SERICULTURE

Silk is produced from cocoons of an insect usually and rather inaccurately called the "silkworm." This popular name originates from the fact that the silk-producing moth, before reaching maturity, passes through a caterpillar or worm stage during which it spins for itself the cocoon from which later it emerges as a true moth, closely related in nature to the butterfly. The cocoon, formed from an unbroken fiber secreted from the caterpillar's body, is gathered and the fiber unwound, thereby furnishing the silk fiber of commerce.

Varieties of silk moths.-There are between three and four hundred varieties of moths that produce silk cocoons, many of these varieties being found in America. Only a few produce cocoons of the kind and quantity that make it profitable to collect them. Most silk comes from a single variety known to science as the Bombyx mori. This silk moth, or silkworm as we shall call it, has been raised for hundreds and even thousands of years. It is correctly called the domesticated silkworm. From just what wild variety it originally came is not known. It has probably changed greatly during its age-long process of culture. By the selection of only the larger ones for breeding purposes, this variety has been increased in size, with consequent en largement of the cocoon. It has lost its power of flight.

The wings of the full-grown moth are practically useless. At the caterpillar stage it has lost its sight. The constant care that man has given to thousands of generations of worms has made it unnecessary for them to see or fly; these functions therefore have been lost. All necessary movements are provided for by human attendants, who carry the worms to the feeding places and supply them with food. The Bombyx mori, the domestic silkworm, is white or cream-colored, whereas the wild varieties vary widely in color. Brown is very common.

Stages in the life of a silkworm.-The silkworms of all varieties pass through four marked stages: first we find them as eggs; second, as caterpillars or worms; third, as chrysalides, inside of the cocoons; and fourth, as full-grown moths. It takes from twenty to thirty days for the eggs to hatch. The caterpillar stage lasts about 3o days. The chrysalis stage lasts but a few days, and the moths die as soon as they have mated and laid the new generation of eggs.

The Bombyx mori produces but one new generation each year. For this reason it is called univoltine. Some of the wild species of silkworms, however, annually produce two, three, and even more generations. The common Chinese wild silkworms produce as many as seven crops each year in the Hongkong district, while a variety in Bengal, India, produces eight generations. These varieties are called multivoltine. The univoltine is preferred for cultivation to the many multivoltine species because it

produces the finest and strongest silk. In the attempt to use the cocoons from the multivoltine species there is a great deal of waste; it is utterly impossible to reel the cocoons of some varieties.

THE EGG.-Silkworm eggs are about the size of a turnipseed and it takes from **30,000 to 40,000 to weigh an ounce**. If all goes well, these will produce about 130 to 140 pounds of cocoons, and from these about twelve pounds of raw silk may be reeled. Eggs are sometimes sold by one grower to another for so much an ounce. When first laid they are yellow, but if fertile they soon turn blue-gray. The univoltine species is hatched in the month of June by the use of incubators in which the temperature is kept at about 75 degrees. In Oriental countries the eggs are sometimes kept at the required temperature by having them wrapped in folds of cloth around the bodies of the people who are caring for the silk-raising establishments.

THE WORMS OR CATERPILLARS.-Finally the eggs hatch and little, dark-colored worms creep out. This is the caterpillar or larva stage. These little baby caterpillars, especially of the domestic species, are almost helpless. Those in charge provide mulberry leaves to the underside of which the caterpillars attach themselves and get food by sucking the juice out of the leaf. In eight days they have attained considerable growth and are ready to shed their skins for the first time. Three other molting take place before the caterpillar is full grown. Each time, as the molting period approaches, the worms stop eating, rise on their hind legs, and remain still for a couple of days. Finally a crack starts in the skin above the nose. This enlarges until it gives room for the head and later for the body to wriggle out. As soon as the skin is shed the caterpillar becomes voraciously hungry and avidly attacks the leaves supplied' to it. After the first few days of caterpillar life, the worms cease sucking and begin to eat the entire soft parts of the leaf by cutting out pieces and devouring them. The noise made by thousands of these worms in a room, all busily feeding, is like that of falling rain.

Care o f the caterpillars.-The worms are kept on shallow trays which are placed by the dozen in frames. Laborers men, women, and children-busily pick leaves from the trees, bring them in fresh to the worms, change the worms from tray to tray, clean the old trays and prepare them for another group of worms. Great care is necessary in so handling the worms that they may not be hurt. Though the worms are blind, they have none the less a very acute hearing; wherefore all noises must be prevented se far as is possible. A sharp noise causes the worm to stop feeding and to give out-really to waste-a part of that liquid in its body which will later make silk fiber. Much silk is lost in this way, even when the utmost care is exercised. Such unavoidable noises as thunderstorms cause very marked losses. As a rule the laborers walk barefooted or in their stocking feet about the room in which the silkworms are kept.

THE COCOON.-After the caterpillar has shed its skin four times it is ready to pass into the next stage, that of the cocoon or chrysalis. One ounce of eggs has become by this time, if good fortune has attended the work, 20,000 full grown worms. These worms have consumed in the period of thirty days over half a ton of green leaves. When ready to spin their cocoons, the worms are transferred to trays constructed with brushy tufts in which they like to make their cocoons.

The cocoon is constructed in most interesting fashion. There are two long bags inside the worm's body, one along each side. These bags or sacs contain a sticky or viscous liquid. This is slowly exuded through the worm's under lip, and immediately upon coming into the air it hardens into a thin little stream of fiber; this fiber is the silk. Usually both bags exude the liquid at the same time; hence the fiber that is formed at the lower lip of the worm is generally double, as can be seen by laying almost any silk fiber under a strong magnifying glass or a microscope.

The worm attaches itself to a tuft on the tray provided for it. The wild worm selects some bush, weed, tuft, or grass, where it begins to give off the silk liquid, and, as it does so, swings its head from one side to the other, depositing the silk fiber in the form of figure eights. At first the directions are somewhat irregular, but later the method of laying the fiber becomes almost uniform. Soon the worm is wholly inclosed by his tent of silk fiber, but he continues spinning on the inside until his silk secretions are used up, and the cocoon is completed.

THE CHRYSALIS,-The caterpillar then changes from a worm to a chrysalis, a thing that looks partly like a worm and partly like an insect. In this condition it sleeps for about eighteen to twenty days. Then, if left undisturbed, it is transformed into a moth; it becomes fully awake, and strives to emerge from the cocoon. Slowly it pushes itself forward against the wall of the cocoon, breaking some of the obstructing fiber and dissolving parts of it by a strong, alkaline liquid which it gives out of its mouth.

THE MOTH.-After it has come out of the cocoon the moth remains quiet until its wings are dry, and then proceeds to the mating which lasts for several hours. The female moth now lays her eggs in two deposits, a few hours apart. Each moth produces from three hundred to five hundred eggs. The male is smaller than the female, but more active. Both are covered with woolly hair and, if of the Bombyx mori variety, are creamy white in color. Neither male nor female eats anything betwen the time when it begins to spin and its death.

COMPLETING THE CYCLE OF LIFE.-The eggs are laid over an even surface, sometimes with a gummy liquid that sticks the eggs to the object upon which they are laid. Shortly after the mating and the laying of the eggs, the moth dies. Its cycle of life is completed. b

HOW THE SILK FIBER IS OBTAINED

As already indicated the cocoons are the source of the silk fiber. The silkworm deposits upwards of 4,000 yards of the tiny fiber in making its cocoon. But when the moth leaves the cocoon by breaking its way out, it cuts this fiber off in many places, thus largely decreasing its value; hence silk producers kill the chrysalis in the cocoon to prevent its coming through. The usual method is that of immersing the cocoons in steam for a few minutes. Sometimes the chrysalides are killed by baking the cocoons in a hot oven; recently a method of freezing them to death has been used to a limited extent. Another method, that of placing the cocoons in boiling water, serves a double purpose. Not only does it kill the chrysalides, but it also softens the "gum" that sticks the threads together, so that they can be unreeled from the cocoon. But in this case the reeling must begin at once, while if the chrysalides are killed by steam, heat, or frost, the cocoons may be kept in their original form for years.

The cocoons of the best domesticated varieties of silkworms are either white or cream-colored. The wild cocoons may have almost any color, according to the feed upon which the caterpillar lives. It has been shown that red coloring matter put into mulberry leaves fed to the worms tends to tint the cocoon red, and that other colors put into their food produce corresponding effects in the cocoons.

Reeling.-The fiber is removed from the whole cocoons by a process of unreeling. The method is as simple as it is laborious. After the fiber in the cocoon is loosened by soaking in boiling water, the cocoons are taken out, and the floss, or loose, fluffy, silky fiber on the outside, is cleaned off to be used in the production of carded silk yarns. Next the cocoons are put into a basin containing water kept constantly at lukewarm temperature. Laborers use a whisk broom or brush and push the cocoons up and down in the water until some loose end of fiber becomes attached to the broom. This fiber, the loose end of a cocoon, is drawn gently; the cocoon tumbles around in the water and gradually it unreels itself. A single fiber is very small, and for reeling purposes usually three or four are combined. These are passed through a smooth ring as one fiber and then onto a reel frame which is usually run by foot power, but sometimes by mechanical power in modern reeling plants, or by filatures as they are called. By means of the reel frames the raw silk is reeled into skeins or hanks.

Care necessary in reeling. The threads as they come from the cocoons are not of even thickness because of the fact that the various glands in the spinning worm do not operate alike at all times. Most of the time both glands or silk sacs secrete together, but occasionally only one produces; hence unevenness results. As a rule the thread is finer when the worm first begins to spin than it is during the middle of the process; the fiber tapers again at the end of the spinning. Since it is very necessary to get an even silk thread in the skein that is being formed, the operator in charge must be constantly on the watch. When the thread grows thin, another is added; when it grows thick a thread or two is taken out. Each operator runs two reels. Keeping both reels going and carefully watching the threads to note changes in size, adding to or taking away to give uniform size, preventing breakage, and keeping a new supply of cocoons properly soaked in the basin-all these are duties that call for extreme deftness of fingers, accuracy of eye, and quickness of mind.

Product per cocoon.-The average cocoon reels off about three hundred yards in a single thread. It will be recalled that there may be as many as 4,000 yards in a cocoon, but considerable is brushed off in the outer floss, and a portion near the inside will not reel well; hence only the middle of the fiber can be saved in the form of one long thread. The very best cocoons reel off as high as four hundred yards. Cocoon wastes.-The portions that are not reeled are used in making coarser yarns by carding, combing, and spinning as with the other textiles. The longer fibers are often carded and combed as in making worsteds. This sort of silk is known as florette silk. Shorter fibers which may only be carded and then spun are called bourette silk. The general names for both varieties are silk waste, floss, schappe, or echappe. Floss is probably the best name, since schappe is used frequently for manufactured goods made out of floss or waste. But it should be remembered that floss is also the name given to the outside loose fibers surrounding the cocoon.

Breeding silk moths.-The cocoons are not all alike in size, shape, color, and other qualities. For example, the cocoons containing female chrysalides are larger than those containing males. The color varies considerably. Not all can be used for making silk fiber; some must be left for breeding purposes. The very largest, best-looking, smoothest, and healthiest are set aside and the moths allowed to come out and breed. This method makes sure that the stock of silkworms will be kept up to a high producing standard.

SORTING COCOONS.-The very best cocoons are often set aside and reeled by themselves for the finest and strongest silk threads. For example, silk warp is usually made from fiber drawn from the better grades of cocoons. The finest sewing silk comes from the most perfect cocoons. The poorest cocoons, the deformed, discolored, or otherwise defective ones, are often not reeled at all but are simply turned at once into silk floss.

Silk wastes.-Various names are given to the grades and kinds of waste or floss silk. Very irregular masses of torn silk fibers are called watt silk. The inner portions of the cocoon next to the chrysalis are called wadding, neri, or ricotti, and various other names. Imperfect cocoons which are not reeled are called cocoons or piques. The wastes accumulated in reeling, due to breakage, loose ends, and so on, are called frissonets,

Use of silk waste. Until about 1857, silk waste was entirely useless, but it is now the material of an important industry. It is cleared of gum by boiling, and then run through machines that break up, card, comb, and draw the fibers into shape for spinning.

Silkworm diseases.-The silkworm is subject to a number of severe diseases, and also to depredations from mice, weevils, and ants. There are times when whole chambers where the silkworms are kept become infected with contagious diseases that kill off the worms before they can spin. Wild worms are by no means so liable to disease. The susceptibility to disease is a direct result of domestication. Under the most favorable circumstances, fully one-fourth of the eggs fail to produce worms that grow to maturity. Some are killed by accident, but the majority by disease.

The principal diseases of the silkworm are: pebrine, grasserie, flacherie (or flaccidity), gattine (or macilonza), and muscardine (or calcino).

Pebrine is a bacterial disease, both hereditary and contagious, which has wrought tremendous damage in the silk industry in Europe, especially in France. At one time, about 1865, the French cocoon production had been almost destroyed. No cure for the disease has ever been discovered. The only means of getting rid of it is to allow the affected worms and moths to die out, carefully to disinfect the premises, and then to start in with a fresh supply of healthy eggs.

SCIENCE IN TREATING SILKWORM DISEASES.-Pasteur, a noted French scientist, showed how the disease might be prevented. Every moth, after laying its eggs, is killed and its interior examined carefully under a microscope, the only means of discovering the germs. If the germs are found in the moth's body, the eggs are destroyed, since they also are sure to contain some germs carried from the mother moth's body. When no signs of germs are found in the moth, the eggs are considered safe to grow. After this method came into use, French silk growing leaped forward again. Experiment stations for the examination of eggs were established by the government in numerous placesan example followed by Italy and other countries. Lately the French growers have become careless again, and silk production is consequently rapidly falling off. Now, Italy and Austria are doing the most to stamp out the disease, and

these two countries are producing the finest raw silks. Particularly in Tyrol, a province in Austria, is this scientific method of propagating disease-free eggs in most successful use. No silk-growing peasant in either Italy or Tyrol would today think of hatching out silkworm eggs that were not certified by some government experiment station as free from disease. Leading growers in France are hoping to revive the careful inspection that Pasteur planned for them.

Flacherie is now the most dreaded disease among European silkworm growers. It attacks and speedily kills the worms shortly before they are full-grown. Often thousands of worms in one room die in a single day. It is really a form of indigestion due to various causes such as overeating, poor leaves, bad air in the room, excessive heat, dust on the leaves, or keeping worms too thick on the trays. Like pebrine, flacherie is contagious and hereditary. It can, however, be prevented by carefully avoiding the causes mentioned, and by disinfecting the rooms where cases have occurred. Eggs that have been exposed to the disease are washed in a disinfecting solution before being hatched.

The worms may easily be overfed at certain stages, especially on young, tender leaves when the worms are almost full-grown. Sometimes, this overfeeding causes a disease that is called grasserie. It is not contagious, but does kill a number of worms every year, especially in warm countries.

Gattine causes the worms to become torpid. This is a germ disease, and can be eradicated by changing the trays and disinfecting the old ones. The growers sometimes shake the worms vigorously and thus jar them out of their torpor.

Muscardine is a mold disease which kills worms very rapidly whenever it gets a start. It is more contagious than any other silkworm disease. The methods of getting rid of it are disinfection, letting in pure air and light into the trays, burning sulphur in the room, and so on.

The possibility of disease, together with the constant need of care, keeps the silk growers constantly on the watch over their worms. The task is tremendous, and the chances for loss are always great.

WILD SILKS

The wild silks are gathered principally in Japan, China; and India. There are, of course, several varieties of wild silk cocoons, each with qualities somewhat different from the rest. The principal variety of Japan

is the Yamai-mai, and the chief varieties of India are the tusser, or tussah, and the ailanthus. As already indicated, most of these silks are much darker in color than the domesticated silk, the Bombyx mori, probably because of the difference in feed. Wild silkworms do not always have mulberry leaves to eat. Great numbers feed on oak leaves and in some cases on other plants.

Quality of wild silk.-In a general way it may be said that wild silks are in most respects of poorer quality than domesticated silk. They are harder to bleach, and do not take dyes so well. They are generally very uneven in texture, but when made up into fabrics are often more durable than common silks. Wild silks are used principally in the manufacture of pile fabrics such as velvet, plush, and imitation sealskin, and in heavy or rough cloths such as pongees and shantungs. While the silkworms of the wild varieties take care of themselves, and therefore do not require the constant labor that must be given to domesticated silk, the expense of gathering is nevertheless high. The wild cocoons must be hunted, trees must be climbed to gather them, and much time may be consumed in collecting comparatively few. On the whole, however, because of the poorer qualities, wild silks are worth considerably less than "tame" silks.

NATURE OF SILK FIBER

The perfect raw silk fiber is a very fine filament with two parts that can readily be seen under a microscope. This filament is composed of a substance called fibroin, and the outside is covered with a waxy substance called sericin. Silk fiber in its raw state is for its size the strongest textile fiber in existence. It is said that it is as strong as an iron wire of the same size would be. Notwithstanding that in the processes of manufacture much of this strength is lost, unless very badly treated, the fiber remains remarkably strong. It is also very elastic and durable. It has a high natural luster which is improved upon in some manufacturing processes. The fabrics into which it is made are beautiful even in the natural silk colors.

Absorptive power of silk.-Silk fiber readily absorbs water; wherefore, in commerce, rules are necessary regarding the amount of water allowable in the fiber offered' for sale. The usual amount allowed by weight is about eleven per cent. It can easily be understood that when raw silk fiber sells for more than three dollars a pound, a large fraction of the total weight, such as one-third, one-fourth, one-fifth, or even one-tenth of water, would make a big difference in the price. Silk markets, therefore, are always equipped with the necessary apparatus for telling just what part of the weight of the silk is water. For example, the Silk Association of America has a large laboratory in New York in which the principal work is the determination of the proportion of moisture in raw silks brought from the market. The process of getting the silk into the proper standard condition as regards moisture is called "silk conditioning."

Because of its absorptive qualities, silk takes dyes very well, in fact better than any other textile; hence silks may be given delicate shades and tints of color that would be quite impossible in cotton or linen. It may also, as we shall see, absorb weighting materials that are introduced by way of adulteration. Pure dye silk should not contain more than ten per cent of its weight in dyeing or weighting materials. Ordinary silks contain much more weighting than this.

HUMAN LABOR IN SILK PRODUCTION

After the raw silk has been reeled into skeins or hanks, the most laborious parts of silk production are completed; that is, most of the work done on the fiber thereafter is done by machine processes instead of by hand. The amount of hand labor that it takes to produce raw silk is almost incredible, and the amount of labor taken after the machine processes begin is no less than for other textiles. It has been said that it takes more human labor to produce a lady's silk dress, from the mulberry leaves into the finished product ready for wear, than it takes to produce and build a locomotive out of the raw ores in the ground. More hours are expended, and more people have something to do with the work.

Cost of production.-If the labor employed in the production of silk were paid as high wages as are commonly paid in the iron and steel industry the silk dress would cost almost as much as a locomotive. As it is, raw silk production is carried on chiefly in countries where wages are very low. At the present prices of silk, the most efficient workmen doing their very best could not earn more than fifteen cents per day at this kind of work. The usual wages in the silk-producing countries are lower than this.

Where the raw silk is produced.-It is not surprising then that 40 per cent of the world's raw silk is produced by the Empire of China, 20 per cent by Japan, 20 per cent by Italy, 10 per cent by Persia, Asiatic Turkey, India, and Arabia, and the remaining 10 per cent by France, Austria, Spain, or Portugal. Italy produces some of the finest silk in the world; India and China, some of the coarsest and poorest.

Attempts to raise silk in the United States.-Several attempts have been made to raise silk in this country, and practically every experiment has shown that a very fine quality of fiber could be produced; but the great obstacle is the cost of labor to care for the worms, pick the leaves, attend to the mating of the moths, make the necessary examinations for disease, and reel the raw silk. No mechanical devices have ever been invented to do away with the great amount of human hand labor. Not while clever people, men, women, and children, in China, Japan, and other countries are willing to work for less than ten cents a day as they now do, can raw silk production become profitable in this country.

Methods of production in Japan.-Silk is often handled as an auxiliary industry by Japanese and Chinese farmers. The women and children are occupied with the care of the silkworms while the adult men are employed in the gardens and fields. Being a home industry of this nature, it is often undertaken even when there is small prospect for payment for time expended. The time of the women and children is not considered worth much in any case. One person cares for about 10,000 to 12,000 worms. The average production per family among the families that do raise silk is about five bushels of cocoons per year. The return for these cocoons generally pays for the labor expended in their production at about the rate of ten cents a day.

Improvements in reeling silk.-Reeling has been greatly improved in modern filatures by the introduction of power for running the reels and by using gas to keep the basins heated at a proper and constant temperature, but this change has not eliminated the necessity for cheap labor. No filature of any consequence is to be found in any country or city except where labor is abundant and very cheap. Silk reeled by hand or foot power is called "re-reel silk," while that reeled by power machinery is called "filature silk."

MARKETING SILK

The products of silk production are marketed in various forms. For example, in certain communities in Italy, there is a large business of selling certified silkworm eggs. These are usually sold at a certain price an ounce. Many silk growers sell the cocoons that they produce. The usual method of preparing them for market is to stifle the chrysalides by steam, by heating in ovens, or by freezing and then drying them thoroughly. When dry, they are sorted according to size, color, and quality, and are sold by weight. As a rule, small silkworm growers everywhere dispose of their product in this manner and at this stage. Finally, raw silk is marketed after it is reeled, some of it as reeled silk, and the parts that will not reel as silk waste. In the Orient, silk is reeled into skeins of varying sizes, which are then packed into square blocks, called books, containing from five to ten pounds. The books are packed in bales, each weighing from 100 to 200 pounds or more. In 1912 the average price for a pound of reeled silk was between three and four dollars. From this it can be seen that a bale is a pretty valuable piece of goods.

Importations into this country.-Steamers coming from China and Japan to the western United States handle the silk as carefully as if it were gold. It is unloaded, usually at Seattle or San Francisco, and then taken east in baggage coaches directly to New York, the great American raw silk market. Often an entire train is made up of baggage coaches loaded with raw silk, and these "silk specials," as they are called, are given the right of way from coast to coast. Passenger trains, freight trains, and all must find the side

tracks when the "silk special" passes through; and well they may, for the silk in each coach may average more than $125,000 in value, and the value of the entire trainload of silk may be $2,000,000.

Markets for waste silk.-Hartford, Connecticut, is the principal port of entry for the large quantities of silk waste and floss imported into this country. Boston comes second. Both are near the great New England silk mills (New London, Winsted, South Manchester, in Connecticut, and Pittsfield, Northampton, Holyoke, and Florence in Massachusetts) where large quantities of spun silk are produced. The center of reeled silk manufacture is in Paterson, New Jersey, and in the hard coal region of Pennsylvania. The state of New York also has a large number of establishments using reeled silk in some stage of manufacture.