DYEING SILKS: BY PROFESSOR CHARLES PELLEW, OF COLUMBIA UNIVERSITY: NUMBER VII

SOME of my readers may have noticed that in the last article, on the Acid Dyes, no details were given about the dyeing of silk, although this fabric, along with wool, feathers, and other animal fibers, is almost universally dyed with colors belonging to this class. But silk is such an interesting and important textile and so unlike, in composition and character, all the others, that it has been thought advisable to devote a special article to its preparation and structure before touching on the dyeing.

DEFINITION—VARIETIES OF SILK:

Silk has been defined as a "smooth, lustrous, elastic fiber of small diameter and of animal origin." As is well known, the ordinary silk of commerce is secreted or "spun" by the silkworm, the caterpillar form of a moth known as Bombyx Mori, the moth of the mulberry tree. These silkworms have been cultivated for thousands of years, but there exist in different parts of the world, notably in India and Japan, wild or uncultivated silkworms, derived from nearly related but not identical families of moths, and whose silk is collected in the forests by the natives, forming what is known in commerce as wild or tussore silk.

Of course, the silk from silkworms, cultivated and wild, is the only one yet produced on a commercial scale. But silk can also be obtained from other animals, notably from spiders, and from a peculiar shellfish, the pinna, found in the waters of the Mediterranean.

Silk from Spiders.—For a couple of hundred years it has been known that in certain tropical and semitropical countries spiders were found of such large size that their webs would furnish a fiber strong enough for textile purposes. In Paraguay and in Venezuela silken fabrics have been made in this way on a small scale for a long time.

During the last few years a similar industry has been started in Madagascar by the efforts of a French missionary, who invented a simple apparatus for confining the spiders and for extracting silk from them in fairly large quantities. The large spiders used for this purpose are extremely abundant in the forests and parks on that island.

The factory, as it was finally fitted up on the very edge of the forest, contains workshops for the spiders in the form of a large number of little pigeonhole cells, in which each insect is carefully shut in by a wooden guillotine-like holder, which fastens around its body, exposing the abdomen and separating it from the legs and head. The operators (native girls with very delicate, light fingers) then proceed to tap these spiders, drawing the silk from them by pressing them until the gummy mass exudes, and then drawing it off in fine threads and joining it to others which, together, are reeled off by a small wheel until the supply from the individual spider is exhausted. It is claimed that if carefuly treated the spiders are not injured by this process and

if well fed can be tapped four or five times a month, giving some thousands of yards of silk each time. The thread thus formed is of a bright yellow color, extremely strong, and very brilliant and lustrous. It has been woven into cloth, making very beautiful material; and at the Paris Exposition in 1900 a piece of spider silk was shown, 18 yards long and 18 inches wide. Unfortunately, on the side of a commercial success, to produce this cloth some 25,000 spiders were required and it is estimated that the silk cost from $30.00 to $40.00 a pound. It is hoped that with experience the cost may in time be lessened until this silk can compete with ordinary silk on fairly equal terms.

Silk from the Silkworm.—As before mentioned, this can be divided into two parts, according to whether the silkworms are the cultivated or the wild varieties. In each case the silk is produced by the caterpillar spinning a covering or shroud, the so-called cocoon, around itself to protect it when in the form of the chrysalis or pupa, awaiting its transformation into the moth. The silk of commerce all comes from the worms of the moth known as Bombyx Mori, which during thousands of years has been studied and grown for this purpose. These worms feed upon the leaves of the white mulberry tree and cannot be successfully cultivated without that plant. The somewhat similar worms producing the various wild silks, or tussore silks, of commerce, live upon leaves of the oak, ailanthus, elm, castor oil plant and others.

History.—So far as we can tell, silk was first discovered and manufactured in China about 1700 B. C., a date corresponding in Biblical history to the time of the patriarch Joseph. From China it was exported to the great and wealthy empire of Persia, and from there was first brought into Europe by Alexander the Great after his defeat of the Persian king. Its origin, although known to and described by Aristotle, was for several hundred years a mystery. During the Roman Empire silken garments woven in Europe from Chinese silk imported by way of Persia were important and very highly prized articles of luxury. About 555 A. D., while commerce with Persia was interrupted by warfare, two monks in the pay of the Emperor Justinian smuggled eggs of the silkworm and seeds of mulberry trees from China to Constantinople.

This was the origin of the European silk industry. Its cultivation spread rapidly to the various countries bordering on the Mediterranean, and by the 17th century was firmly established not only in Spain and Italy but also in France. Efforts were made to introduce it at this time into England, but without much success, and in 1622 King James I started the industry for the first time in the colony of Virginia in this country. Since that time numerous attempts have been made to develop the American silkworm industry, but with very little success, owing to the large amount of hand labor necessary to produce the material.

At the present time the very finest raw silk in the world is produced in the South of France, and next to that comes certain brands of Italian silk. The Japanese silk is more variable in quality, although steadily improving, while the Chinese silk, as a rule, is less satisfactory and more apt to be light and fluffy.

With regard to the consumption, it was estimated that in 1907 Europe used some twenty-five million pounds and the United States fifteen million pounds of raw silk, which at an average price of nearly $5.50 per pound amounted to over two hundred and eighteen million dollars.

It is universally agreed that the United States consumes more silk than any other country in the world. In 1906 the importations of raw silk into the country amounted to nearly sixty-five million dollars; of spun silk, over three million dollars, and of waste (cocoons, etc.) over one million dollars, making a total

of sixty-nine million dollars. Besides this there were imported of manufactured goods over thirty-four million dollars, making the total importations for the year well over one hundred million dollars.

Preparation, Manufacture of Silk.—The full process of manufacturing silk, from the silkworms to the shop, may be divided into the following steps:

(1) Raising of the cocoon,
(2) Reeling or filiature.
(3) Throwing the raw silk,
(4) Stripping, weighting, dyeing and finishing the skeins,
(5) Weaving and finishing the fabric.

Raising the Cocoons.—The eggs collected from the moth are spread out on cardboard, kept warm and damp, and in 10 to 12 days hatch out into minute worms. These are freely fed with mulberry leaves and grow very fast, until at the end of four or five weeks they are full grown and ready to spin. They are then transferred to wicker baskets, and proceed to fasten themselves to the walls at convenient places, and then to gradually enshroud themselves in a fine, closely woven web or cocoon by continuously pressing from the silk glands in their heads a thick, gummy fluid which hardens in the air.

This operation takes about five days, after which the worm changes to the state of pupa or chrysalis, and rests immovable inside the cocoon until after some fifteen or twenty days it changes to a moth. It then proceeds to eat, or rather dissolve by means of an alkaline secretion, its way out of the cocoon, cutting through the threads to such an extent that the silk is useless for reeling purposes, and can only be used for carding and spinning. Accordingly, only enough cocoons are allowed to ripen to furnish a new crop of eggs; the rest are carefully baked, so as to destroy the pupæ contained in them.

Reeling the Raw Silk from the Cocoon.—The amount of silk obtained from each cocoon is but small, and much of it is in the form of floss or waste, useful only for spinning. So it takes from two thousand to three thousand cocoons to furnish one pound of raw silk. The silk is reeled off by hand, after soaking the cocoons in warm water to soften the gum which fastens the fibers together. The threads from several different cocoons are combined by the operator into one continuous fiber, which is reeled off gradually, and as fast as one thread breaks or comes to an end another one is thrown in from another cocoon.

This furnishes the raw silk of commerce and consists of two different compounds. The most important is the fibroin or silk fiber, which is strong, elastic, with brilliant luster, insoluble in water and dilute acids, but readily soluble in alkalies, especially if hot and strong; but besides this, it contains from 30 to 45 per cent. of sericin, or silk gum, which is stiff and brittle, without luster, and, while softening in warm water, dissolves readily in hot soapsuds or warm alkaline solutions.

Throwing the Silk.—Silk differs from cotton, wool, linen and other textile fibers by being made of one continuous thread and not of a series of short threads which have to be twisted tightly together before they can be woven. So, instead of a spinning process, the raw silk is subjected to what is known as "throwing," in order to make the thread suitable for dyeing and weaving. For this purpose the raw silk is softened in hot water and soapsuds and several threads are combined together by twisting and supposition and reeled off into one thread of thrown silk.

Two main varieties of thrown silk are universally recognized in the trade, namely, organzine and tram. The organzine is the thread used for warp. It is very strong and tightly twisted, with, as a rule, considerable luster. In some kind of weaving the luster of the material depends entirely upon the warp. The tram, on the other hand, constitutes the filling. It is usually more loosely woven, of thicker thread, and need not be either so

strong or so lustrous. It is usually made of from two to five threads of raw silk and, of late years, has been generally greatly adulterated.

While this thrown silk has lost some of its original gum, it still contains some 20-30 per cent. of sericin, or gum, which prevents it from having any luster, makes it hard to dye, and causes it to be too stiff for weaving.

Stripping or Degumming the Silk.—To extract this gum, the silk, still in skeins or hanks, is heated for some hours in a strong solution of (neutral) soap, and then washed well in other soap baths and in hot water until it is perfectly soft and has gained the proper luster. The soap containing the gum thus extracted, called "boiled-off liquor" or "soap gum," is carefully kept and used in dyeing colors.

After stripping, there are two lines of treatment, according to whether the silk is to be "piece dyed" or "dyed in the skein."

In piece dyeing the stripped silk is passed through a weak bath of acid, usually acetic acid, and then woven into goods of the desired quality. These goods are then dyed in the piece by being run through the dye bath until they are of the proper shade. The dye bath (for colors) is made by stirring the proper quantity of acid dyestuffs, the same as those mentioned in the last article, into a bath of boiled-off liquor, which is faintly acidified, or "broken," as the technical phrase goes, by the addition of some sulphuric acid. This boiled-off liquor has the property of laying the dyes on the silk evenly and thoroughly and is better for that purpose than any other medium. For amateur work, or where boiled-off liquor cannot be obtained, very fair results can be obtained with a strong bath of olive oil soap (Castile or Marseilles soap), made acid with dilute sulphuric acid.

The term "breaking" the soap bath is very significant. The acid should be added drop by drop to the frothing soap bath until the bubbles disappear and a thin iridescent film of fatty acid rises to the top of the liquid.

After the piece goods are brought to the proper shade, they are then finished, usually by carefully rinsing in water to take away all traces of free acid, then by passing through a cold soap bath, often with a little olive oil emulsified in it, to increase the luster, and finally through a bath of weak organic acid, like acetic acid, to develop the so-called "scroop" or "feel" of the silk. When silk is washed in soap, or, especially, in even a weak bath of alkali, it becomes soft and clammy to the touch, and has no "life" or "snap" to it when dry. The passage through even a weak bath of acid develops the characteristic stiffness of the silk fiber, and causes it to give the peculiar rustling sound when pressed.

Skein Dyeing.—The silk dyers proper, who dye and finish their silk in skeins before weaving, consider the above process as very inferior, in skill and in results, to their own art. It is true that piece-dyed goods are usually rather light and thin in quality, and not, as a rule, as lustrous as the others, while they can only be produced in solid colors, or with patterns stamped or printed upon a background of solid color. On the other hand, it is much more difficult to heavily adulterate and weight piece-dyed goods, and hence the lack of weight has compensating advantages.

The treatment of silk in skeins has been developed to a high art by the skill of dyers and chemists throughout the world, and is not infrequently referred to as one of the triumphs of modern science. Whether the chemist who makes two pounds of silk appear from one, or far less than one, pound of raw material is entitled to quite the same rank, as a benefactor of the human race, as the scientific agriculturist that we have so often heard about, is perhaps open to question. But the products of his skill and labors are met with everywhere and I propose in the next article to discuss his methods with some detail.