hot water in a cup, stir into the kettle of water without further heating, and add one tablespoonful salt. After dyeing the desired shade, rinse in cold water, wrap in cheesecloth, and put through the wringer. Hang to dry. A stronger dye bath is needed for artificial silk than for cotton.

The fastness of cotton and linen to light is improved in the following way: —

The material is taken out of the dye bath, rinsed slightly in cold water, and soaked for a few minutes in a hot bath containing two teaspoonfuls of copper sulphate, one teaspoonful of potassium bichromate, and one of acetic acid to a gallon of hot water. It is then rinsed free from this and dried.

Mercerized cotton is generally dyed with these colors in the same way as described for cotton and linen. The colors produced are much faster to washing, and take more easily than with ordinary cotton.

IV. **Sulphur Dyes.** — These are direct dyes, used especially for cotton, linen, mercerized cotton, and artificial silk. The colors are soft, quite fast to light, and faster to washing than the salt colors. Sulphur dyes are as a rule insoluble in water, but dissolve in a bath containing sodium sulphide. Sodium carbonate is sometimes added for alkalinity, and common salt for better exhaustion of the bath.

Dyeing Directions. — Cotton and Linen. Stir the dyestuff into a bath containing enough sodium sulphide to dissolve it to a clear solution. About twice as much sodium sulphide as dye will be necessary. Make alkaline with a small amount of sodium carbonate, and add twice as much salt as dyestuff. Heat the material in the bath to just below boiling point, and dye at that temperature for fifteen minutes to half an hour, keeping the goods immersed. Remove, pass through the wringer, being careful to effect an even removal of the dye solution, and after a few moments of hanging in the air, boil in a soap solution to soften the material and free it from excess dye. Artificial silk is dyed in a cold or lukewarm bath.

V. **Adjective or Mordant Dyes.** — The alizarin colors are the principal dyestuffs in this class, but most of the natural dyes, including the important logwood, belong here. These dyes have been used extensively for wool, and especially for dyeing Turkey red on cotton; less often, except in the case of logwood, for silk, but the coal-tar dyes have now largely superseded them. A mordant is necessary, which usually precipitates as a metallic hydroxide on the fiber. The dyestuffs unite with these hydroxides to form insoluble metallic salts known as color lakes. Mordants are generally salts of metals, with the exception of Turkey red oil and the tannins. The ones in common use are the potash or soda alums and aluminium acetate, generally applied to cotton dyeing; potassium bichromate or "chrome" for wool, and other chromium and iron salts.

As a rule, mordants darken or "sadden" the color of the dye with which they are used. This is especially true of the iron and chromium salts. The natural claret red of logwood cannot be produced in conjunction with a mordant; with iron, for instance, the famous logwood black is secured. Tin, however, intensifies the natural color of most dyes.

Mordants are applied in three ways: first, to the fiber before dyeing, the usual method; second, in one bath, the cheap and often practiced method; third, after dyeing, a method sometimes applied to wool. When so applied, the process is called after-chroming, since potassium bichromate is the mordant used. The after-chromed colors are generally fast.

Application of Mordant Dyes to Cotton. — With alizarin colors, the principal colors produced are the bright and fast Turkey red, the maroons, and the violets. For Turkey red, different methods are employed, but the color is generally fixed on the fiber by the aid of Turkey red oil and aluminium acetate or sulphate. A so-called Turkey red, which imitates the color but not its fastness, is now produced by direct dyes.

Cotton may be dyed black by logwood.

Experiment. Work a skein of cotton yarn in a 50 per cent solution of ferric sulphate until thoroughly impregnated. Squeeze, rinse in limewater to remove excess of the salt adhering to the fiber, and boil half an hour in a 10 per cent extract of logwood.

Application to Wool. — Wool may be dyed, then mordanted, in the same way that acid dyes are applied.

Experiment. At about 50° C., enter a 5-gm. skein of wool in a bath containing 150 mg. of Chrome Fast Blue in 250 cc. of water, 10 per cent Glauber's salt, and 5 per cent acetic acid. Raise slowly to the boiling point, dye for one half to three fourths of an hour. Cool, add $1\frac{1}{2}$ per cent potassium bichromate, and boil for thirty minutes.

Application to Silk. — The best black dye on silk is still produced by logwood, with a tannin-iron mordant. (See p. 312.)

Mordant dyes are very fast to washing, light, and acids.

Dyeing in the Household. — For home dyeing, such dyes as the Diamond, Rainbow, or E-Z dyes are about the only ones available, because of the small quantity of dyestuff required. Directions are given on the packages. Before dyeing, the nature of the material should be known, and the dye chosen accordingly. For example, if a part of the fabric is cotton, a cotton dye is used, as wool and silk can be made to take cotton dyes better than cotton will take those for the animal fibers. In redyeing, it is a good plan to choose a dye which is of the same color order as that of the material to be dyed, as a dark blue dye for a light blue garment; in case the new color is to be entirely different, as much as possible of the original color must be removed by repeated boiling out, or the blend of the two may be quite different from the shade desired. The material must be clean and free from spots or stains before dyeing. The kettle used should be large enough to take the goods without crowding, and allow for thorough stirring and turning. A sample of the material should be tested in the dye bath. It is a wise precaution to mix the bath rather weak, as more color can be added if necessary. A lack of softness in the colors may be overcome by blending and shading down.

Dyes in amounts of one quarter pound up may be procured directly from the large color houses. The letters following the names of the dyes furnished refer generally to the tone. A violet may run from 6B. to 6R. indicating tones from blue violet to red violet. The letter F indicates fastness to light, and FF would be very fast. As the different supply houses have their own systems of naming their colors, it is necessary that the manufacturer's name accompany the name of the dye.

Selected Dyes

Acid Dyes: —

Benzyl Violet 6B., A. Klipstein & Co., 654 Greenwich St., New York City.
Naphthol Red E. B., Cassella Color Co., 182 Front St., New York City.
Naphthol Yellow, Cassella.
Acid Yellow A. T., Cassella.
Tetracyanol S. F., Cassella.
Brilliant Cochineal R. R., Cassella.

Basic Dyes: —

New Methylene Blue N., Cassella.
Safranine R. S., Cassella.

Thioflavine T., Cassella.
Bismarck Brown E. E., Cassella.
Solid Green Crystals O., Cassella.

Substantive Dyes: —

Congo Red.
Benzo Purpurin 4B., Klipstein.
Diamine Fast Black X., Cassella.
Diamine Pure Blue A., Cassella
Diamine Fast Blue F. F. G., Cassella.
Diamine Fast Yellow F. F., Cassella.
Diamine Fast Red F., Cassella.
Cotton Yellow, Badische Co., 128 Duane St., New York City.
Fast Red, Badische.
Direct Green, Badische.

Mordant Dyes: —

Chrome Fast Blue, Klipstein.
Alizarin Red.

Sulphur Dyes: —

Immedial Direct Blue B., Cassella.
Immedial Yellow Olive 5G., Cassella.
Kyrogene Black T. G. O., Badische.
Kyrogene Brown R. R. O., Badische.

Dyes in Oriental Rugs. — The soft, wonderful colors in Oriental rugs are produced from natural sources, limited in variety only by the ingenuity of the dyer. Onion skins, thistles, leeks, ivy, artichokes, with mordants of pomegranate rind or sumac, may enter into a dye the recipe for which is the hereditary secret of a family. One family will be known for its yellows, another will have the secret of certain reds. The reds are the finest and most difficult colors the Eastern dyers produce, and are the most durable. They are usually combinations with madder, cochineal, or kermes (an insect feeding on oak leaves). A certain shade of violet is produced by equal parts of milk and water to which are added madder and sour grape juice.

Blues have an indigo base. Black is the cheapest dye in a rug, and always wears off first, due to the corroding action of the iron salts used in the dye. A native dyer seldom employs exact methods to get his results. He blends and tops his skeins in successive dye baths until harmonious shades are produced rather than exactly matched colors, and the dyed skeins are then exposed on the roof of his house, while the dyer watches them until the sun has given them just the right mellow tone. His ways are not adapted to the exact operations required with aniline dyes. While these can be made as fast and as soft as the Oriental's natural dyes, he has not learned to handle them, and where aniline dyes have been used a far less beautiful and satisfactory article has resulted. Persia has for some years prohibited the importation of aniline dyes into the country.

A rug dyed with aniline colors may fade to entirely different colors, while in general a vegetable dye fades to tones of its particular color. The manner of fading is apparent if the color deep down in the pile is compared with that on the surface. If any color has run into the white part of a rug, it has been poorly dyed with aniline colors. A test often given consists in laying a wet cloth on the rug, or rubbing the colors with a cloth moistened with saliva, in which case aniline dyes will rub off.

CHAPTER XIV

LAUNDRY NOTES

THE intelligent treatment of textile fibers in the laundry depends ultimately upon a knowledge of the chemical nature and structure of the fibers, and the effect upon them of water and friction, acids and alkalies, heat and cold. The general principle that protein fibers deteriorate in alkaline solutions and vegetable fibers in acid necessitates a knowledge of the particular acids and alkalies of the kitchen and laundry, how they affect each kind of material, and the reasons underlying the choice of cleansing and bleaching agents, and bluings.

Felting of Wool. — From the laundry standpoint the most striking characteristic of wool fibers is their power of felting. The epidermal scales of the fibers, being loosely attached, interlock readily, as if the teeth of two saws should be dovetailed. As a result, the fibers shrink to a matted, boardlike mass. This property is utilized in the production of felted goods such as broadcloth (see Chap. VI), but the problem in the laundry is to cleanse wool with as little felting as possible. Certain influences increase the felting action, *e.g.*, expansion due to heat, followed by sudden contraction from cold; the softening and expanding effect of alkalies, and friction. The soft, elastic quality of a blanket or sweater can be entirely lost by washing it with strong soap or washing powder, rubbing or wringing it, changing from hot to cold water, or hanging the warm, wet fabric outdoors on a cold day.

The peculiar protein nature of the wool fiber makes it very susceptible to hot water, which rapidly deteriorates it. Too hot an iron will cause felting and stiffening, whereas if the heat is regulated to about 100° C. under the damp pressing cloth, the fibers become plastic and will take and retain the shape desired, without losing their elasticity.

Acids and Alkalies of the Household. — The action of acids and alkalies on textile fibers has been treated in detail in Chapter XII. The acids of the household, outside of those found in fruits, are hydrochloric (muriatic) and oxalic, used for removing stains and for cleaning purposes. The last two have a "tendering" effect on cotton and linen if allowed to dry on the fiber, and should be followed by washing and neutralization with ammonia or other alkali. Silk is more susceptible to the action of acids than wool. Hydrofluoric acid is an exception to the general rule of fiber destruction, and is used in about 2 per cent strength in some laundries for removing the soil from collars and cuffs. It attacks mineral matter without materially affecting the fabric. It is a very corrosive acid and must be handled carefully. Since acids and alkalies neutralize each other, color changed in clothing by acids can often be restored by touching the spots with weak ammonia.

The common alkalies in household use are ammonia, borax, carbonated alkalies, such as washing soda, and caustic alkalies found in some soaps and washing powders. Unless carelessly used, the first two are not injurious to fabrics. The carbonated alkalies have a yellowing effect on silk; good soap usually has no deleterious action. Washing soda in strong solution and in an undissolved condition should not come in contact with garments, especially wool, nor should any soap containing free alkali be used for wool. Soap should not be rubbed on wool because of the felting effect, and in fact for many cleansing operations, especially washing colored cotton material, a soap solution is better than direct rubbing.

The tendency in the average laundry is toward the excessive use of washing soda. As a soap saver, to soften hard water, washing soda is most desirable. For this purpose, one part will do the work of about six parts of soap of 100 per cent purity, but as cheap laundry soaps contain only about 33 per cent actual soap, the ratio becomes 1:18. A white laundry soap of good quality contains about 75 per cent soap, the balance being mostly water. An ordinary yellow soap has about 35 per cent resin and 30 per cent water incorporated in it. The amount of washing soda needed to soften a given water may be found by observing how much soap is required to make a permanent lather — *i.e.*, overcome the hardness of the water — in a measured amount, and estimating accordingly. The yellow soaps generally show free caustic alkali, and in such case are injurious to wool or silk fibers. Their continued use will have a yellowing effect on all material, due to both alkali and resin.

Cotton launders less easily than linen, and requires more thorough treatment. It has been estimated that cotton will collect three times as much dirt as linen will, and bacteria have been found on the surface in the ratio of 182 with cotton to 100 with linen, when both have been treated alike. Linen needs careful handling, as the fibers are stiff and inelastic, especially when starched, and soon break in the folds of table damask, for example, under heavy ironing.

Bluings. — Certain aniline blues, or rather dyes, give clear, attractive blue shades. Some of these blues do not require acids to develop them, but in common practice varieties are used which are brought out on the material by the aid of acetic or oxalic acids. While acetic acid is volatile and not necessarily harmful, oxalic is far more likely to be injurious to the fabric, as it is not volatile, and is concentrated on the fiber in the ironing process. It is used for its whitening effect, without regard to its destructive action, and in a short time the clothes go to pieces. Another class of liquid blues is made on an iron base, *e.g.*, Prussian blue. In the presence of alkalies the iron is changed to ferric hydroxide, which becomes ferric oxide or iron rust in the dry material, especially under the heat of the iron. If this kind is used, therefore, the bluing water must be entirely free from soap, otherwise rust spots appear on ironing. To determine whether a liquid blue is of this variety, add caustic soda solution or other alkali, and shake for a few minutes, heating gently meanwhile. If iron is present, the blue color will fade to the reddish yellow color of iron rust. The blue can be restored by the addition of acid, hence the iron-rust spot can be removed by treating with an acid. (See page 343.) The ultramarine blues come in solid forms, and are insoluble in water. They are very satisfactory, provided they are not allowed to settle on the clothing and make blue spots. The choice of a bluing is a matter of individual taste, any standard kind being good provided it is used intelligently.

Fastness of Dyes. — Certain dyestuffs are fast to light, others to washing, or to other influences, according to the particular requirement of the material. For example, a coat lining should be dyed fast to perspiration and crocking. As it is often desirable to test the permanence of a color before purchasing materials for a given purpose, or having them laundered in the ordinary way, the following experiments are suggested: —

Fastness to Light. — Expose the material to direct sunlight in wet and dry condition for four weeks. If the dye fades at the end of one week, it is considered fugitive; at the end of three, moderately fast; if it has not faded in four weeks, it is considered fast.

To Washing. — Use plain water; look for "bleeding."

Plait a strip of the dyed material with one of undyed. Make up a solution of ten grams soap in a liter of water, heat a small portion to about 60° C., and work and squeeze the material in this for about ten minutes. Rinse in cold water, let lie in water fifteen minutes, wring out, dry. Note change in color of material or washing water, and any bleeding on the undyed piece. To test whether the color is proof against severe treatment, repeat the above with strong laundry soap, with and without washing powder.

If the color is inclined to be fugitive, experiment with salt, aluminium acetate, or vinegar in the washing water. A mordanting solution composed of one teaspoonful of potassium bichromate, two teaspoonfuls of copper sulphate, and two of vinegar in a gallon of water may often fix a color that is fugitive to washing. Warm the material in the solution for about ten minutes, remove and rinse. Some colors are changed by this treatment, so a sample of the fabric should be tried first. Materials dyed dark blue are generally successfully treated in this way.

To Perspiration. — Steep portions of dyed material in either of the following solutions for five-minute periods, drying the sample after each immersion. Examine fabric day by day for change: —

1. A solution of 50 gms. of 50 per cent acetic acid and 100 gms. common salt per liter.

2. A solution of 50 cc. of 50 per cent acetic acid and 25 cc. of butyric acid per liter.

To Rubbing. — Rub dry sample vigorously on white material and observe any crocking.

Materials bought by the United States Government must meet certain requirements (see Chap. X), and are tested in part as follows: —

Washing Test. Boil for ten minutes in a solution containing 80 gms. of olein soap (army issue) to one pint of water.

Laundry Test. Boil for ten minutes in a solution containing 10 gms. of dry sodium carbonate to one pint of water.

Roof Test. Expose to weather for thirty days.

Perspiration Test. Soak for 24 hours in lactic acid of specific gravity 1.21.

Bleaching Agents

Calcium or Sodium Hypochlorite. — The first of these may be taken to illustrate the type of chemical action. Calcium hypochlorite, commonly called bleaching powder, is soluble in twenty times its weight of water. When treated with an acid, it gives up chlorine, which unites with water to form hydrochloric acid and free oxygen. The latter oxidizes organic coloring matter and therefore bleaches. The reactions, using acid, are as follows: —

$$Ca(OCl)_2 + 2\,HCl \rightarrow CaCl_2 + 2\,HClO$$
$$2\,HCl + 2\,HClO \rightarrow 2\,H_2O + 2\,Cl_2$$
$$Cl_2 + H_2O \rightarrow 2\,HCl + O$$

The reactions with sodium hypochlorite are similar. The action may take place without the addition of acid, the carbon dioxide of the air forming carbonic acid, as follows: —

$$Ca(OCl)_2 + H_2O + CO_2 \rightleftarrows CaCO_3 + 2\ HClO$$
$$HClO \rightarrow HCl + O$$

Silk and wool would be destroyed by the alkaline nature of calcium or sodium hypochlorite, and yellowed by the free chlorine. These bleaches are therefore used only for vegetable fibers.

Experiment. Soak the material to be bleached in a weak solution of bleaching powder, with and without the addition of hydrochloric acid. After bleaching is accomplished, wash and treat with dilute acetic acid, in order to decompose remnants of bleaching powder and calcium carbonate in the goods. Finally wash free from acid.

Hydrogen (or Sodium) Peroxide. — These are largely used in the bleaching of wool and silk, but may be used for cotton. Oxygen is given up ($H_2O_2 \rightarrow H_2O + O$), which unites with the organic coloring matter of the pigment and destroys it. Hydrogen peroxide gives up its oxygen most freely in an alkaline bath. Ammonia or borax, which will not injure wool, may be used, although sodium silicate is the ordinary agent.

Experiment. Immerse scoured wool fleece in hydrogen peroxide diluted with five to fifteen volumes of water, and make slightly alkaline with borax. Keep temperature at about 40° C., and let action continue several hours. Moderately increasing the temperature hastens the process.

Hydrochloric Acid. — This precipitates the color from direct cotton colors (substantive dyes), and from basic dyes. In the first case a free color acid is formed, and the lost color can be restored by using an alkali. In the latter case an acid salt of the basic dye is formed. Hydrochloric acid can be used as a bleach and color remover in many operations.

Potassium Permanganate. — This is a powerful oxidizing agent, therefore is particularly valuable as a bleaching agent and stain remover. It is used for vegetable fibers in neutral or acid solution. In acid solution the following reaction takes place: —

$$2\ KMnO_4 + 3\ H_2SO_4 \rightarrow K_2SO_4 + 2\ MnSO_4 + 3\ H_2O + 5\ O.$$

In neutral solution, manganese dioxide is precipitated on the material, making a brown stain. This may be removed by treatment with sulphurous acid or sulphites: —

$$2\ KMnO_4 + H_2O \rightarrow 2\ KOH + 2\ MnO_2 + 3\ O.$$
$$MnO_2 + H_2SO_3 \rightarrow MnSO_4 + H_2O.$$

Experiment. Use a cold 1 per cent solution of potassium permanganate, applying it to the dye or stain with a stirring rod. The permanganate may be acidified with 2 per cent oxalic acid, or it may be applied in neutral solution, and the resultant brown color removed by rubbing in sodium bisulphite, sulphurous acid, or a mixture of pulverized oxalic acid crystals and sodium hyposulphite. In the last case sulphur dioxide is generated, which quickly bleaches the fabric. Wash thoroughly at the end of the process. This treatment is efficacious in removing almost all kinds of stains from white material.

Javelle Water. — This is similar to bleaching powder, sodium hypochlorite being the bleaching agent. To prepare, dissolve one half of a pound of bleaching powder in two quarts of cold water, and add this to a solution of one pound of washing soda in one quart of hot water. The reaction is: —

$$Ca(OCl)_2 + Na_2CO_3 \rightarrow 2\ NaOCl + CaCO_3.$$

The sodium hypochlorite breaks up as in the case of the hypochlorite of calcium, yielding hydrochloric acid and oxygen. Javelle water is a bleach for cotton or linen, and is used in weak solution.

Zinc Dust and Acetic Acid. — This combination acts as a reducing agent in that it sets free hydrogen, which decolorizes the organic matter. All organic coloring matter can be decolorized by the use of suitable reducing agents. In this case the reaction is: —

$$2\ CH_3COOH + Zn \rightarrow Zn(C_2H_3O_2)_2 + H_2.$$

Experiment. To the material in 20 cc. of water add 20 cc. of acetic acid of 25 per cent strength, and 5 grams of zinc dust. Mix well, heat to boiling and boil a few minutes.

Sulphur Fumes. — Sulphur fumes are used for bleaching animal fibers, as wool or silk would be turned yellow by the chlorine bleaches. The clean wet article may be hung in a confined space over fumes of burning sulphur, such as the sulphur candle furnishes. The sulphur dioxide of the fumes reacts with the coloring matters, withdrawing oxygen from them and so reducing them to colorless substances.

Oxalic Acid. — Oxalic acid is a reducing agent. It breaks up as follows: $(COOH)_2 \rightarrow H_2O,\ CO_2,\ CO$. The carbon monoxide takes up oxygen from the organic coloring matter to form carbon dioxide, and in so doing decolorizes. Oxalic acid may be used on vegetable fibers if it is not allowed to dry on the material.

Removal of Stains

Grease Spots. — If soap and water cannot be applied, use a solvent for the fat of which the grease spot is probably composed. Such solvents are benzine, gasolene, naphtha, ether, chloroform, carbon tetrachloride, hot alcohol, and a mixture of equal parts of benzol and acetone. All are inflammable except chloroform and carbon tetrachloride, and must be handled accordingly. To apply, place a cloth or several thicknesses of blotting paper under the spot. Rub from outside toward the center, using a piece of the same material if possible; if not, a similar fabric of the same color. Another measure to prevent the formation of a ring is to mix the solvent with talc, magnesia, starch, or other absorbent material before using, and brushing out the powder when dry. The solvent is generally applied to the wrong side of the material. Grease spots which cannot be removed in the above way are treated with absorbents — talc, starch, whiting, or blotting paper. A warm iron on the blotting paper or other absorbent aids by melting and drawing out the grease.

Vaseline. — Vaseline spots should be soaked in kerosene before soap and water are applied.

Coffee, Tea. — Ordinarily, coffee and tea stains can be removed by pouring boiling water over them from a height, or by treatment with warm soap solution and subsequent washing. Glycerin is a solvent for the coloring matter, and may be used in removing the stain from white or colored fabrics, even of silk or wool. Moisten the stained material with diluted glycerin, to which a little ammonia may be added if the color of the fabric will not be affected. Let the action continue until the coloring matter has been absorbed, then either wash out the glycerin in warm, soapy water or steam it out. If the stain is old, a bleaching agent may be necessary. Spot with hydrogen peroxide made slightly alkaline with ammonia, follow with dilute acetic acid, and finally with water.

Chocolate or Cocoa.—Cover with borax and soak in cold water.

Fruit Stains. — Boiling water will generally remove fruit stains when fresh, except peach stains. If a bleach is needed, try hydrogen peroxide with ammonia, or soak in weak Javelle water for a few minutes and rinse well in boiling water. A general rule is that hot water is used for colors held in sugary solutions, and cold water for unknown stains and for those of a protein nature.

Iron Rust. — This is often the result of the careless use of bluings having an iron base. An acid is necessary to change the iron hydroxide or oxide into a soluble compound, and as hydrochloric acid acts readily and forms soluble chloride of iron, its use gives the best results. The acid should be repeatedly applied to the spot with a stirring rod or medicine dropper, and the fabric rinsed after each application. Many short applications are better than one long-continued one. When the stain has disappeared, rinse in clear water and in ammonia water. Oxalic, citric, or tartaric acid is often efficacious, and salt and lemon juice operate in a way similar to hydrochloric acid.

Bluing. — Use strong ammonia, or boil with dilute acid or alkali. Boiling with clear water is often sufficient.

Grass Stains. — Use milk, alcohol, or ammonia. Hydrogen peroxide with ammonia is also effective.

Molds or Mildew. — Two forms of mold are commonly found, the green and the pin mold. Both flourish under moist, "airless" conditions, at a temperature of 68° to 75° F. The green mold can exist at freezing temperature, and up to 95° F.; the pin mold lives in slightly narrower limits. Both produce enzymes which hydrolyze starch or sugary matter. It has been stated that free citric or oxalic acids may result from the hydrolytic action of the green mold, and glycerin and succinic acid from the pin mold. When the stains are newly formed, they may be removed by strong soap solution and sunlight, or by soaking in sour milk (lactic acid). Old stains require strong bleaching solutions such as calcium hypochlorite. One method of treatment is to saturate with ammonia, followed by spotting first with potassium permanganate, then with hydrogen peroxide, followed by washing. With colored fabrics, the bleaching agents are omitted, and ammonia followed by acetic acid is used or the material is covered with a paste of powdered chalk and exposed to the sunlight.

Paint or Varnish. — If fresh, use turpentine, benzine, or gasolene. If old, soften with amyl acetate, then remove with gasolene. The principle is the same as in the treatment of grease. If the oil in the paint is dissolved and removed, the insoluble coloring matter will brush off. In removing lacquer, dissolve the linseed oil constituent with amyl alcohol.

Scorch. — If the fiber is not damaged, sunlight will remove. Soft bread crusts rubbed over the scorched places will often be efficacious.

Ink. — The proper treatment is uncertain, owing to the difficulty in ascertaining the nature of the ink. Colored material may be soaked in sour milk, — other ink removers generally remove color also. As a rule, the ink eradicators depend for their action on free chlorine developed by the addition of an acid to a solution of calcium chloride. Alternate applications of a solution of bleaching powder and dilute hydrochloric or oxalic acids will serve the same purpose. Salt and lemon is as safe and often as adequate in mild cases. Another method recommended is the use of fresh crystals of stannous chloride, followed by oxalic acid. Stannous chloride reduces iron in ink to the more soluble ferrous form, and also prevents some loss of color in the fabric.

Blood Stains. — Cool water, followed by washing in lukewarm soapy water, or water to which ammonia has been added. A lump of starch rubbed into a spot which has been moistened with cool water will absorb the blood. The starch is brushed out when dry, and the treatment repeated if necessary. Old stains may be removed by hydrogen peroxide with ammonia, or potassium permanganate.

To clean straw hats dissolve one ounce of "salts of lemon" in a pint of hot water, and add one ounce of flowers of sulphur. Apply with a brush. Rinse quickly but thoroughly.

CHAPTER XV

HYGIENE OF CLOTHING

The Hygienic Importance of Clothing. — The importance of clothing as a means of maintaining a good physical condition has not yet received the consideration it deserves. A conscious hygiene for the whole body is being emphasized in these days, and it is a most necessary part of this movement that people in general shall recognize that our modern garb, unhygienic in many details, is a large factor in the problem of keeping well, and that rational clothing will not only aid in warding off many diseases, such as tuberculosis, but will be greatly effective in bringing about the desired state of perfect health.

The Body in Its Ideal Condition is maintained at a constant temperature, is dry, clean, well ventilated, and so unrestricted that all its parts can function properly. To meet these needs is the special province of clothing, and that worn next the body must be chosen with reference to its heat conductivity, its capacity for absorbing moisture and affording ventilation, its cleanly qualities, and its weight and fit. The properties of different fibers and textile weaves, the choice of garments hygienic as to fit and fashion, and many other considerations enter into this important study of clothing in its relation to bodily welfare.

Clothing in Its Relation to Body Heat. — The principal object of clothing is to aid in the maintenance of a constant body temperature. No matter what the climatic conditions may be, or what sudden changes in the environment may occur, the healthy body must keep a temperature of about 98°. Very slight variations are normal, but a variation of a few degrees in either direction may be fatal to life. In itself, the human organism has two ways of maintaining heat equilibrium — by chemical and by physical regulation. An instance of the first method is seen in its adjustment to a falling temperature or to sudden cold. The nerves in the skin respond to the new condition, and cause a constriction of the blood vessels supplying the skin; the flow of blood to the internal organs is now greater, and heat is increased by increased oxidation, just as furnace heat is maintained by the addition of fuel. This is called "chemical regulation" because it involves an increased amount of oxidation in the body. Variations in the quantity of blood sent to the skin, affecting the loss of heat by conduction, convection, and radiation, and the varying production of perspiration, affecting the loss of heat by evaporation, are factors in the physical regulation of temperature. The term "physical regulation" implies that the body temperature is maintained without necessarily changing the rate of oxidation. The unclothed races of men meet the demands of the body by increasing their food supply, when chemical regulation of temperature is necessary. Primarily, clothing is intended to do away with the necessity for "chemical regulation," and so conserve body energy and incidentally save fuel. It fulfills this purpose when it provides the body with a covering of equal warmth throughout, adapted to the requirement of the day. The present fashion of exposing the chest and ankles in cold weather makes an unnecessary demand upon body energy which the individual can seldom afford, especially if the dietary has been cut to a minimum for the sake of fashion or for other reasons. In that case the margin of energy available for the maintenance of health is being run dangerously low. Another practice which should be absolutely condemned is the exposure of a child's legs and knees except in the hottest weather. Children require warmer clothing than adults, because of their greater proportional surface area and their need of reserve energy for growth; yet, for the sake of "hardening" the child, or sometimes merely following a fashion, the parent often leaves bare some of the parts of the body which are least capable of resistance. The joints are peculiarly susceptible to cold, because they are areas of slight metabolism, and depend upon adjoining parts for their heat supply.

An attempt to harden the body by exposure is now more difficult than it was in primitive life. Houses, cars, and public buildings are, as a rule, overheated in winter, and the alternation with the cold and dampness out of doors creates a trying condition requiring careful adjustment to it in the matter of clothing, else the resistance of the body is weakened. It is not unusual to see people in heated trains or public buildings keep on their furs and heavy wraps, with consequent overheating. In going into the outer air a feeling of chill is indicative of danger. Standing in the cold air without extra wraps, with thin stockings and slippers, or in evening dress after a dance, is a menace to health. Some hardy people can do these things, but never without an expenditure of energy which could be better employed.

In cold weather especially, the requirements for outer and under garments are different. The main requirement for the outdoor covering is warmth. Most people dwelling in well-heated houses find it best to wear light-weight garments indoors, and depend upon the outer wraps for the extra warmth needed out of doors. Some weight is required, yet two light-weight garments will be warmer than one heavier. A close weave on a windy day is better than an open weave, because it prevents a too free passage of air to the body. Garments worn next the skin, when chosen on hygienic principles, are open in weave, light in weight, and provide ventilation, yet bring the loss of body heat by conduction and convection to a minimum. The amount of heat conducted by a garment depends very little upon the nature of the fiber in it, but a great deal upon the amount of air held in its meshes. Still air (air not in motion) is a poor conductor of heat; furs are especially warm simply because they imprison so much air. No fiber possesses warmth as an innate property, but wool feels warmer than other fibers because it holds more air.

By virtue of this property of non-conduction, wool would be the ideal material for underwear, if other considerations did not affect the conclusion. Some of these will be discussed later; one drawback to its use is the fact that the wool fibers easily mat from washing and other causes, and the air spaces become obliterated. A felted, boardlike wool garment has lost its feeling of warmth. However, a loose weave of wool, carefully laundered, or wool mixed with one quarter to one half cotton is the best cold-weather undergarment for aged people, invalids, and little children, or all with whom there is little perspiration and little blood brought to the skin by muscular activity. A child is comfortably clad in winter in underwear of wool to ankles, wrists, and neck; an underwaist of heavy cotton, warm stockings, shoes with good soles, a plain dress of substantial cotton, wool, or part wool, and gymnasium trousers like the dress. For outdoor wear, a flannel jacket or sweater under a medium weight coat will prove warmer than a single heavy coat.

As has been indicated, the secret of non-conduction of heat lies in the loose weave or open mesh. Cotton and linen woven in this way acquire a feeling of warmth, and possess advantages over wool in points of cleanliness, ventilation, and evaporation of moisture. For most people they make the most satisfactory year-round undergarments. Too open a mesh, however, will defeat its purpose by allowing a free movement of air, and heat loss by convection. Silk combines well with either cotton or linen, and adds its value as a non-conductor of heat. Alone, its smooth, elastic feeling is often unpleasant, but the Chinese utilize it wisely by wearing it over a very open weave of cotton. The same idea, using wool in place of silk, has its advantages, and is a protection against sudden changes in temperature.

Warm-weather underwear differs from that of winter in little except quality of weave. The body's needs are the same, and the difference is mainly in the outer dress, with perhaps a wider mesh in the light-weight cotton or linen undergarment. Both cotton and linen, being good conductors of heat, feel cool in smooth, close weaves, — linen especially; and the latter gives an added feeling of coolness by the rapid evaporation of moisture from it. A linen garment of this kind may cool the body too quickly and cause a chill. There is from 15 to 30 per cent more heat protection in cotton than in linen of equal weave and thickness.

Clothing in Relation to Absorption. — The sweat glands of the average adult give off a daily secretion of about fifty ounces of water. As most of this must be taken up by the clothing, in addition to gaseous and solid constituents of the sweat and oil from the sebaceous glands, the manner in which different fibers absorb and discharge all this material becomes most important. To keep the body in good condition the glands must not become clogged; perspiration must be removed about as fast as it is formed, for that is the time the body needs cooling; it must not stay in the garment to give a feeling of dampness and chill to the cooled skin, and the air pores of the garment must not become so clogged as to prevent ventilation.

Of all the textile fibers, wool is the most hygroscopic. Under ordinary conditions it carries moisture up to 12 or 15 per cent of its weight, and in moist surroundings may take up 30 to 50 per cent. Being a natural skin covering, it is well adapted for the absorption of sweat and oily secretions, but its power of holding these is a disadvantage in a garment. It not only absorbs moisture slowly, but dries slowly. The result is that it becomes very damp, and while this does not prevent it from feeling warm in still air, in a draft of cold air the heat conduction is rapid and the body receives a chill. Dr. Leonard Williams, in an article on "Tubercle and Underwear," in the Clinical Journal, December 10, 1908, said in effect that the serious objection to wool as underwear is that it does not absorb and give up moisture rapidly; the air spaces are closed in the laundry, and the respiratory function of the skin is interfered with by a layer of moist air held between the skin and the garment, which disturbs heat regulation " since it has the same influence as a poultice in keeping the cutaneous vessels in a state of undue relaxation."

Silk is nearly as hygroscopic as wool, but it loses moisture much more rapidly. In open mesh, it has many ideal qualities for underwear, since it is a poor conductor of heat and electricity, and is cleanly.

Cotton and linen are about equally hygroscopic, each taking up perhaps 7 to 12 per cent of moisture, but linen yields it the most readily of any textile fiber. Again the open mesh is needed to counteract the dangerous element of too rapid evaporation.

Clothing and Cleanliness. — A question closely connected with absorption is the ease and thoroughness with which undergarments of the different fibers can be freed from the products of the skin and kept in a sanitary condition. If it is the nature of the textile to hold the dirt and harbor germs, or if the garment is infrequently or carelessly washed, impurities are kept in contact with the body, and infection and disease are invited. Quite as much difference exists between the fibers in respect of natural cleanliness as between their absorptive capacities.

Of the textiles ordinarily used for undergarments, linen is the cleanest because of its smooth surface and lack of natural oil or grease. Cotton yarn has more or less oily matter and many protruding ends of the short fibers in the twist, both of which affect the weave. Experiments have shown that about three times as much dirt clings to cotton as to linen, and nearly twice the number of bacteria will be collected by the skin when wearing cotton, in a comparison of similar weaves of the two. However, cotton launders easily, and can stand a high temperature in sterilization; so with frequent changes it is a sanitary material.

Woolen underwear is the most difficult to keep clean. The natural capacity of the fibers for storing up oily and sweaty secretions makes more than ordinary care imperative, and the difficulties lie in preventing the felting of such impurities into the garment. Loose weaves can be satisfactorily cleansed by expert laundering, but neither strong soaps nor boiling water can be used. Bacteria flourish on woolen underwear, and when this is soiled, they multiply upon it more rapidly than upon an equally soiled garment of cotton or linen. The chest protector which is the constant friend of some people during the winter, the abdominal band of flannel which others find advantageous, and the swaddling bands of the babies of some nationalities should obviously be changed as often and laundered as thoroughly as ordinary underclothing. The textiles which are in contact with the skin are obviously of greatest importance as regards absorptive qualities and cleanliness. Outer garments, however, are by no means free from criticism, and the cheaper transitory materials have in this respect a certain advantage over those bought for long wear. The effect of dry cleansing on clothing of better quality as eliminating dangers must be considered. Wool outer garments hold large quantities of dust, and need to be brushed frequently, not only for appearance, but for health.

The hygiene of the sweatshop and the laundry, and other questions of public health in connection with clothing, are subjects too large to be discussed here. A few rules of sanitation for the home laundry, however, may be emphasized. Soiled clothing should be kept in absolutely clean hampers. The usual wicker one, which is seldom cleaned, often contains myriads of bacteria; a vulcanized or white metal holder is better than a basket. A washable bag of heavy material kept absolutely clean can be used inside wicker hampers and eliminate much of the danger. Separate laundry bags should be used for handkerchiefs or especially soiled articles used in colds or disease, and the entire bag soaked in salt and water before washing the articles in it. Extremely soiled clothing should not be washed with cleaner articles. Steam laundries are usually better than the home laundry as regards sterilization of clothing, because of machine processes and factory inspection. Cotton is the only textile that can well stand boiling. Most bacteria in clothing will be killed, however, by keeping the temperature of the water in which the garments are being washed constant at 150° F. for some time. Tests have been made as to the disinfection which occurs from the heat of the flatiron. As yet nothing more definite has been proven than that very great heat on a moist garment, with pressure on both sides, will kill germs. At lower temperatures the result is not so satisfactory. Many textiles cannot endure so much heat. Alkaline soaps act as sterilizers, but must be used with discrimination

An Unrestricted Body. — A body impeded in any of its movements or functions can never be highly efficient or perfectly well. Tight clothing whether shoes, corsets, or skirts, or clothing so heavy that its weight is a burden, is worn at a sacrifice not only of comfort but of health. Poorly fitting, tight corsets lay the foundation for poor health in later life. Corsets are not really necessary to a woman who has strong muscles. If they are worn, they should fit well, be adjusted carefully each time they are put on, and should be loose at and above the waist, that plenty of room to breathe may be allowed. Garters suspended from the corset may be overtight and very injurious since they bring a pressure downward which may lead to serious displacements. Heavy skirts hanging from the waist increase the pressure, and should not be worn. It would be better to have all such weight suspended from the shoulders. Collars are frequently too tight, and the method by which they are held in place by wires and bones adds to the pressure. Bands about the waist should be loose enough not to cause marking of the body. They should be worn over a waist of some kind and not come directly against the flesh. Shoes should be as straight on the inside line as possible, should fit the heel and instep snugly, and leave the toes free. The heel should be broad and low, and the sole thick enough to be substantial. Pointed-toed shoes have a tendency to weaken the arch of the foot. Many of those who complain of rheumatism in the feet have broken-down or weakened arches, and are really suffering from the shoes they have worn. Orthopedic shoes can be obtained to relieve the pain or even cure the condition if it is not too serious.

Dangers in Textiles. — It should be realized from the above that real dangers may lurk in textile materials and clothing. A large amount of ready-made clothing is made in unsanitary homes, in sweatshops, or tenement rooms, and it is known that disease is carried in this way to the homes of the consumers. Poor or fugitive dyes in textiles or in hosiery may cause trouble. Bright-colored, striped cotton-flannel shirts have been known to injure those who are working in overheated workrooms or before hot furnaces, and black stockings may poison the skin, especially when it has been broken or scratched. The towel for the general use of the public may be more dangerous to health than the common drinking cup. Small individual towels which are kept absolutely clean by repeated laundering should be used in schools or public toilet rooms. If these are too expensive, paper towels may be used, but they are not altogether satisfactory.

When all is said, personal environment and idiosyncrasy must influence an individual's choice of textile and manner of dress. Wool may be the right material for one case because it does not evaporate moisture rapidly; in other cases this property is disadvantageous. The value of a study of the hygiene of clothing lies in the ability it gives to make an intelligent adjustment of clothing to one's needs, and further, to see the value of dressing according to good sense rather than fashion. Women are flagrant offenders, but not all the efforts of the clothing reformers should be directed at them. As a whole, the clothing for men shows superior good sense to women's, but men's attire is quite deficient in its adjustment to heat regulation, nor can much be said for some of its details such as stiff, unventilated hats and stand-up collars. It may be unusual to defend women's hats, but from a hygienic standpoint they are generally better than the derby and top hat. An interesting experiment in temperatures has been made[1] whereby a thermometer kept in a top hat showed an inside temperature of 90° F. when the outer air stood at 77°, and of 108° when the temperature rose at noon to 90°. In the evening there was a temperature outside of 68° and inside of 88°. A motor cap showed 98° inside against 78° outside.

Scientific investigations of many kinds are needed that more knowledge may be gained of the relation of clothing to health. We need further data on the increase of germ life on various textiles when they are clean or soiled or when disease is present, and the effect of laundering and other methods for the elimination of bacteria; a study of fugitive dyes, dressings, and treatments, and the effect on the skin; the influence on the body of each fiber and the union of different fibers; thermal properties of textiles, and the relation of weight and pressure in clothing to bodily condition.

[1] Cavanagh: *The Care of the Body.*

CHAPTER XVI

SOME ECONOMIC AND SOCIAL ASPECTS OF TEXTILE PURCHASE

Among the greatest industries in the United States as in other civilized countries is the series of occupations which supply textiles for clothing and household purposes, and here the kind of materials made, the later use of the products, and to some extent the condition of the industries may be said to be chiefly in the hands of the women who are the chief purchasers and consumers.

The value of the combined products of the textile industries in the United States in 1909 was $1,684,636,499 (U. S. Census of Manufactures, 1910). According to the Bureau of Foreign and Domestic Commerce, the value of the product in the manufacture of clothing in 1909 was:—

Clothing, men's and women's,	$953,610,000	
Corsets,	33,257,000	
Hats and caps (other than felt, straw, and wool),	13,689,000	
Hats, fur and felt,	47,865,000	
Hosiery and knit goods,	200,143,000	
Millinery and lace goods,	85,894,000	$1,334,458,000

The imports of textiles including wearing apparel in the United States in 1912, as stated in the bulletin of the Bureau of Foreign and Domestic Commerce was:—

Cotton and manufactures,	$85,305,516.43	
Fibers and manufactures,	96,085,213.84	
Hat materials and manufactures,	9,158,943.94	
Silk and manufactures,	97,889,203.84	
Wool and manufactures,	48,324,102.16	$336,762,980.21

In the same year, 1912, the import of clothing alone into the United States was:—

Cotton,	$7,142,787.74	
Fibers,	305,188.27	
Hats, etc.,	4,292,900.94	
Silk,	4,142,318.05	
Wool,	2,190,301.60	$18,073,496.60

An economic study of woman as a textile consumer is yet to be written, but thoughtful women can be of service now in considering the subject and obtaining data from homes, stores, and factories, that knowledge may be available on which to base some needed conclusions. Former chapters are referred to for other economic facts on the development, growth, and manufacture of the various raw materials; the conditions of strength or weakness in the yarn or cloth on account of the treatment undergone; the adulterations practiced or the substitutes for the pure fiber; commercial data and the present state of the textile market. The tariff charges placed on importations of raw fibers and manufactured goods have their economic effect on the cost of textiles. It seems unwise to enter upon a discussion of the influence of the tariff further than to point out the great amount of data available in Government publications on the subject.

For the promotion of the intelligent interest and efficiency of the consumer of textiles it may be suggested that club women could consider general economic relations, make investigations in the factories, department stores, and clothing workrooms, and make their deductions. Women in the home could bring together data of the use and care of materials and give budgets which had been tried and found successful. College women and higher technical students could furnish scientific data from their chemical, physical, and biological experiments, and girls in the elementary and high schools could study the materials that are manufactured and connect the subject with their school or home work in sewing and dressmaking and the choice of household linens, including the table linen used in connection with cookery and table service.

The increase of individual wealth in the United States has made possible the spending of larger sums than ever before in personal adornment and in the interior decoration of the house. A general tendency is now found among women of all classes to spend an undue amount of their income on dress. This is true not only of the rich women whose extravagance in dress is notorious, but also of vast numbers of those in moderate or even straitened circumstances whose expenditures for dress, though not absolutely large, are out of proportion to the means available for other necessities. The market has been affected by the demand for large supplies of material for garments, and consequently the prices for textiles and the cost of making them up have risen greatly and caused much hardship among the very poor.

It has been argued that the large sums spent for clothing by many women have been an advantage to the poor in that money has been placed in circulation and therefore the workers are benefited. This argument is especially unsound as affecting the production of woman's wear, for the workers are often overworked at extra hours without pay to supply the demand. There are many reasons why extravagance in clothing is not advantageous, such as (1) the money which is spent in such dress is badly invested and is failing to obtain, either for the individual or for the community,[1] the good returns of well-invested money; (2) it is having a deteriorating effect on the spenders by increasing their selfishness; (3) it is setting a pace which is followed by those of less means in the use of flimsy, showy fabrics which not only do not endure, but often have a degrading moral effect on the wearers; (4)

[1] From the standpoint of the community there is an irreparable waste when human energy which should be directed to the production of the necessities of life is diverted to the elaboration of superfluous things.

irritation is caused in those who desire but cannot afford such gratification; (5) and it increases a general tendency on the part of the young wage earner to sacrifice housing and food in order to spend too much of her wages on display in dress.

The Need of an Economics of Consumption. — The ability to use money wisely has not increased as rapidly as wealth. The importance of woman's part in economics has not been understood and has been underestimated. The production of wealth has heretofore occupied mankind's attention to the exclusion of the best way to use it. It is principally as women have appreciated their responsibility for the right use of the money intrusted to them that attention has been given to the laws which should govern consumption. Many women have turned for help to economics only to find the emphasis on production and commercial relations rather than on choice and purchase, and are urging a consideration of the latter phases of the subject also. There are some difficulties in the way, however, for those versed in general economics need information on the household use of wealth before they can feel competent to speak on laws which should govern selection and purchase and prevent waste.

It seems necessary, therefore, to consider the various fields in which woman's influence as a consumer is preëminent in order to provide the required information. The textile field is one in which to begin such study. Before the Industrial Revolution women were the home producers of all cloth. They not only decided what should be made and how to make it, but judged the worth of it afterward. They later used the woven material to make the needed clothing and household articles for their homes. In 150 years from that time women have become principally consumers, with little ability to judge of the value of the materials they buy. It is true that many of them still remain producers in textile mills, though in the capacity of hands rather than of heads. We also find some women producers of a higher type as forewomen in the great clothing industries where textiles are manufactured into garments, as dressmakers and as makers of clothing in the homes, but at the same time they also are apt to be consumers without sufficient knowledge of the use of money. A large class of influential women, however, are consumers only. As a class, women neither choose materials wisely nor indicate satisfactorily what shall be produced from the manufactured goods — hence are not efficient as planners or users of wealth for textiles. Their demand is, however, having its effect on the quality of the output, for the goods and clothing produced are made to satisfy them.

The Consumer's Influence on the Manufacturer. — The present efficiency of the textile factory is often in the skill it can show in satisfying the demand for effective goods at a low price, in the management, in the patents, and in methods by which wealth is accumulated rather than in producing an enduring fabric. For various causes, of which the influence of the consumer is a large one, there is on the market at present a flood of unenduring yet attractive-looking textiles which frequently are worth less than they cost the purchaser and which are so cleverly constructed that even the textile expert finds difficulty in determining their value. It is almost impossible to find the strong, enduring, hand-spun, hand-woven materials of the past. The economic question to be answered is: Do we wish only the purest and best materials to be manufactured, or do we also need the cheaper materials, and that each consumer shall be able to know or be informed of the imitations, the adulterated and union goods, and thus not only distinguish them from the better and purer materials, but be asked to pay only for the values really received? The ability of the manufacturer to make a cheap fiber, like cotton, give warmth in such articles as blankets, sweaters, underwear, and bedding, is indeed of inestimable value to the poor and is to be encouraged, but an undue price should not be charged nor properties claimed which are not present. The rapidity with which fashions in dress change is a factor in the customer's desire for the well-appearing yet inexpensive materials and naturally has its consequent reaction on the manufacturer. The latter's risk is great if he makes goods ahead of the demand, for he must expect that broadcloth may suddenly be desired in place of a heretofore fashionable worsted suiting, or pin stripes may be called for when he is stocked in plain-colored materials. Entire mills may be thrown out of work or expensive machinery may be rendered useless by these rapid alterations of fashion. Sudden changes from fancy suiting to plain cloth will often leave a factory overstocked with no resource except selling at a loss, redyeing and selling the material as plain cloth, or tearing up the cloth into shoddy. Moreover, changing fashion often causes clothing to be discarded before it is half worn. Such garments are torn up to supply wool for new cloth, as there is not enough wool in the world to make so many fabrics entirely of pure fiber. The amount of material required for garments has also its effect on the factory production, for fashion causes variations, and it is not an unusual condition for twice as much goods to be used in a gown one season as in the next. Every textile mill has men in the field trying to determine, months ahead, what the fashion will be, or endeavoring to create a demand for some specialty which they wish to sell. The strain upon the manufacturer is often great, and much of it could be lessened if women realized their influence and would endeavor to exert it wisely.

Most of the American-made cloth compares favorably with that of Great Britain and the continent of Europe, but public demand for some of the finest material is made upon foreign countries; consequently American factories are obliged to specialize on medium-grade fabrics. Domestic goods when equal in quality should have the preference with American consumers. If the experience in making the better goods were given to the home factories, they would soon overcome any difficulties with texture and color, of which we now sometimes complain, and be able to supply the best. We have already many firms which make the highest class goods. A movement toward the use of domestic goods would be of benefit, therefore, not only in developing the work of some of our factories, but also in removing foreign labels from many of our domestic goods.

A Law for Honest Labeling. — In order to help women to obtain honest materials there are now before the House of Representatives in Washington several bills for the honest labeling of textile goods. Few women yet realize the need of such labels or would be apt at present to profit by the passage of such a measure. A practical consideration of the values and conditions of the materials they buy, and their effect upon the economics of the household, must come first to open their eyes to the value of a government labeling system and to the work of supervision which must accompany it, which would be an expense reacting again perhaps on the price of cloth.

Dress has its economic significance, for people well dressed in the style of the period are generally regarded as successful. This may be a recognition of the success of the individual or of the head of the family. The women of a family are selected as a means of showing wealth, and a well-dressed family reflects distinction upon the one who is responsible for its support. This has been undoubtedly one reason for excessive dress in women. The extent to which they have been physically handicapped in their clothes has been another means of showing that sufficient wealth is possessed by the head of the family to free the woman from work; and that therefore her activity may be interfered with by tight clothing, trailing gowns, lacy trimmings without endurance, shoes in which it is impossible to walk easily, and other evidences of her uselessness.

Economy in Clothes. — There are justifiable differences of opinion on the subject of economy in clothes. Some women prefer a number of inexpensive garments to a few high priced ones. In many homes the clothing for the mother and daughters is made principally in the house, this being considered an economy. A visiting dressmaker comes at each season to help the family with the work of remodeling old and making new garments. The wisdom of this plan is questioned by other women somewhat as follows: Are the results really satisfactory? Is the time taken justified or could the mother and daughters use it to better advantage? Is not the family under a nervous strain which reacts on the home life and is the dressmaker amply paid for the class of work which she is doing?

Another plan used by many is to rely almost entirely on the department stores. Up-to-date, transitory garments are bought and discarded as soon as the newness has worn off. The time taken for home manufacture, the making over, repairs, and the nervous strain of personal construction or several fittings at a dressmaking establishment are superseded by one fitting at the store. Many business women find this method satisfactory and not overextravagant, but much depends on the conformity of the purchaser to the regulation sizes of such garments, since much refitting is both expensive and unsatisfactory. The garments offered in the stores, however, are not suited in style to all women. Some professional women prefer another plan, *i.e.*, they order two or three gowns each year at the higher class custom tailors or dressmakers. The best material is purchased and the styles used are "exclusive" but not extreme. Each garment can be used for two or more years with almost no alterations or repairs. Many who are occupied with social or civic matters are adopting this plan also. They state that they can thus preserve the dignity and individuality of dress without spending too much time upon it. There are other well-dressed women of this type, however, who feel that it does not pay to spend much time at an expensive dressmaker's or tailor's and who are demanding with much success the best kind of exclusive ready-made garments from the department stores. There is still another class which combines all of these methods and insists that innumerable changes of clothing are necessary. They give their personal time to shopping for ready-made garments or for materials, to being fitted at home or at a dressmaker's, and to personal attention to remodeling unless they can afford to pay workers to do everything for them.

Consideration is needed of the best plan for women to forward in the future. Many feel that they will have to adopt an easier and more professional dress, as men have. The tailored suit and shirt waist are valuable steps in this direction. Other women, who accept the business dress as necessary, hold strenuously to the need of preserving the attractive individual dress for its influence in the home and in society. They argue that a still greater study of art in dress is needed in order that beautiful garments may result, and they justify their expense by a willingness on the part of the women to wear them several years. The press is urging the introduction of American fashions for American women rather than the reliance upon Paris. This can be done if women will see to it that in schools of all classes there is given a study of art as applied to dress and home decoration that shall result in our having among us, as there is among all classes in France, the general knowledge of industrial and applied art.

Dress as an Ethical Influence. — The home is the greatest factor in the happiness of the race, and in it woman's part is supreme. As she becomes wiser in selection and purchase, the home will increase in value. Training for economy in consumption should lead, therefore, to higher levels of social life; art should be a part of the background, and social betterment should be a necessary accompaniment. Little is often made of large wealth in ministering to the higher pleasures of home and social life, and the future study of the economics of spending must include a consideration of the highest service that can be given through wise consumption.

Dress has undoubtedly an objective and also a subjective influence. It is recognized that character is shown through it and is itself acted upon by the kind of clothing worn. It is difficult to be self-respecting when dressed in dirty rags, or to win the respect of others when overdressed. One who is content to wear showy outside clothing and inadequate, torn garments beneath has some defect in her of which this condition is merely an evidence. Good nature is easily increased through wearing clean, comfortable, pleasing clothes. The effect on children of being dressed in ragged, inadequate clothing is not only irritating, but also acts on the disposition as well as the health. On the other hand extravagant or showy dress on a child is apt to produce priggishness and selfishness. It is not possible to state the relation in exact terms, but we believe that adequate, attractive, neat clothing is a factor in virtue, and being well dressed gives a feeling of satisfaction and self-confidence which often enables the wearer to conquer a difficult situation.

Practical Investigations. — The study of the economics of consumption must be, therefore, in a large degree a study of the time and its needs, a consideration of the influence of factors large and small in the home life, and a realization of the requirements for woman's training for service in the home, and also in civic and national life.

There are several direct methods by which the judgment of women as spenders of wealth for textiles may be developed, such as a study of the service of each textile, facility in testing fabrics in order to judge of their content, and a consideration of the art of shopping.

Women in their homes, students, or teachers who wish to know more of textile fabrics should begin first a practical investigation of materials for the recognition and naming of standard cloths, well-known mixed goods, and adulterated materials. A card catalogue of fabrics should be made in connection with the study. A sample of cloth can be placed on each card with the name, price, width, and place of purchase. If a guarantee is given, it should be so stated. If the material is in use, its value after trial should be given. Whenever it is possible the name of the manufacturing firm should be obtained, so that by degrees the student can have a list of reliable firms.

A white list of manufacturers would aid the housekeeper in the same way as the white list of department stores of the Consumer's League has shown them where saleswomen receive fair treatment. Other data should be entered as it is obtained, such as the class of weave in any piece of cloth and its relation to strength, the condition of the warp and filling, and a personal judgment as to the reliability of the sample. The card even with simple information, should be a valuable aid to the housekeeper or student and a help toward the formulation of economic laws regarding purchase. Second, the properties of each fiber should be studied comparatively and confirmed by personal experience. The result of unions and adulterations as altering the properties should be noted. The knowledge of the qualities inherent in any textile is an aid in choice, and the hygiene of the material should be considered also as a factor in keeping the body in good physical condition. Third, in order fully to comprehend the present status of the making of textiles, the conditions of growth and manufacture should be studied that a fuller understanding may be gained of the varied state in which even pure material reaches us, of the possible combination of different fibers in any one piece of cloth, of the strain on the fiber which comes in the processes of manufacture, and also of possible injuries from carelessness, haste, poor or strong chemicals, hasty cleaning or bleaching, and cheap dyeing, and of the effect of beauty and solidity which can be given by surface dressing and finishing. The necessary cost for pure and enduring goods becomes apparent when the processes of manufacture are known and also the methods by which cottons are made to look like linen or like wool, sleazy cottons are finished with size and made to look solid and strong, light weight silks are increased in solidity or cotton or artificial silk is mixed with pure silk. Fourth, physical tests (see Chap. X) of the materials should be made to aid in forming judgments and as a means of accumulating information on the market conditions. Chemical and microscopical tests (see Chaps. XI and XII) are the surest, but can be satisfactorily conducted only in the laboratory by the most exact and careful methods; hence homes cannot use them freely. The result of any test should be noted on the card with the sample.

Such a study as indicated above should aid a woman to understand the textile field and help her to determine what she wishes to accomplish in the future.

Labels and Guarantees. — There are still reliable standard materials which are made by mills whose guarantee can be trusted among the many materials made for show. The entire labeling and guaranteeing of materials, however, is at present unsatisfactory as misleading statements are constant. It is quite a common thing to see "heavy all wool" men's suits advertised at $10, "pure silk stockings" at 50 cents a pair, "strong, heavy, pure silk shoe ribbons" at 25 cents a pair, "pure linen" handkerchiefs at 10 cents apiece, and "all linen" towels at 12 cents apiece. Labels on goods are often equally untrustworthy. Foreign labels are placed on domestic goods; "pure linen" is stamped on cotton mixtures, and names are used for inferior goods which suggest the better textile and attract the public unduly; for instance, near-silk, silkaline, flannel, India linen, linon, and flaxon, are all names for cotton goods. Duplex printed cottons at times masquerade as ginghams. The work of embroidery machines is often labeled "hand work" and purchased as such at prices above the real value. Mercerized cotton is sold for silk, and unions of cotton and linen for pure linen. States which have laws against dishonest advertising allow misleading or untrue statements to appear on textiles or clothing without prosecution, so little heed is given to this class of deception. Honesty of statement is requisite if a good economic situation is to be brought about. Such a time will come when women know enough to contradict the false assertion and insist on having the truth. At present a clerk telling the truth usually loses a sale. Saleswomen do not always know the content of the stock, and if they do know, naturally desire to sell their goods, realize that the public is unable to bear the truth, and hence govern their assertions as the customer seems to desire.

The situation which thoughtful women wish to combat is the lack of truthful statement which at present is prejudicial to honest purchase and does not assure the consumer a fair return for money spent, since paying for pure goods does not of necessity procure them. Experiments in shopping for "all wool" flannel have proved beyond doubt that material called "all wool flannel" may have varying percentages of cotton from 50 to 75 per cent. Chemical tests tried on such flannel have shown that a majority of the samples were not "all wool." The price charged varied, and in general was not sufficient for pure all wool, but was higher than was necessary for so large a proportion of cotton.

The economical housekeeper frequently wishes as dependable cloth as the Government demands (see Chap. X), but at present cannot get it. Men's suitings, in general, are more reliable than those for women, as the former demand material which will give longer service. The beginning of textile analysis and testing in some of the best department stores in some of our large cities, the marking of the result of such tests on the bolts of cloth, and the truthful labeling of doubtful commodities in these stores, show the temper of the time and the effort of the retailer to meet the growing desire of the customer to know the content of the cloth she is about to purchase and to have some guarantee that her money is well spent. The time has now come to give the textile and clothing subjects publicity. This can be done through the public press, educational institutions, the department stores, the women's clubs, and the individual housekeeper. The managers of department stores stand ready to coöperate. There are laws in some states requiring honest advertising, and bills are before the Federal Congress demanding honest labeling of textiles. The consumer could bring about the desired economic reform in a short time by organized action.

Shopping. — Each woman must decide for herself or her family whether enduring or temporary fabrics are ultimately the cheapest for her. There is no objection to materials which appear to be better than they are if they are purchased for transient use, but misstatement should not be made about them, and they should be sold at an honest price for cheap goods. Inexpensive materials certainly have their economic place, for the easy soiling of light colors, the tendency to fade, which cannot be prevented in some fabrics, passing whims of fashion, and the outgrowing of clothing make it desirable to have materials which are not too high in price.

There are occasions, therefore, when it pays to buy the best materials and other times when cheap, presentable materials may be more economical. If a child will soon outgrow garments and there is no one to whom they can descend the cheaper goods may be more desirable. When a consumer decides on pure, well-made, enduring fabrics, she must pay the price and expect the materials to wear if care is taken of them. If she concludes to buy cheap, ready-made garments, she must not complain if they soon look shabby. It is true that ready-made clothing, such as one-piece lingerie gowns, lace waists, and underwear, are sometimes cheaper than if made at home, but the materials are not apt to be so good as those which one would buy, and consequently they do not usually wear as well. Cheap materials cannot be expected to endure whether they are in ready-made or in homemade clothing. When a gown is made at an expensive dressmaker's, the cost is more in the making than in the materials. The difference in cost between enduring and temporary material is usually relatively small in the total price paid for a gown, and economy in this case is in purchasing the best goods of the kind. Even the most careless purchaser usually wishes such articles to endure as petticoats, linings, umbrella covers, toweling, table linen, handkerchiefs, sewing silk, sheets, pillow cases, rugs, and other household articles. A frequent cause of unnecessary expense is on account of the lack of knowledge in many consumers of the amount of material required for a garment and the reliance placed on the sales person for the information. Unless there is a special reason for purchasing an extra amount of goods it is usually an economic loss to have more than is needed.

Price is an indication of worth on many occasions, especially at the best stores. It cannot always be relied upon, however, for chemical tests have frequently shown that even the very highly priced dress goods, upholstery goods, blankets, and table linen are not as pure or enduring as the price would indicate.

The consumer who desires to be economical should not make a practice of wandering about the shops to get ideas, for in that way her desires increase and are apt to become confused in her mind with her needs. When garments are really required in a family, the mother should consider the various sides of the question before she does any shopping at all: first, the amount of money she has to spend for them; second, the purpose for which they are needed; third, how long they are expected to wear; fourth, where to buy them, and the best material for the purpose, or ready-made; and fifth, the least amount of cloth which will make them and keep them in good condition. The materials or garments which will be most satisfactory for her need may be, on the one hand, something which will endure for years, or, on the other, a passing fancy only, but she should decide the best course for her to pursue before she is ready to shop. Samples should be obtained of materials whenever there is a question of endurance and tested at home before purchasing, that mistakes may not be made. Bargain sales, as usually conducted, are a doubtful advantage for the ordinary shopper; for poor materials, good materials with defects in the making, silk which is sold because it is doubtful if it will long endure on the shelves, and a few good values are often combined on the counters, and confuse the purchaser. It is really the expert only who is able to judge whether it really pays to buy any of the materials offered in the ordinary bargain sale. There are honest bargain sales which are of the greatest service to the economic consumer who knows what she wants and recognizes good material, but the thoughtless shopper is apt to buy more than she needs. Goods are often offered at these sales in lengths, and in general there is either more material or less than the shopper wishes, consequently she pays for more than she wants or has not enough and thus any profit from the bargain is apt to be lost. Buying the past season's clothing between seasons when the prices are lowered is wise if the purchaser knows exactly what she wants, the amount to spend, and can herself make such changes as will bring the garments up to date.

The mothers who make money go the farthest usually set aside a certain sum for clothing each year and carefully plan all of their purchases that the amount they are allowed to spend may certainly buy the necessities for each member of the family. (See the chapter on Clothing Budgets which follows.) If there is any money left, it can be used for the little odds and ends which "run away with money." Careless buyers often take the bulk of the money for attractive notions when it should have gone for shoes, stockings, underclothing, and everyday dresses. Careful buyers never purchase washable outer and underclothing without considering the laundry, for time is taken in ironing frills and insertions and in mending torn lace and lacy muslins, and the expense is high for having lace-trimmed garments laundered. Clothing otherwise good is made useless and unattractive by torn trimming, while simple clothing continues to look well after much wear.

Making clothing at home in simple style by members of the family has many advantages, if the time of the worker is not of greater value in some other direction. Ready-made clothing is not always constructed of the most substantial material; therefore, homemade garments of good cloth are usually better after repeated laundering and continued wear than those which are ready made. If the latter are purchased, the selection should be made of as simple designs and as good material as possible, in neutral color and with substantial trimming. Elaborate trimming adds greatly to the constant as well as initial expense of dress. Belts, collars, and ties, which wear well, but can be laundered, repaired, and renewed, can be made at home by mothers and daughters whereby a simple garment is made attractive. Knowing how to renovate materials and trim hats is also a help in saving money. The economic household thinks it wiser to buy plain than figured materials and standard rather than ultrafashionable fabrics. It is considered better for each individual to keep to one scheme of color that old waists, skirts, and coats may be kept in use and look well with new garments until they are worn out. Evening and party gowns for young girls can readily be made of mercerized or other cotton materials and wear much better than cheap silks, but must be carefully laundered and frequently pressed. Rompers and overalls for the little children are easily made at home and thus save money as well as prevent the spoiling of other clothing. Cotton crêpe has been lately used much by economical business women for shirt waists, nightgowns, petticoats, and underclothing. The garments can be laundered easily in the room and do not require ironing. When these garments are made from a good pattern and trimmed with narrow linen lace, an attractive result follows.

In the care of clothing brushing, folding, hanging up, washing out stains, and pressing are factors in the length of service. Mending stockings, blacking and repairing shoes, keeping buttons, hooks, and eyes on clothing and wearing aprons when at work, are necessary for people who wish to be economical.

The responsibility of the consumer for the present state of the textiles manufactured for her is closely related to her responsibility for the working conditions of women and children wage earners in these industries. The Federal Census of 1910 shows the employment of children in the manufacture of textiles to be 40,221 in cotton goods, 11,111 in hosiery and knitting mills, 9942 in the woolen and felt industries, and 8143 in silk factories. Large numbers of women and children are employed also in the clothing industries and in department stores. The conditions under which they have had to work have often been appalling; for whereas the Industrial Revolution brought new opportunities for all classes and helped develop a powerful middle class it also introduced heavy problems for wage earners. Long hours of work, uncertainty of employment, unsanitary workrooms, unsatisfactory moral conditions, dangerous occupations, sweatshops with overcrowding and underpay, unfit dwellings and likelihood of disease, child labor, undermined health, and a wage which was often not sufficient to live upon, became a burden too heavy to be borne.

The bad conditions in workrooms have pressed more heavily on women than on men. The lack of rest, the nerve fatigue, the sometimes inhuman treatment and immorality have not only been hard to bear and to combat by girls who had to have money for their families' support, but the undermined physical conditions which often attended the wage-earning experiences have been a menace to the future of the race. The little children that have worked in textile mills, clothing factories, and in sweatshops on artificial flowers, willow plumes, and other articles, in noise, rush, dust, bad companionship, for long hours and upon dull tasks requiring no skill, have been stunted in moral and physical development.

Legislation to improve conditions among the workers began at least a century ago. Since then many improvements have been inaugurated, but there is need of further legislation, of uniform laws in the different states, and of attention to the enforcing of laws. The employment of women and children in sweatshops is passing away in some cities on account of laws which have been enacted and are being carried out successfully, but the home workroom has been particularly difficult to deal with. It is frequently a single room only where work is done by the mother and children as it is obtained from the various department stores and factories, and satisfactory inspection of such places has been almost impossible as their existence is often unsuspected. The entire subject is now under serious discussion. It is a question whether laws absolutely prohibiting home work are the desirable outcome, for many wage-earning occupations are still carried on in homes under the best conditions by craft workers, by those who are too handicapped by orthopedic or other physical deformities to go regularly to trade, or by women who have cares at home requiring constant supervision, such as looking after little children or old people. The line is, therefore, difficult to draw between the classes of employment which are usually carried on satisfactorily at home and those which are generally unsanitary and underpaid, and the inspection of private homes offers some difficulties. Nevertheless, in some of the states laws are being made to regulate such work in the homes as is injurious both to the worker and the consumer.

At present the majority of the states have laws prohibiting child labor at night, forbidding children under fourteen to work (this law is not yet applied to all occupations), keeping women and children out of dangerous trades, regulating moral and sanitary conditions, and demanding inspection of factories and workrooms. In some states those under sixteen are limited to an eight-hour day; the minimum wage and payment for overtime are also being considered. In order to fit children to make a living wage, vocational education of several kinds is being provided for them. Guidance plans are also being forwarded by public education that each child may be directed into the work best fitted for his or her ability. The working women themselves are fighting bravely in the Trade Union League and in other ways for improved conditions, but are handicapped by the pressure of poverty and the need of the wage. They have been greatly helped by women who are not under such stress for daily bread. A large number of women are consumers and users of wealth, rather than producers, and they owe the women workers their intelligent consideration of this entire situation and their assistance in further betterment.

The Consumers' League began its work by an effort to improve the conditions of employment in the department stores. The investigations made resulted in a series of recommendations as to the fairness of treatment of women employees by employers, sanitary conditions in the stores, and the necessary training of the consumer to her responsibility toward the saleswoman. The names of firms which lived up to the ideal of a fair house were placed on the "white list" of the Consumers' League, and the members of the association dealt as far as possible with such firms. The investigations of the League have gradually been directed also toward the manufacture of garments and the conditions under which they are being made. The result is a label placed on garments which satisfy the demand. All classes of articles in women's wear are not yet bearing the label, but the number is increasing. The work of the Consumers' League has thus been a factor in improving working conditions.

The Woman's Trade Union League also has been of service as an educative as well as helpful medium in the influence of many devoted working girls united in an effort to better conditions. The Consumers' League and Trade Union League have worked together to establish the label. By it they are calling the consumer's attention to the ready-made clothing she buys, to its sanitary condition and the standard of work in the factory instead of to whether it is cheap and attractive.

As a result of the work of the Woman's Trade Union League the "white" protocol was first brought forward in the cloak, suit, and skirt trade in September, 1910, and the shirt-waist trade has now adopted it.

The Joint Board of Sanitary Control in the Cloak Industry came from a suggestion of the employers in settling the strike in 1910. It took into account three parties to the controversy — the employers, the workers, and the public. An important part of the work is the education of the workers themselves to respect the value of sanitary control. The need for education was met in coöperation with the Board of Education for lectures to be held in the public schools. The subjects included: factory legislation, factory education, industrial poisons, and factory sanitation.

Many factory owners and heads of department stores are also earnestly forwarding betterment plans among their employees. The result has been the providing of suitable seats, good toilet rooms, lunch rooms, recreation rooms, medical and dental attention, good ventilation and cleanliness in the workroom, and other advantages. In many places a social secretary is employed to look after the employees and their welfare. Courses of education for the young worker have been organized to make up for inferior elementary education, to train for better salesmanship or for specific processes of manufacture. These schools are found within the factory or store and also as continuation schools under public instruction. Employees' associations are being organized for the discussion and regulation of conditions affecting the working girls.

The home seamstress and dressmaker have not as yet had sufficient attention given to their labor conditions and the amount of work demanded of them in a given time. The need of such home workers still continues, but the uncertainties and lack of adequate remuneration do not encourage any serious preparation for such positions or their holding by a skilled and businesslike class of workers.

The work of the custom dressmaker is influenced also by the unintelligent attitude of her clientele and her own deficiencies in business training. The price of a garment should be based on the actual cost of materials, the hours of work and consequent wages of the expert and unskilled workers who have constructed it, the time taken by the designer, draper, and fitter, overhead expenses of the shop, and the percentage of profit. Overhours which are required in changing a gown or hastening the completion (when the demand comes from the consumer) should be paid for as an addition to the bill. Hours set for fitting should be kept by the customer or she should notify the dressmaker of the purposed change. The garment should be delivered at the time specified. All laws concerning workers and sanitary condition of workrooms should be kept as carefully as in the factory. The pay for garments should be prompt. Many custom dressmakers desire to be absolutely businesslike, but have been prevented by the irritation felt at such changes by many of their clients. Those who have been able to organize their workrooms with efficient business methods are finding the benefit for themselves and their employees. Women can now help greatly by considering and urging forward a better system.

The making of ready-made clothing has become a large business in the United States. The manufacture of cloth for this specific purpose is the work of many factories, and is known in the market as the "cutting up" trade. New York City leads the world in the production of men's clothing, the output of which in 1909 was $232,609,284 out of $568,077,000 for the whole country. The work included coats, suits, overcoats, overalls, blouses, shirts, aprons, bathing suits, hats, caps, collars, cuffs, gymnasium and sporting goods. The making of women's clothing is also one of New York's great industries, the output in 1909 being $261,049,287 made by 96,162 employees, the majority of whom were women.

The condition under which much of this clothing was made has been a question of concern to those interested in social betterment, and as before stated has brought forth much legislation. A large up-to-date ready-made clothing factory, under an employer interested in the best conditions for his employees, offers a very satisfactory employment for women who have the kind of health to allow them to work at electric power machines or to sit sewing all day.

The system of organization and division of labor in these large clothing factories is similar, whether expensive or inexpensive clothing is made. The inspection of the factories helps to keep the workrooms in safe and sanitary condition, while home workshops are often run under conditions which are not only a menace to the workers, but also to those who wear the clothing.

To those who have never made garments or thought much of the subject, the youth of the girls working in these great factories and the amount of work on one garment are a surprise. In large workrooms the division of labor is carefully arranged, being more or less the following: the original garment and the paper pattern for it are made by the designer and her helpers. It then goes to the calculator who figures on the amount of material required and indicates on a slip the way the material is to be used. For illustration, let us suppose a fancy waist is to be made: the calculator will note if the material must be tucked, shirred, or folded in any way and enters this on the slip. He then sends the waist, the pattern, and the slip to the estimator, who considers the price of the materials, the probable labor cost, the overhead or factory charges, *i.e.*, rent, light, heat, office, and the cost of the designer and staff, and enters these on a slip. He then sends the two slips and the waist and pattern to the office. The design is now judged as to style, cost, and probable sale. It is tried on a living model and considered for line and fit. The manufacturer's profit is added to the estimates of production, which gives the wholesale price of the waist, and the waist is ready to be seen by the buyers who have come from the retailers. Orders in dozens will probably come for the model, and as the waists are needed in several sizes, the pattern must be adjusted before the work of construction begins. The paper pattern made by the designer goes, therefore, to the pattern room, where the various sizes are graded from it and patterns cut for different bust measures. These are sent to the cutter who cuts the material into the several parts of the waist by a knife or by an electric cutter. In the latter case several dozens of layers can be cut at one time in some materials. The cut material is sent to the sorter, who brings together the various parts of each waist. If tucking is to be done, the sorter sends the material to the tucker and on its return puts the tucked parts with the other sections. The assembled parts are sent to the trimming room, where the exact amount of lace, embroidery, passementerie, or other decoration is added. All parts of the waist are now assembled and go to the forewoman of the workroom. She distributes to the hemstitchers, the Corneli machine workers, or the trimmers the parts requiring their skill, and the waist is later put together by the machine operators. It is finally sent to the finishers for buttons, loops, hooks and eyes, or any small adjustments. Inspectors judge the work after each step. If a full gown is to be made, the skirt and waist go to the draper, who joins them and sees that the skirt hangs well. Pressing follows, and the gown is ready for packing and shipping. In most of the large houses skilled workers alone are employed.

The United States Government has published in nineteen volumes a careful investigation of the condition of women and child wage earners. From this series of books information on the various phases of the present occupations of women and children can be obtained.

CHAPTER XVII

CLOTHING BUDGETS

The Family Budget. — Apportionment for Clothing. — The investigation of textiles from the many standpoints connected with the home leads naturally to a consideration of the best selection of fabrics for garments and to the part of the income to be devoted to clothing in any well-organized family. The division of the income into definite items and the percentages usually devoted to these purposes have been dealt with by many economists and social workers. In these budgets the amount allowed for clothing varies from one sixth to one eighth of the income, *i.e.*, from 17 to 12 per cent of the money received. On account of the need for adequate clothing in some business positions a larger proportion of a small income is sometimes given to dress, whereas in small family incomes the greater percentage is usually devoted to food and shelter and less to clothing.

It is evident, therefore, that the mode of life has a large influence over the amount to be spent. For instance, the suburbanite has to allow a large share for traveling expenses and consequently must cut this off from other items, but the lower cost of shelter in the suburbs than in the city sometimes balances this. The late Mrs. Ellen H. Richards gave a scientific study to budget making on small incomes and published as representative the following estimates: —

Yearly	Food	Rent	Clothing	Operating Expenses	Higher Life
\$800 to \$1000	30 per cent	20 per cent	15 per cent	10 per cent	25 per cent
\$1000 to \$2000	25 per cent	20 per cent	20 per cent	15 per cent	20 per cent
\$2000 to \$4000	25 per cent	20 per cent	15 per cent	15 per cent	25 per cent

Miss Grace W. Pitman of East Orange has worked out and published a working basis for a family budget. She states, in the *Ideal Home Expense Guide*, that the following percentages are averages taken from the expense accounts of different families in various parts of the United States and which cover a period of twenty years. Average income, $1500; average family, 4; rent, 17 per cent; heat, 4 per cent; light, 1½ per cent; food, 28 per cent; wages, 8½ per cent; incidentals, 3 per cent; personal expenses (including clothing), 15 per cent; operating, 3 per cent; intellectual life and investment, 20 per cent (religion, 8 per cent; education, 4½ per cent; investment, 7½ per cent).

Mrs. More, in *Wage Earners' Budgets*, published in 1907, gave from a study of 200 families the following itemized statement: —

		Per Cent of Total Expenditures
Food	$343.42	43.4
Rent	162.26	19.4
Clothing	88.45	10.6
Light and fuel	42.46	5.1
Insurance	32.35	3.9
Sundries	147.31	17.6
	$836.25	100.0
Average surplus	15.13	
	$851.38	

A professional woman living in a large city on a fair income and trained in both domestic art and domestic science studied a number of standard budgets and made her own calculations. She reduced the percentage of some expenses, yet obtained good results. Her family consisted of three adults (including herself) and a servant. The budget was in use for ten years and was slightly readjusted at the beginning of each year.[1] The average yearly percentage was: (1) household

[1] The higher cost of living would now require a larger income than was then used, but the percentages remain approximately the same.

expenses, 40 per cent, covering rent, food, and operating, which included service; (2) clothing, varying from 12 per cent to 15 per cent, and including large and small articles and repairing materials; (3) personal items, about 12 per cent, for doctor and dentist charges, clubs, medicine, toilet articles, and laundry; (4) travel, 5 per cent; (5) education, higher living, and pleasure, 15 per cent; (6) gifts and charities, 10 per cent; (7) investment and insurance, 6 per cent. It must be understood that any budget must be elastic enough to change from month to month, so that if one item is increased, another can be lessened.

The great variety of demands upon women makes it almost impossible to form a single budget of clothing expenditure suitable for all conditions. The mother living at home needs a very different wardrobe from a professional woman, and a society girl in a large city requires altogether different clothing than if she were at college in a small town. Each individual or each mother for her family must decide the special needs. The climatic conditions to be expected have much influence on the clothing required, and city life differs in its demands from country life.

In the clothing budget for a moderate income the following matters must be considered before making final plans: Is it well to spend the money on a few garments made at the best places, for which a large amount must be spent; on good material made up at home; or on ready-made clothing? The probable laundry costs should be considered, especially if there are to be many lingerie gowns. The hygiene of clothing (see Chap. XV) should also influence the selection of materials. The usual divisions of the clothing budget are: (1) coats, skirts, suits, and gowns; (2) underclothing and lingerie; (3) boots, shoes, stockings, slippers, and rubbers; (4) hats, caps, and gloves; (5) sundries. It is advisable first to set aside money for the most important articles and afterward to use any remaining money for minor articles and for luxuries. The underclothing should not be slighted, as health demands many changes, and simply-made garments of good material last a long time. There is sometimes a tendency to give little attention to the undergarment and lay stress on the outer ones. When the mother of the family must plan the budget for a number of children as well as for her husband and herself, she should first roughly divide the sum at her disposal among the members of the family. When the children are very young, her problem is not great, even if the income is small. If, however, they are of school age, very careful planning of a small income is needed. In addition the handing down and making over of her own and husband's clothing and the care of all garments must contribute to the length of her purse. It is only when fortified with definite ideas of the way to spend the money that she is ready to begin to purchase. It has been proved by experience that a woman trained to a knowledge of textile buying and to budget making can make an income go twice as far as the one who buys without careful planning.

Typical Budgets. — The following budgets represent various phases of the use of the income for clothing. The majority have been or are in actual use. Estimates and plans for small incomes have in most cases been selected as requiring more close calculation than larger incomes. They include: —

I. The study of a family living on an $850 income.

II. The budgets of clothing used in demonstration at the Child Welfare Exhibit in New York City in 1911, — $65 being allowed on clothing for three children.

III. A representative budget of $75 per year taken from a number made by a group of young working girls.

IV. A budget of a business girl whose family helps her by making some of her clothing at home. Expense $100 a year.

V. A budget of $150 a year worked out by a group of college girls.

VI. A professional woman's budget of $350 a year.

VII. A clothing budget for two children: the girl's, $51.43, and the boy's, $65.51.

Clothing Budget of a Family

The following is a budget of a family of five living on an income of $850, spending 15 per cent, or $127.50, on clothing. The student who obtained the information lived in a settlement and made her report from discussions with the families of the neighborhood. The budget that follows was a typical one selected from those collected. The division of the clothing money was as follows: —

Man	$36.49
Woman	20.65
Girl of 12	18.51
Boy of 8	21.63
Girl of 5	14.77
Total	$112.05

The remaining $15.45 was used for sundries: thread, tape, buttons, and other items. The mother made her own and most of the children's clothing at home. Many of the garments were expected to wear more than one year. The items were as follows: —

Man

Suit	$10.00
Overcoat	10.00
Trousers	2.00
2 flannel shirts $3\frac{1}{2}$ yds. flannel at 39¢	2.74
Shirt (percale)	.50
Overalls	.50
Winter underwear	2.00
Summer underwear	.50
Winter hat	1.00
Summer hat	.50
Socks, 8 pairs	.80
Shoes, 2 pairs	5.00
Suspenders	.25
Neckties, 2	.20
Collars, 2	.20
Handkerchiefs, 6	.30
	$36.49

Woman

Suit, 6½ yds. serge at 59¢	$3.84
4 yds. mercerized poplin at 24¢ for lining	.96
Dress, 8 yds. gingham at 7¾¢	.62
Dress, 6½ yds. calico at 5¾¢	.33
Skirt, 4½ yds. serge at 49¢	2.21
Shirt waist, 3 yds. madras at 19¢	.57
Shirt waist, 3 yds. lawn at 12¢	.36
10 yds. val. lace at 2¢	.20
Petticoat, 5 yds. gingham at 7¾¢	.39
Petticoat, 5 yds. muslin at 7¢	.35
Petticoat, 2½ yds. outing flannel at 7¢	.18
Drawers, 2 yds. muslin at 7¢, 2 pairs	.28
Corset covers, 1⅜ yds. muslin at 7¢, 2	.20
Nightdress, 5⅜ yds. muslin at 7¢, 2	.76
Corset	.50
Winter underwear	1.00
Summer underwear	.50
Winter hat	1.50
Summer hat	1.00
Shoes, 2 pairs	4.00
Stockings, 6 pairs	.60
Handkerchiefs, 6	.30
	$20.65

Girl of 12

Dress, 4 yds. wool material at 49¢	$ 1.96
Dress, 5 yds. gingham at 7¾¢	.39
Dress, 5 yds. gingham at 7¾¢	.39
Dress, 4 yds. percale at 9½¢	.38
Dress, 4 yds. lawn at 12¢	.48
Bloomers, 1⅜ yds. gingham at 7¾¢, 3 pairs to match dresses	.33
Petticoats, 2½ yds. muslin at 7¢, 2	.28
Drawers, 1½ yds. muslin at 7¢, 2 pairs	.22
Underwaist, ½ yd. muslin at 7¢, 2	.08
Nightdress, 4 yds. muslin at 7¢, 2	.56
Coat, 3 yds. material at 49¢	1.47
3 yds. lining at 24¢	.72
Winter underwear	1.00
Summer underwear	.50
Winter hat	1.00
Summer hat	1.00
Shoes, 4 pairs	5.00
Stockings, 12 pairs	1.20
Handkerchiefs, 6	.30
Gloves	.25
Rubbers	.50
Ribbons	.50
	$18.51

Boy of 8

Suits, $2\frac{1}{2}$ yds. material at 49¢, 2	$2.46
Trousers, $1\frac{1}{2}$ yds. serge at 49¢, 2	1.48
Blouses, $1\frac{1}{2}$ yds. calico at $5\frac{3}{4}$¢, 2	.18
Blouses, $1\frac{3}{4}$ yds. gingham at $7\frac{3}{4}$¢, 2	.14
Overcoat	5.00
Winter underwear	1.00
Summer underwear	.50
Caps, 2	.50
Shoes, 6 pairs	7.50
Rubbers	.50
Stockings, 12 pairs	1.20
Ties	.20
Gloves	.25
Handkerchiefs, 6	.30
Pajamas, 3 yds. flannel at 7¢, 2 pairs	.42
	$21.63

Girl of 5

Dress, $2\frac{1}{2}$ yds. material at 49¢	$ 1.23
Dress, 3 yds. gingham at $7\frac{3}{4}$¢, 2	.48
Dress, $2\frac{5}{8}$ yds. calico at $5\frac{3}{4}$¢	.16
Dress, 3 yds. lawn at 9¢	.27
Coat, $2\frac{1}{2}$ yds. material at 49¢	1.23
3 yds. lining at 24¢	.72
Bloomers, $1\frac{3}{8}$ yds. gingham at $5\frac{3}{4}$¢, 3 pairs to match dresses	.33
Underwaist, $\frac{1}{2}$ yd. muslin at 7¢, 2	.07
Drawers, 1 yd. muslin 7¢, 2	.14
Petticoats, $1\frac{1}{2}$ yds. muslin at 7¢, 2	.22
Nightdress, 3 yds. muslin at 7¢, 2	.42
Winter underwear	1.00
Summer underwear	.50
Winter hat	1.00
Summer hat	.75
Shoes, 4 pairs	4.00
Rubbers	.50
Stockings, 12 pairs	1.20
Gloves	.25
Handkerchiefs, 6	.30
	$14.77

Child Welfare Budgets

In a large city incomes of less than $800, to support two adults and three children over ten years of age, result usually in underfeeding, poor clothing, poor housing, and depleted health. When the income is as low as $600, actual want stares the family in the face unless charity supplements the insufficient amount. The average income of a family on the lower east side of New York has been stated to be $851.38; the average size of the family is a little over five. If 12 per cent of the income is used for clothing, about a hundred dollars may be so used, but this is not sufficient for five people. Even an expert judge of textiles who can sew and repair cannot satisfactorily clothe the family at this price.

Investigations have proved that in those families where the mother or daughter knows something of the value of materials, can sew, make over, launder, and remove stains, the money for clothing goes twice as far. Unfortunately the majority of women are not trained to such economies, and other women who do know have not the time to give.

The relation of the high price of materials to the daily life of the poor was brought before the New York public in the spring of 1911 at the Child Welfare Exhibit, when clothing was shown as one of the influences on child life. Homemade and ready-made clothing for a number of children, ranging from the baby to the high school girl, were shown with the prices attached. It was found by careful study[1] and tests that $112.50 ($65 being the amount for three children) was the least sum by which even fairly adequate clothing could be obtained for a father, mother, and three children, two of the children being above ten. One eighth of the income was allowed for clothing; consequently the requisite yearly income should

[1] From a study of New York conditions and of various budgets such as More's and Chapin's as a basis for deciding on the amount to spend on the clothing budget at the Child Welfare Exhibit in 1911.

be $900, whereas that is above the average. The full division of this income would be about as follows: rent, $15 per month, or $180 annually; food would take about one half of the income, say $430; light and heat, $50 annually; clothing, $112; insurance, $26; carfare, 50¢ per week, $26 a year; all other expenses for doctors, dentists, repairs, and pleasures, $36.

The plan for making the homemade clothing began with a careful search for the best materials to use. Those were purchased at the regular prices of the time and not at bargain counters. A fair-sized sample of cloth was always obtained first and subjected to tests for laundering, fading, and endurance. If the material stood the tests, it was purchased. Large numbers of samples were tested before the right fabrics could be found. The highest qualities were not expected in the material as the price which could be paid was too low, but simply the best for the money. It was indeed a sad showing of the small range of worthy textiles which the poor can buy. Wool was almost entirely excluded, being too expensive; cotton cloths had to be used in place of wool. Dyes proved so defective that the choice of color narrowed principally to grays, whites, and blacks. The clothing was discussed, designed, and made by girls in the various schools of New York City. Simple, attractive, though plain, garments were made that any mother might construct at home. The ready-made clothing cost about the same as the homemade. It was purchased at stores on the White List of the Consumers' League, and when possible, the garments which had on them the Consumers' League label were selected. At first the public preferred the ready-made clothing as it looked more attractive, the garments having been made primarily to please the taste. After many days of exhibition almost all of the clothing had to be laundered and the advantage was then seen to be with the homemade garments. Some of the budgets are as follows: —

Clothing Budgets of Welfare Exhibit

Baby: Age to 2 Years — Outfit for One Year

(Items marked * are ready made)

Home Made

2	Skirts (flannel),	at $.50		$1.00
4	Bands (1 yd. flannel),			.50
2	Nightgowns,	at .25		.50
3	Slips,	at .25		.75
1	Bonnet (interlined for winter),			.15
1	Coat (interlined for winter),			1.25
3	Shirts (⅓ wool),*	at .25		.75
20	Diapers,*	at .10		2.00
4 pr.	Stockings (wool),*	at .25		1.00
1 pr.	Tan shoes,*			.25
1 pr.	Black shoes,*			.50
			Total	$8.65

Ready Made

3	Shirts (⅓ wool),	at $.25		$ .75
4	Bands,	at .25		1.00
20	Diapers,	at .10		2.00
4 pr.	Stockings,	at .25		1.00
2	Skirts,	at .25		.50
2	Nightgowns,	at .25		.50
3	Slips,	at .25		.75
1 pr.	Tan shoes,			.25
1 pr.	Black shoes,			.50
1	Bonnet (interlined for winter),			.25
1	Coat (interlined for winter),			1.25
1 pr.	Mittens,			.25
			Total	$9.00

Girl: Kindergarten Age, 4 to 6 Years — Outfit for One Year

Ready Made

3	Summer vests,	at $.125		$ .38
2	Winter combinations (fleece lined),	at .75		1.50
2	Flannelette petticoats,	at .25		.50
2	White petticoats,	at .25		.50
2	Underwaists,	at .12		.24
4 pr.	White drawers,	at .10		.40
			Carried forward	$3.52

		Amount brought forward	$3.52
2 pr.	Night drawers (flannelette),	at $ .50	1.00
3 pr.	Rompers,	at .50	1.50
1	Wool dress,		1.00
2	Cotton dresses,	at .50	1.00
1	Coat,		2.00
1	Summer hat,		.50
1	Winter hat,		.50
3 pr.	Shoes,	at 1.10	3.30
1 pr.	Overshoes,		.60
1 pr.	Mittens,		.25
6	Handkerchiefs,		.25
2 pr.	Garters,	at .12	.24
3 yds.	Hair ribbon,	at .10	.30
2	Aprons,	at .25	.50
8 pr.	Stockings,	at .125	1.00
		Total	$17.46

Girl: Primary Age, 6 to 8 Years — Outfit for One Year

Home Made

(Items marked * are ready made)

3	Summer vests,*	at $ .125	$ .38
2	Winter combinations,*	at .75	1.50
3 pr.	White drawers,	at .11	.33
2	Underwaists,	at .14	.28
2	Flannelette petticoats,	at .11	.22
2	White petticoats,	at .12	.24
2	Flannelette nightgowns,	at .32	.64
3	Cotton dresses,	at .45	1.35
1	Wool dress (with bloomers),		1.84
2	Aprons,	at .24	.48
1	Coat (to be worn 2 seasons),	at 1.81	.90
1	Summer hat,		.50
1	Winter hat,		.50
8 pr.	Stockings,*	at .125	1.00
3 pr.	Shoes,*	at 1.50	4.50
2 pr.	Overshoes,*	at .70	1.40
6	Handkerchiefs,*		.25
2 pr.	Garters,*	at .15	.30
3 yds.	Hair ribbon,*	at .10	.30
1 pr.	Woolen gloves,*		.25
		Total	$17.16

GIRL: INTERMEDIATE AGE, 8 TO 12 YEARS — OUTFIT FOR ONE YEAR

Home Made

(Items marked * are ready made)

3	Summer vests,*	at $ .125	$ .38
2	Winter combinations,*	at .75	1.50
3 pr.	White drawers,	at .22	.66
2	Underwaists,	at .50	1.00
2	Flannelette petticoats,	at .14	.28
2	White petticoats,	at .38	.76
2	Nightgowns,	at .48	.96
2	Cotton dresses,	at .52	1.04
1	Wool dress (with bloomers),		3.06
2	White aprons,	at .17	.34
1	Coat (to be worn 2 seasons),	at 3.75	1.88
1	Summer hat,		.76
1	Winter hat,		.50
8 pr.	Stockings,*	at .125	1.00
3 pr.	Shoes,*	at 1.50	4.50
2 pr.	Overshoes,*	at .70	1.40
1 pr.	Woolen gloves,*		.25
6	Handkerchiefs,*		.25
2 pr.	Garters,*	at .15	.30
3 yds.	Hair ribbon,*	at .10	.30
		Total	$21.12

BOY: 10 YEARS OF AGE — OUTFIT FOR ONE YEAR

Ready Made

3	Summer vests,	at $ .25	$ .75
3	Summer underdrawers,	at .25	.75
3	Winter underdrawers,	at .30	.90
3	Winter undervests,	at .35	1.05
2 pr.	Garters,	at .15	.30
2 pr.	Pajamas,	at .75	1.50
8 pr.	Stockings,	at .125	1.00
3 pr.	Shoes,	at 2.00	6.00
3	Cotton blouses,	at .50	1.50
2	Ideal waists,	at .25	.50
1	Wool suit,		3.85
1	Reefer Coat (to be worn 2 seasons),	at 3.85	1.93
3	Cotton trousers,	at .50	1.50
1	Straw hat,		.50
1	Wool hat,		.50
1 pr.	Wool gloves,		.25
6	Handkerchiefs,		.25
	Ties.	at .10	.20
		Total	$23.23

GIRL: HIGH SCHOOL AGE, 14 TO 16 YEARS — OUTFIT FOR ONE YEAR[1]

Ready Made

2	Summer vests,	at $ .125	$ .25
2	Winter combinations,	at .75	1.50
3 pr.	White drawers,	at .25	.75
2	Corset waists,	at .50	1.00
3	Corset covers,	at .25	.75
2	Flannelette petticoats,	at .25	.50
1	White petticoat,		.85
1	Black petticoat,		.75
2	Nightgowns,	at .59	1.18
4	Shirt waists,	at 1.00	4.00
1	Dress skirt,		3.75
1	Cotton dress,		2.50
1	Wool Dress,		3.50
1	Coat (to be worn 2 seasons),	at 6.50	3.25
1	Summer hat,		1.00
1	Winter hat,		1.24
1 pr.	Wool gloves,		.25
1 pr.	Kid gloves,		1.00
1	Tie,		.10
1	Ribbon,		.15
6	Handkerchiefs,		.25
6 pr.	Stockings,	at .125	.75
3 pr.	Shoes,	at 2.00	6.00
1 pr.	Overshoes,		.70
		Total	$35.97

Budgets of Students in Trade School for Girls

A number of young working girls in New York City, who had been trained in a trade school and taught to make clothing budgets as part of their arithmetic, made plans for the utilization of their income the first year in which they worked in trade. Their wage averaged $6 per week throughout the year, and they all lived at home. If they had had to depend on themselves entirely, the wage would have been about two thirds of the amount required for simple and decent living with adequate food and clothing and a small room. The general division

[1] By working in the summer the girl was able to spend more on her clothes than the apportionment of the income could have allowed.

of the wage per week which they decided upon was as follows: clothing and recreation, $1.50; lunch, 90¢; carfare, 60¢; savings bank, 25¢, and family support, $2.75. They had been taught at the school to sew, repair, and consider the small economies necessary to make money go as far as possible, and hence were able to dress well on the $75 a year, more or less, which was set apart for clothing and recreation.

The plans for clothing differed considerably; some girls spending more in pleasure and incidentals and other girls desiring better clothing. Those who put aside the largest amount for recreation usually cut down on the dress skirt, winter underwear, millinery, and odds and ends. They decided that they must have a good lunch, even though they could not get a stylish hat. They also agreed that they themselves could make corset covers, nightgowns, summer clothes, and jabots, and even at times might be able to make some of their winter clothes. They all felt that homemade clothing wore better than the cheap, ready-made kinds and that by taking good care of their old clothes and by making the old dress skirts into petticoats, they could save money. Each girl planned to give a regular amount of her wage to her mother, as she washed her clothing and cooked her meals, which the girl wage earner could not get time to do. One budget is given below; it is the one in which the smallest amount was allowed for recreation; — this latter item ranged in the various calculations from $1.50 to $11.50 annually. All of the girls agreed that when a new coat or suit was needed, they should be careful to put money aside weekly for a long time or they would not have enough to get a good one.

Clothing Budget of a Working Girl

Winter Outfit

(Much of the simpler clothing made by the wearer)

2	Woolen undersuits,	at $2.75	$5.50
3	Flannelette petticoats,	at .50	1.50
1	Black petticoat,		1.25
1	Corset,		.50
3	Corset covers,	at .25	.75
2	Flannelette nightgowns,	at 1.00	2.00
6 pr.	Stockings,	at .15	.90
2 pr.	Shoes,	at 2.50	5.00
1 pr.	Rubbers,		.75
5	Shirtwaists,	at .89	4.45
1	Skirt,		3.00
1	Coat suit,		12.00
1	Plain hat,		1.50
1	Fancy hat,		2.00
1 pr.	Kid gloves,		1.00
1 pr.	Woolen gloves,		.50
			$42.60

Summer Outfit

(Much of the simpler clothing made by the wearer)

6	Vests,	at .10	.60
6 pr.	Drawers,	at .25	1.50
1	Plain petticoat,		.35
1	Fancy petticoat,		1.00
3	Corset covers,	at .25	.75
1	Corset cover,		.50
2	Muslin nightgowns,	at .79	1.58
6 pr.	Stockings,	at .15	.90
2 pr.	Shoes,	at 2.50	5.00
5	Shirt waists,	at .89	4.45
1	Skirt,		3.00
1	Dress,		4.00
1	Hat for business,		.75
1	Fancy hat,		2.00
			$26.38

Miscellaneous

Ribbons,	$1.00
Ties,	.75
Belts,	.20
Collars,	.60
Handkerchiefs,	.60
Purse,	.10
Umbrella,	.79
Hairpins, etc.,	.50
	$4.54

Summary: —

$42.60	spent for winter clothes.
26.38	spent for summer clothes.
4.54	spent for miscellaneous.
$73.52	spent for clothing for 1 year.

$75.00	year's allowance for clothing and recreation.
$73.52	spent for clothing.
$ 1.48	left for recreation.

The following suggestions were also made by these working girls: —

The Care of Clothes

Mend your clothes as soon as they tear.

Air your clothes before putting them away.

Hang your clothes up so they will not become wrinkled.

Sponge and press woolen dresses, skirts, and coats.

Launder shirt waists at home if you can.

Keep all buttons and hooks and eyes carefully sewed on.

When skirt bands wear out, put on new ones.

Keep skirt braids sewed on.

The skirt of an old dress can be ripped and washed and made into a petticoat.

Put new ruffles and facings on old petticoats.

Make your own corset covers at home; corset covers that will wear a year can be made for 25 cents.

Clean your own corsets; remove the bones, wash and dry the corset, replace the bones, and bind the top with a piece of ribbon.

An old sheet or nightgown can be made into a bag to keep the best dress in.

Darn your stockings.

Keep your shoes clean and nicely polished.

Keep your gloves clean, always mended, and buttons sewed on.

Put your gloves away neatly when not in use.

Wash your own ties and jabots.

Make jabots from pieces of lawn and lace left over from waists and dresses.

Keep your hats well brushed.

Keep your best hat in a box or pillow slip when not in use.

On a stormy day wear a veil over your hat.

When your hat becomes shabby and dusty, take off the trimming, brush and steam it thoroughly, and retrim the hat.

Keep your coat on hanger. A coat keeps its shape longer when kept on a hanger.

What a Well-dressed Girl wears to Business

Neat gloves and shoes — old gloves and shoes are neat when they are clean and carefully mended,

Neat tailor-made shirt waists,

Neatly made suits and coats,

Neat, well-made hats,

Clean, neat underwear,

Clean collars and jabots,

Hair neatly dressed,

Clean hands and finger nails.

What a Well-dressed Girl does not wear to Business

Fancy shirt waists,

Too much jewelry,

Very big or conspicuous hats,

Low shoes and thin stockings in winter,

Bright, gay colors,

Many colors at one time,

Dresses cut too low,

Short sleeves and low-cut waists on a cold day.

Petticoats that are longer than the dress,

Dusty clothes,

Fussy neckwear,

Dirty shirt waists and collars,

Coats, dresses, skirts, or waists on which buttons or hooks and eyes are lacking.

Clothing Budget for Business Girl

Living at home and assisted by the family in making garments and in repairs

The salary is about $15 per week and the need is for good, everyday garments. The suits are made by a dressmaker outside of the home, the coat is ready made, and other clothing is made at home as far as possible. Advantage is taken of past season sales. The long light-weight coat is serviceable all the year. The coat of the three-piece winter suit serves when a short coat is desired. The cost is on an average of $100 annually. This plan of budget making and the two that follow consider the possible service of garments as continuing from year to year.

BUDGET FOR BUSINESS GIRL'S CLOTHING FOR THREE YEARS

		Number	Total Cost	Years of Wear	Average Yearly Cost (omitting small fractions)
Suit — 3 piece, for winter: —		1			
Coat — skirt — waist. Suiting material, serge — 16 yds. 36 in. at $1.25 = $20 (12 yds. 50 in. at $1.50) . .	$20.00				
Lining — sateen, 4 yds. 36 in. at .50	2.00				
Interlinings, trimmings, etc. .	6.00				
Dressmaker	20.00		$48.00	3	$16.00
Coats — Covert cloth: —					
Long light weight, ready made		1	20.00	3	6.66
Sweater		1	3.50	3	1.17
Dresses — summer (each summer a new one. This lasts over the next summer): —					
Carried forward . . .			71.50		23.83

		Number	Total Cost	Years of Wear	Average Yearly Cost (omitting small fractions)
Brought forward . .			71.50		23.83
Dresses: —					
Ginghams (in washable colors)		1			
10 yds. 30 in. at .25 . . .	$2.50				
Dressmaker	5.00		7.50	1	7.50
Batiste, etc.		1			
10 yds. 36 in. at .25 . . .	2.50				
Dressmaker	7.00		9.50	2	4.75
Separate waists (made at home): —					
Cotton		3			
3 yds. 36 in. at .15 . . .	.45				
Trimming (av. for 3) . . .	.15		1.80	1	1.80
Scotch flannel		1			
3 yds. at .35	1.05		1.05	1	1.05
Silk					
5 yds. at .75 (average) . .	3.75	2	7.50	3	2.50
Dress skirts (made at home): —					
Wool (Panama)		1			
5 yds. 36 in. at $1.00 . .	5.00		5.00	2	2.50
Cotton		1			
5 yds. (30–36 in.) at .15 . .	.75		.75	1	.75
Petticoats: —					
Sateen, 5 yds. at .35 . . .	1.75	1	1.75	2	.88
Colored cotton, 5 yds. at .15	.75	1	.75	1	.75
White cotton, 4 yds. at .15 . .	.60	2	3.20	3	1.10
Embroidery or lace	1.00				
Corset covers: —		4			
1¼ yds. at .15	.20				
Lace or embroidery (average)	.30		2.00	1	2.00
Nightdresses: —		3			
4 yds. at .15	.60				
Trimming	.40		3.00	2	1.50
Drawers: —		2			
1¾ yds. at .15	.28				
Trimming (average)	.30		1.16	1	1.16
Hats: —					
Winter		1	8.00	1	8.00
Summer		1	5.00	1	5.00
Carried forward . . .			129.46		65.07

		Number	Total Cost	Years of Wear	Average Yearly Cost (omitting small fractions)
Brought forward			129.46		65.07
Gloves: —					
Kid	1.25	2	2.50	1	2.50
Silk	.50	2	1.00	1	1.00
Chamoisette	.50	2	1.00	1	1.00
Corsets		1 or 2	2.00	1	2.00
Hosiery, 9 pr. at 3 for $1		9	3.00	1	3.00
Shoes, 3 pr. at $4 each (or 4 pr. at $3 average)		3	12.00	1	12.00
Rubbers, 2 pr. at .75 each		2	1.50	1	1.50
Underwear: —					
Cotton shirts, .25		4	1.00	1	1.00
Combinations, $1.00 (heavy)		3	3.00	2	1.50
			156.46		90.57
Sum left for extras					9.43
Total					100.00

Clothing Budget for a College Girl

The following budget has been worked out by several girls attending college in a large city. The basis is an allowance for clothing of $150 per year for three years. The garments in general are made at home. An additional column tells how much more the budget would be if the clothing was made outside of the house. The allowance for extras differs each year, being dependent upon the cost of standard articles. The amount given for it is approximate. The entire scheme is developed from the standpoint of present-day desires and fashions. The scale of expenditure corresponds to a total living expense of about $4000 a year for a family of five. As the vast majority of family incomes is much less than this it follows that most girls, if they desire to be fair to other members of the family, must learn to clothe themselves in much less expensive fashion.

Budget for College Girl's Clothing for Three Years

$150 PER YEAR. $450 TOTAL FOR THREE YEARS

(If articles are made away from home, they will cost at least $37 extra per year)

Bought 1st Yr.	2d Yr.	3d Yr.	Total			Expenditures	Construction	Probable Cost if Made Out
1		1	2	Suits	at $50.00	$100.00		
1	1		2	Woolen dresses	at 8.00	16.00	made at home	$14.00
1	1		2	Gowns	at 15.00 30.00	15.00 30.00	made at home	15.00
1		1	2	Silk waists	at 5.00	10.00	made at home	10.00
2		2	4	Tailored waists	at 2.00	8.00		
2	2	2	6	Lingerie waists	2 at 3.00 4 at 1.25	6.00 5.00	made at home	6.00
	1	1	2	White wash skirt	at 1.00	2.00	made at home	4.00
1	1	1	3	"Tub" dresses	at 3.00	9.00	made at home	9.00
1	1	1	3	Dainty cotton dresses	at 3.00	9.00	made at home	9.00
2	2	2	6	Undervests	at .25	1.50		
2			2	Combinations (knit)	at .75	1.50		
	3		3	Woolen combinations	at 3.50	10.50		
3	6	3	1 doz.	Stockings	at 3 for 1.00	4.00		
1	2	1	4	Silk stockings	at .75	3.00		
2	2	2	6	Combinations (petticoat, corset covers)	at .75	4.50	made at home	6.00
1	1	1	3	White petticoats	2 at 1.50 1 at 1.75	3.00 1.75	made at home	3.00
1		1	2	Silk petticoats	at 5.00	10.00		
1	1		2	Cotton petticoats (colored)	1 at 2.00 1 at 1.00	3.00		
2		2	4	White drawers	at .50	2.00		
	2		2	White drawers	at .75	1.50		
	3		3	Nightdresses (flannel)	at 1.00	3.00		
2	2	2	6	Nightdresses (white)	at .90	5.40	made at home	4.50
1	1	1	3	Corsets	at 3.00	9.00		
1	1	1	3	Oxfords	at 4.00	12.00		
1	1	1	3	Shoes	at 5.00	15.00		
1	1	1	3	Rubbers	at .75	2.25		
	1		1	House slippers	at 1.50	1.50		
	1	1	2	Slippers	at 3.00	6.00		
	1		1	Winter coat	at 30.00	30.00		
1			1	Evening coat	at 15.00	15.00	made at home	15.00
1			1	Sweater	at 5.00	5.00		
		1	1	Furs	at 35.00	35.00		
1		1	2	Summer hat (street)	at 2.50	5.00	made at home	5.00
	1	1	2	Summer hat (best)	at 4.00	8.00	made at home	8.00
1	1		2	Winter hat (street)	at 2.50	5.00	made at home	5.00
	1	1	2	Winter hat (best)	at 5.00	10.00	made at home	7.00
						423.40		
				Gloves, veils, shields, hairbows, repairing of shoes, handkerchiefs, neckwear, and other extras		26.60		
$150	$150	$150				$450.00		$111.50

Clothing Budget for Professional or Business Woman

A professional woman whose circumstances require that she give special attention to dress made her clothing budget to meet her needs with the minimum of expense which would meet these special conditions. The climate offered extremes of heat and cold. The budget was made on a three years' schedule which, it was thought, allowed for a more economical basis than a yearly one; the clothing was considered from hygienic, artistic, and economic standpoints. The scale of expenditure was necessarily higher than is economically possible in the majority of professional men's families. The budget is included here to show the advantage of careful planning even where the amount of money available is comparatively liberal. Garments with simple and graceful lines that would not soon go out of fashion were chosen, and little elaborate trimming was used. One good tailor-made suit was purchased in general every other year which could be worn throughout the year and was expected to last at least three years, the third year for rough wear or stormy weather. The muslin underwear was decorated with fine tucks and narrow linen lace. Material was selected which was strong enough to stand the laundry. This budget with some variations was in continual use for many years.

The yearly outlay for clothing was $350. Everything was made out of the house at good dressmakers, tailors, or seamstresses, or purchased ready made. The emphasis was on the tailor-made gown and the reception or evening dress. By care and careful repairs, made by the professional woman herself, the life of many of the garments covered a longer time than stated and thus money was saved to add to special purchases in any one year, or if a special article of some expense, such as a sweater or liberty scarf, was needed, there was a systematic reduction in all the articles for the year to cover it. The expense of summer gowns was saved to a great extent as the three summer months were spent where the plainest clothing was used.

	First Year	Second Year	Third Year	Probable Years of Wear
Suits, coats, waists, and gowns: —				
Tailor-made, to wear at all seasons	$75.00		$75.00	2
Dark waist to go with it	25.00	$35.00	25.00	1
Light waist to go with it	30.00		30.00	2
Evening or reception gown		70.00		2
Marquisette or chiffon cloth gown		35.00		2
Summer silk (light)	30.00		30.00	2
Black Crêpe de Chine (3 piece)		50.00		2
Storm coat	10.00			4
Negligée and cap or blanket wrapper			8.00	3
Fur coat or evening wrap, $50 (buying out of season). Average per year	12.50	12.50	12.50	4
Muff and boa, $50. Average per year	12.50	12.50	12.50	4
Lingerie gown	15.00		15.00	2
Cotton crêpe or muslin waists, 2 at $3 (sufficient, as not worn during summer)	6.00	6.00	6.00	1
Cotton or linen suit	10.00	10.00	10.00	1
Underclothing: —				
Combinations, for winter, silk and linen, 4 at $3.75		15.00		3
Combinations, for mid seasons, lisle thread, 4 at .75	3.00		3.00	2
Linen undershirts, summer, 8 at .75			6.00	3
Muslin combinations, 3 at $2	6.00		6.00	2
Underwaist, fancy, for special occasions	2.00		2.00	2
Drawers, fancy embroidered, 2 at $2, for special occasions		4.00		2
Nightgowns, 1 at $3	3.00		3.00	2
4 at $1.50		6.00		2
Brassieres, 3 at $1.00	3.00		3.00	2
Petticoats: —				
Muslin, white, 2 short at $1.25	2.50			3
Muslin, white, 2 long at $3	6.00			3
Crêpe de Chine, white, 1 at $5			5.00	3
Crêpe de Chine, or taffeta, black	8.00	8.00	8.00	1
Storm underskirt, mohair with silk trimming			3.00	3
Corsets, 2 at $4 or 1 at $8	8.00	8.00	8.00	1
Carried forward	$267.50	$272.00	$271.00	

	First Year	Second Year	Third Year	Probable Years of Wear
Brought forward	$267.50	$272.00	$271.00	
Shoes: —				
Heavy winter	4.00	4.00	4.00	1
Ties	3.50	3.50	3.50	1
Evening suede	5.00			4
Slippers	3.50		3.50	2
Room slippers		1.00		2
Rubbers	.75	.75	.75	1
Gloves: —				
White, long	2.50	2.50	2.50	1
White, short, 2 at 1.25	2.50	2.50	2.50	1
Black or tan, long	3.00	3.00	3.00	1
Black or tan, short	1.50	1.50	1.50	1
Silk, long black	2.00	2.00	2.00	1
Silk, short black	1.00	1.00	1.00	1
Silk, or chamoisette, long white . .	1.50	1.50	1.50	1
Hats: —				
Business, — summer	5.00	5.00	5.00	1
winter	5.00	5.00	5.00	1
Dress, summer	8.00	8.00	8.00	1
winter	15.00	15.00	15.00	1
Hosiery: —				
Winter stockings, 6 at .50 . . .	3.00	3.00	3.00	1
Summer stockings,				
Plain, .50	1.50	1.50	1.50	1
Fancy, $1.00		3.00	2.00	2
Sundries: —				
Veils, 2 at .40	.80	.80	.80	1
1 at $1.50 (large size)	1.50			3
Repairs and cleaning	10.00	7.00	10.00	1
Handkerchiefs, ½ doz. at .50 . . .		3.00		2
3 at .75		2.25		2
Miscellaneous, pins, hairpins, etc. .	1.95	1.20	2.95	1
	$350.00	$350.00	$350.00	

As a matter of fact less than $350 worth of clothing was actually consumed per year because the life of the garments was generally longer than indicated, so that there was some increase in the amount of clothing on hand from year to year. Usually also the sum available for sundries was increased by savings effected in the purchase of the larger items. The above schedule is therefore a budget in the stricter sense of an advance estimate and allowance rather than an absolute record of actual detailed expenditure.

Clothing Budget for Two Children

This budget is a suggestion for an economical method of dressing two children — a boy and a girl who are between the ages of four and eight. The children for whom it was originally intended were one and a half years apart in age, and the plan was used for several years. The following statements give the mother's ideas on the selection of clothing.

A fair price should be given for children's clothes, as very cheap garments are not only badly made, but soon look shabby and wear out very quickly. Many articles can be made at home with great saving of money, and give better satisfaction than those bought ready made. At the same time there are many garments that it is foolish to try to make at home, for they can be bought for almost the retail price of the material and are better made; as, for instance, boys' clothes, suits and pajamas, and girls' drawers and underwaists. Extremes of fashion, materials that tear easily, that are not of fast color or of close weave are to be avoided; above all, material should be bought that washes well, for ability to launder is a requisite in a child's outfit. In carrying out the general scheme for dressing these two children the wardrobe of one was made to dovetail into the wardrobe of the other. Not only do children look well when dressed somewhat alike; but for economical reasons the younger can wear the outgrown garments of the older, and with a little repairing — as the materials used are all of good quality — look quite as well as ever. The boy's white galatea sailor suit, for instance, can be handed down to his sister, and by the addition of a new skirt to match gives her a blouse dress, with the trousers as bloomers. The latter save wear and tear on petticoats and are warm and comfortable. The winter overcoats and hats were exactly alike; dark blue chinchilla coats were chosen and hats which could withstand all conditions of weather. Knitted worsted caps were used for playing out of doors. In summer tan coats and dark hats of a good substantial straw that would not chip or break were selected. In addition to these hats the little girl can have a white lingerie hat to go with her summer dresses, and the boy a hat of white duck. The girl's gingham dresses had bloomers to match, thus eliminating the frequently soiled white petticoat, and in fact keeping all of the underclothes clean. The mixture of cotton and wool for underwear for the ordinary healthy child is preferable to all wool, which not only is very expensive, as it is quickly outgrown, but must be so often washed that it is apt to shrink. The active body of the normal child does not require such heavy covering as all wool.

This budget is good for three to four years, with now and then a few additions made to it. The growing boy requires many of the new things, and yet the little girl's needs are well provided for if she has an additional new white muslin dress, a gingham dress, and a dress or two of tan linen made with ample allowances for growth. The simple box-plaited dress, belted in at the waist with a leather belt, can be let out under each box plait for width, and the length can be regulated by the allowance in the hem. Between the ages of five and eight years the same dress can be worn each succeeding season.

Tucks should always be put into drawers and petticoats, as well as a tuck around the underwaist of the blouse dress skirts, so that they can be let down from that point.

By the time these children reach the age of nine years an entirely new order of budget will be required. The amount spent on the boy was $65.51 and on the girl $51.43. The estimates given were the following:—

Boy's Clothing

2	White Galatea suits,	at $3.50	$7.00
1	Blue serge,		5.00
1	Corduroy trousers,		1.50
2	Flannel shirt waists,	at .50	1.00
1	Overcoat (winter),		6.50
2	Khaki suits,	at 1.50	3.00
2	Dark linen suits,	at 2.00	4.00
2 pr.	High laced shoes,	at 3.00	6.00
1 pr.	"Sneaker" shoes,		.60
1 pr.	Rubbers,		.50
2 pr.	Low shoes,	at 2.00	4.00
2	Underwear suits,	at 1.25	2.50
4	Underwear suits (summer),	at .75	3.00
3	Underwaists,	at .25	.75
6 pr.	Stockings,	at .30	1.80
	Hats for year,		3.50
	Gloves and mittens,		1.50
2	Windsor ties,	at .25	.50
1	Belt,		.50
1	Bathrobe,		2.00
1	Reefer jacket,		3.50
1 pr.	Bedroom slippers,		.50
1 pr.	Rubber boots,		2.00
2 pr.	Pajamas,	at .75	1.50
1 pr.	Overalls,		1.00
2 pr.	Knee protectors,	at .18	.36
1	Sweater,		1.50
			$65.51

(The shoes mentioned are for one year only.)

Girl's Clothing

2	Galatea suits (boy's blouse), skirts make at home, $1\frac{1}{2}$ yds.,	at	.30	$ .90
1	Blue serge dress, box-plaited, and worn with white turnover collar, $2\frac{3}{4}$ yds.,	at	1.00	2.75
1	White dotted-Swiss dress, 3 yds.,	at	.45	1.35
	Trimming of lace, 3 yds.,	at	.20	.60
2	Box-plaited ginghams, 3 yds.,	at	.20	1.20
2	Box-plaited tan linens, 3 yds.,	at	.20	1.20
2	Underwear, winter suit,	at	1.20	2.40
4	Underwear, summer shirt,	at	.25	1.00
4 pr.	Drawers,	at	.25	1.00
2	Flannel petticoats, each $1\frac{1}{2}$ yds.,	at	.60	1.80
3	Muslin petticoats, 1 yd. material and trimming, each,	at	.40	1.20
3	Underwaists,	at	.25	.75
6	Stockings,	at	.25	1.50
	Hats for 1 year,			3.50
	Gloves, mittens,			1.50
2 pr.	Shoes, high,	at	2.25	4.50
1 pr.	Rubbers,			.50
2 pr.	Shoes, low,	at	2.00	4.00
1 pr.	Sandals for summer,			1.25
1 pr.	Rubber boots,			2.00
2	Neckties,	at	.25	.50
1	Belt (black),			.50
1	Wrapper (made at home),			.60
2	Suits pajamas (or boy's),	at	.75	1.50
1	Knee protectors,			.18
1 pr.	Bedroom felt slippers,			.50
1	Reefer jacket,			3.50
1	Overcoat (winter),			5.00
1 pr.	Serge bloomers,			1.25
1	Sweater,			1.50
4	Handkerchiefs, 2 for .25			.50
2	Rompers,	at	.50	1.00
				$51.43

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GLOSSARY

(The index should be used in connection with the glossary, as terms which are unfamiliar when first encountered may be fully explained elsewhere in the book.)

Battening. The driving up in close order of the filling threads in weaving.

Beetling. A special finish of cotton and linen cloth in which the threads are beaten flat.

Boiled-off silk. Silk which has had the sericin or gum removed.

Breaking. The crushing and first separation of the woody portion from the flax or hemp fibers after the retting process.

Calendering. A finish for cotton cloth particularly, which gives smoothness, luster, and special effects by pressure under rollers.

Carbonizing. Removing vegetable matter from wool by acids.

Chlorinated wool. Wool treated with bleaching powder to give luster, destroy its felting property, and increase its affinity for dyestuffs.

Conditioning. All moisture held in the fiber is removed by this process, and the legal amount restored.

Cosmos, peat and wood wool. Vegetable fibers treated to look like wool.

Cotted wool or cotts. Matted wool from sick sheep which it is hard to open up. — Inferior wool.

Denier. A measure of weight used in silk counting. As recently quoted by the United States Silk Conditioning Company, a denier is a skein of silk 450 meters long, weighed by a unit of 0.05 gm. (called denier); 13 to 16 is written 13/16, etc.

Extract Wool. See Remanufactured Wool.

Felting wools. Clips of Mexico, Texas, and California sheep. There are two clips annually, hence the wool is short stapled.

Filatures. Machines for silk reeling which supplement hand work.

Flocks. Soft, fluffy fibers thrown off by different processes in woolen and worsted manufacture, such as raising and cropping.

Frame. An upright machine for twisting or spinning.

Fulling or milling. Processes of shrinking or felting woolen cloth for the purpose of making a close, firm material such as broadcloth.

Garnetting. The Garnett machine converts thread waste into loose fiber.

Gassing. Burning off fuzzy protruding ends from cloth to produce a smooth surface.

Ginning. Separating seed hairs of cotton from the seed.

Hackling. A combing process which separates woody particles and tow from the line or long flax fibers.

Harness. A collection of healds or heddles.

Healds or heddles. Cords or sticks having openings or eyes in their centers, through which the warp threads pass in the loom.

Kemps. Dead wool which will not dye. White, shiny hairs in the wool of sheep that have not had good care.

Lathe or sley. The stick or lath used for battening in weaving.

Lease. The crossing made in the warp threads in preparing the loom for weaving.

Line. Long flax fibers.

Lint. Cotton fibers after removal from seed.

Linters. The short seed hairs left attached to the cotton seeds after first ginning.

Mercerized cotton. Cotton treated with strong caustic alkali under certain conditions, resulting in the formation of cellulose hydrate. The material is stronger and, as commercially made, more lustrous.

Mungo. See Remanufactured Wool.

Neps. Small knots in cotton due to poor ginning or to immature or diseased bolls.

Noils. Short fibers remaining in the comb after the long stapled ones have been removed. Many grades are valuable.

Organzine. Silk thread used for warp. For the sake of strength it is of good quality and has a special twist.

Picking. Putting in the filling threads in weaving.

Pulled wool. Also called Skin Wool and Dead Wool. It is pulled from dead pelts treated with chemicals.

Raddle. A device through which the warp threads pass in order to wind smoothly on the warp beam.

Reed. An attachment of the lathe consisting of fine cords or wires between which the warp threads are carried.

Reeled silk. Silk filaments unwound from the cocoon but not yet twisted.

Remanufactured or recovered wool. Wool recovered from old clothes, rags, and such sources, and rewoven. Three principal grades are recognized: (1) Shoddy or softs. From unfelted clothing such as blankets and stockings. (2) Mungo or hard wool. From felted or milled cloth. Usually ground fine to mix with wools and make a cheap material. (3) Extract. Wool left from mixtures with cotton, after the cotton has been removed by carbonizing.

Retting. Rotting the flax stalks to effect the removal by decomposition of the pectin and resinous substances which hold the bast fibers to the woody portion.

Rippling. Removing the seeds and leaves from the stems of the flax plant.

Roughing. A coarse combing or hackling of flax, following scutching.

Roving. The last stage of drawing out a lap or combination of filaments in preparation for spinning.

Schreinerized cotton. Cotton given the appearance of mercerized cotton by special machine treatment.

Scroop. The rustle or crunch of silk. It is a natural property in some cases, but is increased by treatment with dilute acids.

Scutching. Knocking off the woody particles adhering to the flax fibers after the breaking process.

Seed cotton. Cotton seed with fibers attached.

Shaft of healds. A number of healds fastened together, which draw up to form a shed.

Shed. The opening in the warp threads through which the filling passes.

Shoddy. See Remanufactured Wool.

Singles. Silk thread which has no twist.

Skirts. Clippings or trimmings from the fleece of sheep; principally dirty ends from the legs. The skirting removes the poorer portions.

Sliver. A soft, untwisted rope produced by drawing out a lap or sheet of fibers in preparation for spinning.

Slubbing. An intermediate stage of drawing out after the sliver is formed.

Sorts. The divisions of a pelt into grades of wool.

Souple. Silk with about one sixth of the gum removed.

Spun or waste silk. Inferior silk from various sources such as pierced cocoons and wastes from manufacturing processes. The filaments are carded and spun.

Standard samples. Collections of government samples which show the decision of experts as to the values of wools. Imported wools are compared with these samples.

Staple. Length of fiber in a group or lock of wool, cotton, etc. In the case of wool "long" signifies between four and twenty inches; "short," from two to four inches.

Stripping. Removing the sericin or natural gum from silk by boiling off.

Sword. A stick thrust into a shed to widen the opening for the filling threads in hand weaving.

Temple or tenterhook. A device for holding the cloth in hand weaving stretched to an even width.

Thrown silk. Silk carried through the processes which follow reeling. The result is a thread suitable for weaving. Boiling off, dyeing, and weaving follow throwing.

Tops. The long wool fibers prepared for worsted yarn by the combing process.

Tow. Short flax fibers separated from the line in the hackling process.

Tram Silk thread used for filling.

Warp or ends. The threads running lengthwise of a weave.

Waste. Ends broken off from processes of manufacture. It may be from spinning processes, such as ring waste, or from yarn waste. Much of the waste is put through the Garnett machine.

Weft, woof, picks, or filling. The threads running across the warp in a weave.

Woolens. Made from fibers which have not been combed and laid parallel.

Worsteds. Made from combed and parallel-fibered yarns.

Yolk or suint. Secretions of the skin of sheep which coat the wool, keep it waterproof, and prevent matting.

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