DEPARTMENT OF AGRICULTURE.
SPECIAL REPORT—No. 11.

THE SILKWORM;

BEING A BRIEF

MANUAL OF INSTRUCTIONS

FOR THE

PRODUCTION OF SILK.

WITH ILLUSTRATIONS.

WASHINGTON:
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1879.

SIR: In obedience to your directions, the following brief manual of information relating to the Mulberry Silkworm and to silk culture has been prepared.

Respectfully,

CHAS. V. RILEY,
Entomologist.

HON. W. G. LE DUC,
Commissioner of Agriculture.

INTRODUCTION.

Whatever opinions may be held as to the feasibility, or as to the profits of silk-culture in this country, the desire for information on the subject and the ambition to embark in the industry, evinced by correspondents of the Department, demonstrate the fact that there will be no difficulty in getting our people to turn their attention to it. Without going into details as to the history of past attempts at silk-culture in North America, it must be obvious to all who thoroughly investigate them that the causes of failure have ever been transient ones. They may be summed up in the statements that (1) labor has found more profitable avenues of employment, and (2) that there has been no home market for the cocoons. At the present time the first statement no longer has force, but the second holds as true now as it ever did.

As a means of meeting the difficulty, I have urged, and would urge, that Congress give to this Department the means to purchase, erect, and appoint with skilled hands, on the Department grounds, a small filature or reeling establishment. In such an establishment reelers could be trained, and the cocoons, at first raised from eggs distributed by the Department, could be skillfully reeled and disposed of to our manufacturers. A market would thus be formed for the cocoons raised in different parts of the country, and a guarantee be given to those who choose to embark in silk-culture that their time would not be thrown away. All industries should be encouraged in their infancy; and for the first few years, or until the silk industry could be considered well established, the cocoons should be paid for at the European market rate, plus the cost of reeling, which would range from 50 cents to 75 cents per pound of choked cocoons. This last should be looked upon as a premium offered by the government to the raisers, in order to stimulate the industry until such time as the reeling might be safely left to private enterprise, when government encouragement could be withdrawn.

Meanwhile, and pending Congressional aid, those who desire to raise silkworms in this country, for profit, have three alternatives: either (1) to ship the choked cocoons to Europe, (2) to reel them, or (3) to raise eggs and sell these.

(1) That the children and more feeble persons in a household may find profitable employment in raising cocoons to be shipped abroad is proved by the case of Mr. E. Fasnach, of Raleigh, N. C., who has for several years been in the habit of thus shipping the cocoons reared by his family. He sends in bales 6 by 5 feet in size, and averaging about 40 pounds of stifled cocoons, for which he has obtained as high as $2.50 per pound net, the freight costing only $3 per hundred pounds between Raleigh and Marseilles. Mr. B. A. Weber, of Rockford, Ill., last year raised 40 pounds of cocoons, and also shipped

to Europe through New York brokers, and others have done likewise; but I would advise no one to invest capital on this basis.

(2) Nor would it be safe for individuals to rely on reeling their own silk. The art of reeling in modern filatures and with steam appliances has been brought to such perfection that the hand-reeler cannot hope to produce a first-class article. The only way in which silk-reeling can be managed profitably, at present, is where a colony of silk-raisers combine to put up and operate a common filature, as in the case of the settlement at Silkville, Kans., the colony of French and Italians who located at Fayetteville, N. C., in 1876, or the Italian settlement at Vineland, N. J.

(3) Under existing circumstances, more money has been made by the sale of eggs than by either of the other means, and silkworm growers in this country have gradually drifted into this branch of the industry. Eggs raised in this country are free from disease, and the fact that as high as $6 and $8 per ounce have been paid for them, and that France paid in 1876 114,000 francs and in 1877 1,691,400 francs for eggs exported from the United States,* is as eloquent in showing the remarkable adaptation of our country to silk culture as that other fact, not generally known, that the chief of the French commission to our Centennial confessed that there was no silk in France superior to some that was there on exhibition and grown in North Carolina. The production of a certain number of eggs does not necessarily prevent the production at the same time of choked cocoons or reeled silk; and the pierced cocoons that have been used for breeding purposes have also a certain market value, commanding about $1 per pound at Paterson, N. J. This egg-producing branch of the industry can, however, only admit of a limited expansion.

As a means of indicating the profits in silk culture I have prepared the subsidiary estimates. Optimistic theorists have done much harm in the past by making fabulous calculations as to the profits of silk culture. The figures here given are based on data furnished by men like Messrs. E. V. Boissière and L. S. Crozier, of Silkville, Kans., E. Fasnach, of Raleigh, N. C., T. N. Dale, of Paterson, N. J., &c., and on the current prices as quoted in the *Moniteur des Soies*. They are in every sense moderate estimates, but it must not be forgotten that they do not include capital invested in the shape of food plants. As yet, and until Congress gives the necessary encouragement, it were safest for those only to embark in this culture who already have mulberry trees to use or who decide to feed Osage orange.

PROFITS OF PRODUCING COCOONS: ESTIMATES FOR TWO ADULTS, OR MAN AND WIFE.

Average number of eggs per ounce, 40,000.

Average number of fresh cocoons per pound, 300.

Average reduction in weight for choked cocoons, 66 per cent.

Maximum amount of fresh cocoons from one ounce of eggs, 130 to 140 pounds.

Allowing for deaths in rearing—26 per cent. being a large estimate—we thus get, as the product of an ounce of eggs, 100 pounds of fresh or 33 pounds of choked cocoons.

Two adults can take charge of the issue of from 3 to 5, say 4 ounces of eggs, which will produce 400 pounds of fresh or 133 pounds of choked cocoons.

* These figures are on the authority of the *Moniteur des Soies* for January 18, 1879, but they may include also those received from China through the United States.

Price per pound of fresh cocoons (1878), 50 cents.

Four hundred pounds of fresh cocoons, at 50 cents, $200.

Price per pound of fresh cocoons (1876), 70 cents.

Four hundred pounds of fresh cocoons, at 70 cents, $280.

Actual sales in Marseilles, December, 1878, of choked cocoons, 15 francs per kilogram, or $1.66 per pound, which for 133 pounds choked cocoons would be $220.78.

Price per pound of choked cocoons (1876), $2.25; 133 pounds of choked cocoons at $2.25, $299.25.

Freight, packing, commissions, and other incidental expenses, say $25, making as the return for the labor of two persons for six weeks, at the present low prices, $195.78.

Calculating on the basis of $1.50 per pound of choked cocoons, which, as shown in the following estimates, a reeling establishment in this country could afford to pay, we get approximately the same amount, viz, $199.50. As already stated, the capital invested in food for the worms is not included in these estimates, nor is the first cost of the ounce of eggs deducted. The silk grower should raise his own "seed," and the time required for this purpose is more than compensated for by the time saved in feeding during the first and second ages of the worms, when the whole time of two adults is not required as it is subsequently.

APPROXIMATE PROFITS OF REELING.

One pound of reeled silk requires 3⅔ pounds of choked cocoons.

An expert can in six days reel 4½ pounds of raw silk.

Price of best raw silk in French market, 1878 (market very low), $8.50 per pound.

Nine pounds of raw silk, at $8.50, $76.50.

The discount for cash, commissions for selling, and transportation would reduce this to $65.42.

To produce 9 pounds of raw silk would require the labor of two reelers for six days, at $1 per day, or $12; adding to this $2.50 for indirect labor, we get $14.50 as the cost of labor in reeling 9 pounds.

Thus the labor to reel 1 pound of raw silk will cost $1.70, or that to reel 1 pound of choked cocoons, approximately, 50 cents.

Deducting the cost of reeling from the $65.42 obtained, we have $50.92 with which to buy the necessary cocoons; say 33 pounds of choked cocoons for the 9 pounds reeled silk. If we use $49.50 of this sum for this purpose it will enable us to pay $1.50 per pound for our cocoons and we still have $1.42 as a profit on every 9 pounds of raw silk manufactured. This, if we employed two hundred reelers, would be a yearly income of $7,384.

It is safe to say that the process of reeling just about doubles the value of the product, and if the silk-raiser can reel his own cocoons he may safely count on this increase of its value, provided it is *well* reeled.

What the actual profits are that accrue to the owners of the large filatures in Tarascon, and other parts of South France or Italy, it would be impossible to state without having access to the books of the companies.

ESTIMATE OF PROFITS IN RAISING EGGS.

Average number of eggs in an ounce, 40,000.

Maximum number of cocoons from one ounce of eggs, 40,000.

One-half of these, or 20,000, are females.

Number of eggs laid by each female, say, 300.

Quantity of eggs from one ounce, 6,000,000, or 150 ounces.

Deducting, as probable loss from all causes combined, one-half, we have 75 ounces.

Price of eggs in Europe, $2 to $5, say $3 per ounce.

Amount realized on 1 ounce, $225.

On the basis of the first estimates two adults could take charge of the issue from 4 ounces of eggs. These would yield the sum of $900, and, even after allowing for the first cost of eggs, trays, commission, freight (which is light), extra time and labor (say another month), and incidental expenses, it leaves a very excellent return.

In studying the above estimates the reader must bear in mind that the silk industry, like all industries, will have its ups and downs—its periods of buoyancy and depression. It is just now going through one of these last. Silk-culture never was and never will be an exceedingly profitable business, but it adds vast wealth to the nations engaged in it, for the simple reason that it can be pursued by the humblest and poorest, and requires so little outlay. The question of its establishment in the United States is, as I have elsewhere said, "a question of adding to our own productive resources. There are hundreds of thousands of families in the United States to-day who would be most willing to add a few dollars to their annual income by giving light and easy employment for a few months each year to the more aged, to the young, and especially to the women of the family, who may have no other means of profitably employing their time.

"This holds especially true of the people of the Southern States, most of which are pre-eminently adapted to silk culture. The girls of the farm, who devote a little time each year to the raising of cocoons, may not earn as much as their brothers in the field, but they may earn something, and that something represents an increase of income, because it provides labor to those members of society who at present too often have none that is remunerative. Further, the raising of a few pounds of cocoons each year does not and need not materially interfere with the household and other duties that now engage their time, and it is by each household raising a few pounds of cocoons that silk culture must, in the end, be carried on in this as it has always been in other countries. Large rearing establishments seldom pay."

In what follows there has been no attempt to give a detailed treatise on the silk industry. It has been the endeavor rather to convey the more important information required for beginners. The few quotations are from the writer's fourth report on the insects of Missouri (1871), and it is hoped that, by the aid of a closing glossary of the few unavoidable technical terms that are used, the language will be clear to all.

THE SILKWORM.

A BRIEF MANUAL OF INSTRUCTIONS FOR THE PRODUCTION OF SILK.

NATURE OF THE SILKWORM.

The Silkworm proper, or that which supplies the ordinary silk of commerce, is the larva of a small moth known to scientific men as *Sericaria mori.* It is often popularly characterized as the Mulberry Silkworm. Its place among insects is with the *Lepidoptera*, or Scaly-winged insects, family *Bombycidæ*, or Spinners. There are several closely allied species, which spin silk of different qualities, none of which, however, unite strength and fineness in the same admirable proportions as does that of the mulberry species. The latter has, moreover, acquired many useful peculiarities during the long centuries of cultivation it has undergone. It has in fact become a true domesticated animal. The quality which man has endeavored to select in breeding this insect is, of course, that of silk producing, and hence we find that, when we compare it with its wild relations, the cocoon is vastly disproportionate to the size of the worm which makes it or the moth that issues from it. Other peculiarities have incidentally appeared, and the great number of varieties or races of the Silkworm almost equals those of the domestic Dog. The white color of the species; its seeming want of all desire to escape as long as it is kept supplied with leaves, and the loss of the power of flight on the part of the moth, are all undoubtedly the result of domestication. From these facts, and particularly from that of the great variation within specific limits to which the insect is subject, it will be evident to all that the following remarks upon the nature of the Silkworm must necessarily be very general in their character.

The Silkworm exists in four states--egg, larva, chrysalis, and adult or imago—which we will briefly describe.

DIFFERENT STATES OR STAGES OF THE SILKWORM.

THE EGG.—The egg of the Silkworm moth is called by silk-raisers the "seed." It is nearly round, slightly flattened, and in size resembles a turnip-seed. Its color when first deposited is yellow, and this color it retains if unimpregnated. If impregnated, however, it soon acquires a gray, slate, lilac, violet, or even dark green hue, according to variety or breed. It also becomes indented. When diseased it assumes a still darker and dull tint. With some varieties it is fastened to the substance upon which it is deposited, by a gummy secretion of the moth produced in the act of ovipositing. Other varieties, however, among which may be mentioned the Adrianople whites and the yellows from Nouka, in the Caucasus, have not this natural gum. As the hatching point approaches, the egg becomes lighter in color, which is due to the fact that its fluid contents become concentrated, as it were, into the central, forming worm, leaving an intervening space between it and the shell, which is semi-transparent. Just before hatching, the worm within becoming more active, a slight clicking sound is frequently heard, which sound is, however, common to the eggs of many other insects. After the worm has made its exit by gnawing a hole through one side of the shell, this last becomes quite white. Each female produces on an average from three to four hundred eggs, and one ounce of eggs contains about 40,000 individuals. It has been noticed that the color of the albuminous fluid of the egg corresponds to that of the cocoon, so that when the fluid is white the cocoon produced is also white, and when yellow the cocoon again corresponds.

THE LARVA OR WORM.—The worm goes through from three to four molts or sicknesses, the latter being the normal number. The periods between these different molts are called "ages," there being five of these ages including the first from the hatching and the last from the fourth molt to the spinning period. The time between each of these molts is usually divided as follows: The first period occupies from five to six days, the second but four or five, the third about five, the fourth from five to six, and the fifth from eight to ten. These periods are not exact, but simply proportionate. The time from the hatching to the spinning of the cocoons may, and does, vary all the way from thirty to forty days, depending upon the race of the worm, the quality of the food, mode of feeding, temperature, &c.; but the same relative proportion of time between molts usually holds true.

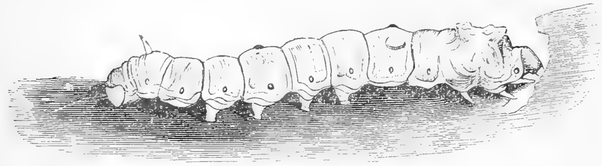

FIG. 1.—Full-grown larva or worm (after Riley).

The color of the newly hatched worm is black or dark gray, and it is covered with long stiff hairs, which, upon close examination, will be found to spring from pale-colored tubercles. Different shades of dark gray will, however, be found among worms hatching from the same batch of eggs. The hairs and tubercles are not noticeable after the first molt and the worm gradually gets lighter and lighter until, in the last age, it is of a cream-white color. When full grown it presents the appearance of Fig. 1. It never becomes entirely smooth, however, as there are short hairs along the sides, and very minute ones, not noticeable with the unaided eye, all over the body.

The preparation for each molt requires from two to three days of fasting and rest, during which time the worm attaches itself firmly by the abdominal prolegs (the 8 non-articulated legs under the 6th, 7th, 8th, and 9th segments of the body, called prolegs in contradistinction to the 6 articulated true legs under the 1st, 2d, and 3d segments), and holds up the fore part of the body, and sometimes the tail. In front of the first joint a dark triangular spot is at this time noticeable, indicating the growth of the new head; and when the term of "sickness" is over, the worm casts its old integument, rests a short time to recover strength, and then, freshened, supple, and hungry, goes to work feeding voraciously to compensate for lost time. This so-called "sickness" which preceded the molt was, in its turn, preceded by a most voracious appetite which served to stretch the skin. In the operation of molting the new head is first disengaged from the old skin, which is then gradually worked back from segment to segment until entirely cast off. If the worm is feeble, or has met with any misfortune, the shriveled skin may remain on the end of the body, being held by the anal horn; in which case the individual usually perishes in the course of time. It has been usually estimated that the worm in its growth consumes its own weight of leaves every day it feeds; but this is only an approximation. Yet it is certain that during the last few days before commencing to spin, it consumes more than during the whole of its previous worm-existence. It is a curious fact, first noted by Quatrefages, that the color of the abdominal prolegs at this time corresponds with the color of the silk.

Having attained full growth, the worm is ready to spin up. It shrinks somewhat in size, voids most of the excrement remaining in the alimentary canal; acquires a clear, translucent, often pinkish or amber-colored hue; becomes restless; ceases to feed, and throws out silken threads. The silk is elaborated in a fluid condition in two long, slender, convoluted vessels, one upon each side of the alimentary canal. As these vessels approach the head they become less convoluted and more slender, and finally unite within the spinneret, from which the silk issues in a glutinous state and apparently in a single thread. The glutinous liquid which combines the two, and which hardens immediately on exposure to the air, may, however, be dissolved in warm water. The worm usually consumes from three to five days in the construction of the cocoon and then passes in three days more, by a final molt, into the chrysalis state.

The Cocoon.—The cocoon (Fig. 2) consists of an outer lining of loose silk known as "floss," which is used for carding, and is spun by the worm in first getting its bearings. The amount of this loose silk varies in different breeds. The inner cocoon is tough, strong, and compact, composed of a firm, continuous thread, which is, however, not wound in concentric circles as might be supposed, but irregularly, in short figure of 8 loops, first in one place and then in another, so that in reeling, several yards of silk may be taken off without the cocoon turning round. In form the cocoon is usually oval, and in color yellowish, but in both these features it varies greatly, being either pure silvery-white, cream or carneous, green, and even roseate, and very often constricted in the middle. It has always been considered possible to distinguish the sex of the contained insect from the general shape of the cocoon, those containing males being slender, depressed in the middle, and pointed at both ends, while the female cocoons are of a larger size and rounder form, and resemble in shape a hen's egg with equal ends. Mr. Crozier, however, emphatically denies this and thinks it "next to impossible for the smartest connoisseur not to be mistaken."

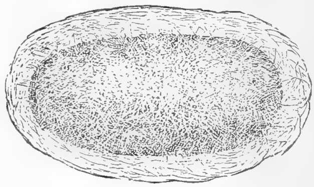

Fig. 2.—Silkworm cocoon.

The Chrysalis.—The chrysalis is a brown, oval body, considerably less in size than the full-grown worm. In the external integument may be traced folds corresponding with the abdominal rings, the wings folded over the breast, the antennæ, and the eyes of the inclosed insect—the future moth. At the posterior end of the chrysalis, pushed closely up to the wall of the cocoon, is the last larval skin, compressed into a dry wad of wrinkled integument. The chrysalis state continues for from two to three weeks, when the skin bursts and the moth emerges.

THE MOTH.—With no jaws, and confined within the narrow space of the cocoon, the moth finds some difficulty in escaping. For this purpose it is provided, in two glands near the obsolete mouth, with a strongly alkaline liquid secretion with which it moistens the end of the cocoon and dissolves the hard gummy lining. Then, by a forward and backward motion, the prisoner, with crimped and damp wings, gradually forces its way out, and when once out the wings soon expand and dry. The silken threads are simply pushed aside, but enough of them get broken in the process to render the cocoons, from which the moths escape, comparatively useless for reeling.

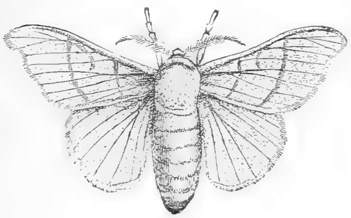

FIG. 3.—Silkworm moth, male (after Riley).

The moth is of a cream color, with more or less distinct brownish markings across the wings, as in Fig. 3. The males have broader antennæ or feelers than the females, and may, by this feature, at once be distinguished. Neither sex flies, but the male is more active than the female. They couple soon after issuing, and in a short time the female begins depositing her eggs, whether they have been impregnated or not. Very rarely the unimpregnated egg has been observed to develop.

ENEMIES AND DISEASES.

As regards the enemies of the Silkworm but little need be said. It has been generally supposed that no true parasite will attack it, but in China and Japan great numbers of the worms are killed by a disease known as "uji," which is undoubtedly produced by the larva of some insect parasite. Several diseases of a fungoid or epizoötic nature, and several maladies which have not been sufficiently characterized to enable us to determine their nature, are common to this worm. One of these diseases, called *muscardine*, has been more or less destructive in Europe for many years. It is of precisely the same nature as the fungus (*Empusa muscæ*), which so frequently kills the common House-fly, and which sheds a halo of spores, readily seen upon the window-pane, around its victim.

A worm, about to die of this disease, becomes languid, and the pulsations of the dorsal vessel or heart become insensible. It suddenly dies, and in a few hours becomes stiff, rigid, and discolored; and finally, in about a day, a white powder or efflorescence manifests itself, and soon entirely covers the body, developing most rapidly in a warm, humid atmosphere. No outward signs indicate the first stage of the disease, and though it attacks worms of all ages, it is by far the most fatal in the fifth or last age or stage, just before the transformation.

"This disease was proved by Bassi to be due to the development of a fungus (*Botrytis Bassiana*) in the body of the worm. It is certainly infectious, the spores, when they come in contact with the body of the worm, germinating and sending forth filaments which penetrate the skin, and upon reaching the internal parts, give off minute floating corpuscles which eventually spore in the efflorescent manner described. Yet most silkworm raisers, including such good authorities as E. F. Guérin-Méneville and Eugene Robert,* who at first implicitly believed in the fungus origin of this disease, now consider that the Botrytis is only the ultimate symptom—the termination of it. At the same time they freely admit that the disease may be contracted by the Botrytis spores coming in contact with worms predisposed by unfavorable conditions to their influence. Such a view implies the contradictory belief that the disease may or may not be the result of the fungus; and those who consider the fungus as the sole cause certainly have the advantage of consistency." Dr. Carpenter, of microscopic fame, believes in the fungus origin of the disease, and thinks it entirely caused by floating spores being carried in at the spiracles, or breathing orifices of the worm, and germinating in the interior of the body.

Whichever view be held, it appears very clear that no remedies are known, but that care in procuring good eggs, care in rearing the worms, good leaves, pure, even-temperatured atmosphere, and cleanliness are checks to the disease. The drawers, and other objects with which the diseased worms may have been in contact, should be purified by fumigations of sulphurous acid ($S\ O_2$), produced by mixing bisulphite of soda with any strong acid, or, better still, by subjecting them to a carbolic-acid spray from an atomizer. In this way all fungus spores will be destroyed. In fact it will be well to wash off the trays or shelves once in a while with diluted carbolic acid, as a sure preventive. It is the best disinfectant known to science. The cheapest kinds may be used with the same efficacy as the more expensive.

Another disease, known as *pébrine*, has proved extremely fatal in Southern Europe, and for twenty years has almost paralyzed silk culture in France. It is a disease which, in its nature and action, except in being hereditary, bears a striking analogy to cholera among men. "The worms affected by *pébrine* grow unequally, become languid, lose appetite, and often manifest discolored spots upon the skin. They die at all ages, but, as in *muscardine*, the mortality is greatest in the last age. The real nature of this malady was for a long time unknown. In 1849 M. Guérin-Méneville first noticed floating corpuscles in the bodies of the diseased worms. These corpuscles were supposed by him to be endowed with independent life, but their motion was afterwards shown by Filippi to depend on what is known as the Brownian motion, and they are now known either by the name of *panhistophyton*, first given them by Lebret, or by that of *psorospermiæ*. They fill the silk canals, invade the intestines, and spread throughout the tissues of the animal in all its different states; and though it was for a long time a mooted question as to whether they were the true cause or the mere result of the disease, the praiseworthy researches

*Guide à l'éleveur de vers à soie.

of Pasteur have demonstrated that *pébrine* is entirely dependent upon the presence and multiplication of these corpuscles. He has analyzed the disease so clearly that not only do we see its nature, but are able to point out the remedy. The disease is both contagious and infectious, because the corpuscles which have been passed with the excrement or with other secretions of diseased worms have been taken into the alimentary canal of healthy ones in devouring the soiled leaves, and because it may be inoculated by wounds inflicted by the claws. It is hereditary on the mother's side, because the moth may have the germ of the disease and yet oviposit. Indeed, the eggs may be affected and yet look fair and good, the microscopic *psorospermiæ* not being visible, so that the only true test of disease or health is an examination of the parent moth; and by killing off all infected moths the disease can be controlled.

"Both the diseases mentioned are, therefore, in the strict sense of the word, Silkworm plagues; the one of a fungus and the other of an epizoötic nature. Each may become epidemic when the conditions are favorable for the undue multiplication of the minute organisms which produce them, or when the checks to the increase of such organisms are removed by carelessness or ignorance." Cleanliness and purification are absolutely necessary in treating both these diseases, and in *pébrine* care must be taken that the eggs are sound by a microscopic examination of the moths. This may be done after the eggs are laid, and if the corpuscles be found in the mother, her eggs should be discarded.

Silkworms are subject to other diseases, but none of them have ever acquired the importance of those described. What is called *gattine* by older authors is but a mild phase of *pébrine*. The worms are apt to be purged by unwholesome leaves; too great heat makes them sickly; or they may become yellow, limp, and die of a malady called *grasserie* or jaundice, which is almost sure to appear in large broods, and which is very common in those reared in this country. When the worms die from being unable to molt they are called *lusettes*, and such cases are most abundant at the fourth molt. All these different ailments, and others not mentioned, have received names, some local, others more general; but none of them warrant further notice here, as they are not likely to become very troublesome if proper attention and care be given to the worms.

VARIETIES OR RACES.

As before stated, domestication has had the effect of producing numerous varieties of the Silkworm, every different climate into which it has been carried having produced either some changes in the quality of the silk, or the shape or color of the cocoons; or else altered the habits of the worm.

Some varieties produce but one brood in a year, no matter how the eggs are manipulated: such are known as *Annuals*. Others, known as *Bivoltins*, hatch twice in the course of the year; the first time, as with the Annuals, in April or May, and the second, eight or ten days after the eggs are laid by the first brood. The eggs of the second brood only are kept for the next year's crop, as those of the first brood always either hatch or die soon after being laid. The *Trevoltins* produce three annual generations. There are also *Quadrivoltins*, and, in Bengal, a variety known as *Dacey* which is said to produce eight generations in the course of a year. Some varieties molt but three times instead of four, especially in warm countries and with Trevoltins. Experiments, taking into consderation the size of the cocoon, quality of silk, time occupied, hardiness, quantity of leaves required, etc., have proved the Annuals to be more profitable than any of the polyvoltins, although Bivoltins are often reared; and Mr. Alfred Brewster, of San Gabriel, Cal., says that he found a green Japanese variety of these last more hardy than the Chinese Annuals. Varieties are also known, by the color of the cocoons they produce, as Greens, or Whites, or Yellows, and also by the country in which they flourish. The white silk is the most valuable in commerce, but the races producing yellow, cream-colored, or flesh-colored cocoons are generally considered to be the most vigorous. No classification of varieties can be attempted, as individuals of the same breed exported to a dozen different localities would, in all probability, soon present a dozen varieties. The three most marked and noted European varieties are the Milanese (Italian) breed, producing fine small yellow cocoons; the Ardêche (French), producing large yellow cocoons, and the Brousse (Turkish), producing large white cocoons of the best quality in Europe. Owing to the fearful prevalence of *pébrine* among the French and Italian races for fifteen or twenty years back, the Japanese Annuals have come into favor. The eggs are bought at Yokohama in September, and shipped during the winter. There are two principal varieties in use, the one producing white and the other greenish cocoons, and known respectively as the White Japanese and the Green Japanese Annuals. These cocoons are by no means large, but the pods are solid and firm, and yield an abundance of silk. They are about of a size, and both varieties are almost always constricted in the middle (Fig. 4, *c* green, *d* white). Another valuable race is the White Chinese Annual (Fig. 4, *e*), which much resembles the White Japanese, but is not as generally constricted. Fig. 4, *a* and *b* represent, respectively, white and yellow French annuals.

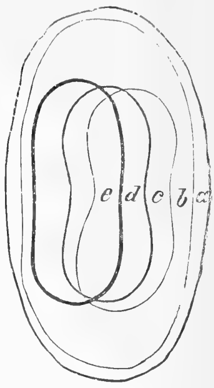

FIG. 4.—Shapes of silkworm cocoons.

WINTERING AND HATCHING THE EGGS.

We have already seen the importance of getting healthy eggs, free from hereditary disease, and of good and valuable races. There is little danger of premature hatching until December, but from that time on, the eggs should be kept in a cool, dry room in tin boxes to prevent the ravages of rats and mice. They are most safely stored in a dry cellar, where the temperature rarely sinks below the freezing point, and they should be occasionally looked at to make sure that they are not affected by mold. If, at any time, mold be perceived upon them it should be at once rubbed or brushed off, and the atmosphere made drier. If the tin boxes be perforated on two sides and the perforations covered with fine wire gauze, the chances of injury will be reduced to a minimum.

The eggs may also, whether on cards or loose,* be tied up in small bags and hung to the ceiling of the cold room. The string of the bag should be passed through a bottle neck or a piece of tin to prevent injury from rats and mice. The temperature should never be allowed to rise above 40° F., but may be allowed to sink below freezing point without injury. Indeed, eggs sent from one country to another are usually packed in ice. They should be kept at a low temperature until the Mulberry leaves are well started in the spring, and great care must be taken as the weather grows warmer to prevent hatching before their food is ready for them, since both the Mulberry and Osage orange are rather late in leafing out. One great object should be, in fact, to have them all kept back, as the tendency in our climate is to premature hatching. Another object should be to have them hatch uniformly, and this is best attained by keeping together those laid at one and the same time, and by wintering them, as already recommended, in cellars that are cool enough to prevent any embryonic development. They should then, as soon as the leaves of their food-plant have commenced to put forth, be placed in trays and brought into a well-aired room where the temperature averages about 75° F. If they have been wintered adhering to the cloth on which they were laid, all that is necessary to do is to spread this same cloth over the bottom of a tray. If, on the contrary, they have been wintered in the loose condition, they must be uniformly sifted or spread over sheets of cloth or paper. The temperature should be kept uniform, and a small stove in the hatching-room will prove very valuable in providing this uniformity. The heat of the room may be increased about 2° each day, and if the eggs have been well kept back during the winter, they will begin to hatch under such treatment on the fifth or sixth day. By no means must the eggs be exposed to the sun's rays, which would kill them in a very short time. As the time of hatching approaches, the eggs grow lighter in color, and then the atmosphere must be kept moist artificially by sprinkling the floor, or otherwise, in order to enable the worms to eat through the egg-shell more easily. They also appear fresher and more vigorous with due amount of moisture.

FEEDING AND REARING THE WORMS.

The room in which the rearing is to be done should be so arranged that it can be thoroughly and easily ventilated, and warmed if desirable. A north-east exposure is the best, and buildings erected for the express purpose should, of course, combine these requisites. If but few worms are to be reared, all the operations can be performed in trays upon tables, but in large establishments the room is arranged with deep and numerous shelves, from 4 to 8 feet deep and 2 feet 6 inches apart. All wood, however, should be well seasoned, as green wood seems to be injurious to the health of the worms. When the eggs are about to hatch, mosquito-netting or perforated paper should be laid over them lightly. Upon this can be evenly spread freshly-plucked leaves or buds. The worms will rise through the meshes of the net or the holes in the paper and cluster upon the leaves, when the whole net can easily be moved. In this

* For explanation, see what follows under egg-laying, p. 24.

moving, paper has the advantage over the netting, in that it is stiffer and does not lump the worms together in the middle. They may now be spread upon the shelves or trays, care being taken to give them plenty of space, as they grow rapidly. Each day's hatching should be kept separate in order that the worms may be of a uniform size, and go through their different moltings or sicknesses with regularity and uniformity; and all eggs not hatched after the fourth day from the appearance of the first should be thrown away, as they will be found to contain inferior, weakly, or sickly worms. It is calculated that one ounce of eggs of a good race will produce 100 pounds of fresh cocoons; while for every additional ounce the percentage is reduced if the worms are all raised together, until for 20 ounces the average does not exceed 25 pounds of cocoons per ounce. Such is the general experience throughout France, according to Guérin Méneville, and it shows the importance of keeping them in small broods, or of rearing on a moderate scale.

The young worms may be removed from place to place by means of a small camel's-hair brush, but should be handled as little as possible. The best mode of feeding and caring for them is by continuing the use of the feeding-net first mentioned. As the worms increase in size the net must have larger meshes, and if it should be used every time fresh food is furnished, it will save a large amount of time and care. It entirely obviates the necessity of handling the worms, and enables the person having charge of them to keep them thoroughly clean; for, while they pass up through the net to take their fresh food, their excrement drops through it and is always taken up with the old litter beneath. It also acts as a detective of disease; for such worms as are injured, feeble, or sickly, usually fail to mount through the meshes and should be carried off and destroyed with the refuse in the old net below. This placing on of the new net and carrying away of the old is such a great convenience and time-saver that, in France, for many years, paper, stamped by machinery with holes of different sizes, suited to the different stages of the worms, has been used. The paper has the advantage of cheapness and stiffness, but a discussion as to the best material is unnecessary here, the aim being to enforce the principle of the progressive rise of the worms. Details will suggest themselves to the operator.

Where the nets are not used, there is an advantage in feeding the worms upon leaf-covered twigs and branches, because these last allow a free passage of air, and the leaves keep fresh a longer time than when plucked. In thus feeding with branches consists the whole secret of the California system, so much praised and advocated by M. L. Prevost. The proper, stamped paper not being easily obtained in this country, mosquito-netting will be found a very fair substitute while the worms are young, and when they are larger I have found thin slats of some non-resinous and well-seasoned wood, tacked in parallel lines to a frame just large enough to set in the trays, very serviceable and convenient—small square blocks of similar wood being used at the corners of the tray to support the frame while the worms are passing up through it. Coarse twine-netting stretched over a similar frame will answer the same purpose, but wire-netting is less useful, as the worms dislike the smooth metal.

Where branches, and not leaves, are fed, the Osage orange has the advantage of Mulberry, as its spines prevent too close settling or packing, and thus insure ventilation. It is recommended by many to feed the worms while in their first age, and, consequently, weak and tender, leaves that have been cut up or hashed, in order to give them more edges to eat upon and to make less work for them. This, however, is hardly necessary with Annuals, although it is quite generally practiced in France. With the second brood of Bivoltins it might be advisable, inasmuch as the leaves at the season of the year when they appear, have attained their full growth and are a little tough for the newly-hatched individuals. In the spring, however, the leaves are small and tender, and nature has provided the young worms with sufficiently strong jaws to cut them.

Many rules have been laid down as to regularity of feeding, and much stress has been put upon it by some writers, most advising four meals a day at regular intervals, while a given number of meals between molts has also been urged; but such definite rules are of but little avail, as so much depends upon circumstances and conditions. The food should, in fact, be renewed whenever the leaves have been devoured, or whenever they have become in the least dry, which, of course, takes place much quicker when young and tender than when mature. This also is an objection to the use of the hashed leaves, as, of course, they would dry very quickly. The worms eat most freely early in the morning and late at night, and it would be well to renew the leaves abundantly between 5 and 6 a. m. and between 10 and 11 p. m. One or two additional meals should be given during the day, according as the worms may seem to need them. Great care should be taken to pick the leaves for the early morning meal the evening before, as when picked and fed with the dew upon them they are more apt to induce disease. Indeed, the rule should be laid down, never feed wet or damp leaves to your worms. In case they are picked during a rain, they should be thoroughly dried before being fed; and on the approach of a storm it is always well to lay in a stock, which should be kept from heating by occasional stirring. Care should also be taken to spread the leaves evenly, so that all may feed alike. During this first and most delicate age the worm requires much care and watching.

As the fifth or sixth day approaches, signs of the first molt begin to be noticed. The worm begins to lose appetite and grow more shiny, and soon the dark spot already described appears above the head. Feeding should now cease, and the shelves or trays should be made as clean as possible. Some will undoubtedly undergo the shedding of the skin much more easily and quickly than others, but no feed should be given to these forward individuals until nearly all have completed the molt. This serves to keep the batch together, and the first ones will wait one or even two days without injury from want of food. It is, however, unnecessary to wait for all, as there will always be some few which remain sick after the great majority have cast their skins. These should either be set aside and kept separate, or destroyed, as they are usually the most feeble and most inclined to disease; otherwise, the batch will grow more and more irregular in their moltings and the diseased worms will contaminate the healthy ones. It is really doubtful whether the silk raised from these weak individuals will pay for the trouble of rearing them separately, and it will be better perhaps to destroy them. The importance of keeping each batch together, and of causing the worms to molt simultaneously, cannot be too much insisted upon as a means of saving time.

As soon as the great majority have molted they should be copiously fed, and, as they grow very rapidly after each molt, and as they must always be allowed plenty of room, it will probably become necessary to divide the batch, and this is readily done at any meal by removing the net when about half of the worms have risen and replacing it by an additional one. The space alloted to each batch should, of course, be increased proportionately with the growth of the worms. The same precautions should be observed in the three succeeding molts as in this first one.

As regards the temperature of the rearing-room, great care should be taken to avoid all sudden changes from warm to cold, or *vice versa*. A mean temperature of 75° or 80° F. will usually bring the worms to the spinning-point in the course of 35 days after hatching, but the rapidity of development depends upon a variety of other causes, such as quality of leaf, race of worm, &c. If it can be prevented, the temperature should not be permitted to rise very much above 80°, and it is for this reason that a room with a northern or northeastern exposure was recommended as preferable to any other. The air should be kept pure all of the time, and arrangements should be made to secure a good circulation. Great care should be taken to guard against the incursions of ants and other predacious insects, which would make sad havoc among the worms were they allowed an entrance, and all through the existence of the insect, from the egg to the moth, rats and mice are on the watch for a chance to get at them, and are to be feared almost as much as any other enemy the Silkworm has.

The second and third casting of the skin take place with but little more difficulty than the first, but the fourth is more laborious, and the worms not only take more time in undergoing it, but more often perish in the act. At this molt it is perhaps better to give the more forward individuals a light feed as soon as they have completed the change, inasmuch as it is the last molt and but little is to be gained by the retardation, whereas it is important to feed them all that they will eat, since much of the nutriment given during the last age goes for the elaboration of the silk. At each successive molt the color of the worm has been gradually whitening, until it is now of a decided cream color. Some breeds, however, remain dark, and occasionally there is an individual with zebra-like markings. During these last few days the worms require the greatest care and attention. All excrement and litter must be often removed, and the sickly and diseased ones watched for and removed from the rest. The quantity of leaves which they devour in this fifth age is something enormous, and the feeding will keep the attendant busily employed.

Summed up, the requisites to successful Silkworm raising are: 1st. Uniformity of age in the individuals of the same tray, so as to insure their molting simultaneously. 2d. No intermission in the supply of fresh food, except during the molting periods. 3d. Plenty of room, so that the worms may not too closely crowd each other. 4th. Fresh air and as uniform temperature as possible. 5th. Cleanliness. The last three are particularly necessary during the fourth and fifth ages. While small, the frass, dung, and detritus dry rapidly, and may (though they should not) be left for several days in a tray with impunity, but he who allows his trays to go uncleaned for more than a day during the ages mentioned will suffer in the disease and mortality of his worms just as they are reaching the spinning-point.

PREPARATION FOR SPINNING.

With eight or ten days of busy feeding, after the last molt, the worms, as we have learned before, will begin to lose appetite, shrink in size, become restless, and throw out silk, and the arches for the spinning of the cocoons must now be prepared. These can be made of twigs of different trees, two or three feet long, set up upon the shelves over the worms, and made to interlock in the form of an arch above them. Interlace these twigs with broom-corn, hemlock, or other well-dried brush. The feet of each arch should be only about a foot apart. The temperature of the room should now be kept above 80°, as the silk does not flow so freely in a cool atmosphere. The worms will immediately mount into the branches and commence to spin their cocoons. They will not all, however, mount at the same time, and those which are more tardy should be fed often, but in small quantities at a time, in order to economize the leaves, as almost every moment some few will quit and mount. There will always be a few which altogether fail to mount, and prefer to spin in their trays. It is best, therefore, after the bulk have mounted, to remove the trays and lay brush carefully over them. The fact that the worms already mounted make a final discharge of soft and semifluid excrement before beginning to spin makes this separation necessary, as otherwise the cocoons of the lower ones would be badly soiled. As the worms begin to spin they should be carefully watched, to guard against two or three of them making what is called a double or treble cocoon, which would be unfit for reeling purposes. Whenever one worm is about to spin up too near another, it should be carefully removed to another part of the arch. In two or three days the spinning will have been completed, and in six or seven the chrysalis will be formed.

GATHERING THE COCOONS.

Eight days from the time the spinning commenced, it will be time to gather the cocoons. The arches should be carefully taken apart, and the spotted or stained cocoons first removed and laid aside. Care should be taken not to stain the clean ones with the black fluids of such worms as may have died and become putrid, for there are always a few of these in every cocoonery. The outer cocoons of loose or floss silk are then torn from the inner cocoons or pods, and the latter separated according to color, weight, and firmness of texture; those which best resist pressure indicating that the worm has best accomplished its work. Too much care cannot be taken to remove the soft or imperfect cocoons, as, if mixed with the firm ones, they would be crushed and soil the others with their contents. The very best of the firm cocoons are now to be chosen as seed for the next year, unless the raiser prefers buying his eggs to the trouble of caring for the moths and keeping the eggs through the winter. Eggs bought from large establishments are, however, apt to be untrustworthy, and it is well for all silk-raisers to provide their own seed. These cocoons should be chosen for their firmness, and the fineness and color of the silk, rather than for their size. Mr. Crozier says: "If white, take them of the purest white, neither soft nor satin-like; if yellow, give the preference to the straw-colored, which are the most sought after; and, last, if they are the green of Japan, the greener they are, of a dark, sharp color, very glossy, the better is the quality of the thread. Discard the pale shades in the last breed." If there are any double or treble cocoons in the batch, of the right color, quality, and consistency, they should be used before the others, as they are just as good for breeding purposes, though unfit for reeling. In estimating the quantity that will be required, the following figures will be of use: The general estimate is always made of 40,000 eggs to the ounce, and also that each female lays from 300 to 400 eggs. Taking the higher estimate, it will require only 100 females to lay an ounce of eggs; taking the lower, it will require 133. It will, therefore, not be safe to take fewer than 200 cocoons, half males and half females, if an ounce of seed is desired, and from that to 225 would be safer. While it may not always be possible to determine the sex of the cocoons by their shape, we may approximately separate them by weighing. The whole quantity set aside for breeding purposes is first weighed in order to get the average, and then each one is weighed separately, and all above the average may be pretty accurately considered females and all below it males. These breeding cocoons should now be either pasted upon card-board on their sides, or strung upon a string, great care being taken to run the needle through the silk only and not deep enough to injure the chrysalis, the object being in both cases to secure the cocoon so that the moth can the more readily make its escape. They can be laid aside in a rat-proof place to await the appearance of the moths, and in the mean time the other cocoons should be taken care of.

CHOKING THE CHRYSALIS.

In most silk-producing countries the parties who raise the cocoons sell them to the reeling establishments before suffocation is necessary, as these establishments have better facilities for this work than are to be found in private families. If, however, the reeling is done by the raiser, or some time must elapse before the cocoons can be sent to a reeling establishment, some means must be used to kill the contained chrysalis before the cocoon is injured for reeling purposes by the egress of the moth. This can be done by stifling them with steam or choking them by dry heat. Steaming is the surest, quickest, and best method, if the facilities are at hand: it can be done at any steam mill. The cocoons are laid upon shelves in a tightly-sealed box and the steam is turned in. Twenty minutes will suffice to do the required work, and the cocoons are then dried in the sun. The dry-heat method occupies a much longer time. The cocoons are placed in shallow baskets and slipped on iron drawers into an oven which is kept heated to a temperature of about 200° F. This should not be increased for fear of burning the silk. This operation lasts from two to twenty-four hours. A certain humming noise continues so long as there is any life, and its cessation is an indication that the chrysalids are all dead. Where the choking is well done there is little loss, only about one per cent. of the cocoons bursting at the ends. After choking in this manner, the cocoons should be strewn upon long wooden shelves in the shade, with plenty of air, and, for the first few days, frequently stirred. After remaining on these shelves for about two months, with occasional stirrings, the chrysalids become quite dry and the cocoons will preserve indefinitely. They are, however, still subject to the attacks of rats and mice, and the little beetles known as "museum pests," belonging to the genera *Dermestes* and *Anthrenus*, are attracted by the dead chrysalis within and will penetrate the cocoon, injuring it for reeling purposes. In the warm, Southern States the dry-heat choking can be accomplished by simple exposure to the sun. This was done by M. L. Prevost in Southern California, and is practised habitually by Mr. Crozier in Silkville, Kansas, who says: "Here the cocoons need only to be fully exposed to the rays of the sun, from 9 o'clock in the morning till 4 o'clock in the afternoon. Two or three days of such exposure are sufficient. But, as some time strong wind can annihilate the effect of the sun's warmth, it is good to have for that purpose long boxes, 4 feet wide, sides 6 inches high, to be covered with glass frames. This will increase the heat, and, by absorbing the air of the box, stifle your chrysalis most surely." Ed. Müller, another California grower (Nevada County), always makes use of this method of stifling by the sun's rays, but says that the glass cover of the box should be left open a crack to allow the evaporation of the moisture, which otherwise would collect in large drops upon the glass, and, falling back upon the cocoons, would keep them moist for a longer time. Do not, however, allow the ants to creep in at the crack, as they too will penetrate the cocoon to feed upon the chrysalis.

In the colder climates it has been suggested that the chrysalis could be well choked, with no injury to the cocoons, by placing them in a vacuum box and exhausting the air. Chloroform has been used to a certain extent, and experiments are now being made in France with sulph-hydric acid gas, a vapor which is evolved from the mixture of dilute sulphuric acid and sulphide of iron; also with bisulphide of carbon.

EGG-LAYING—REPRODUCTION.

In from 12 to 20 days from the time when the worm commenced to spin, the moths will begin to issue from the cocoons laid aside for breeding purposes. They issue most abundantly during the early morning hours, from four to eight o'clock, and as they appear, they should be taken by the wings and the sexes kept apart for a short time. The males may be readily distinguished from the females by their broader antennæ and smaller bodies, as also by the incessant fluttering of their wings. The females remain comparatively quiet, their abdomens being heavy and distended with eggs. A few hours after issuing, the sexes, in equal numbers, may be placed together, great care having been taken to destroy any that are at all deformed, in order to keep the breed as fine as possible. They should be placed upon paper or card-board, and the room should be kept as dark as possible in order that the males shall not uncouple themselves. For the complete impregnation of the eggs, the sexes should be kept together six hours, neither more nor less, and occasionally visited in order to replace those males which may have become separated. Should there, on this day, more males than females issue, the superfluous males may be put in a closed box and kept till the next day, when the state of things may be reversed. Should there, on the other hand, be a superfluity of females, a sufficient number of the strongest and most vigorous males should be uncoupled at 4 hours and placed with the unpaired females for 6 hours more. As the pairs are uncoupled at the end of 6 hours, care should be taken to injure neither sex. The female should be held by the wings with one hand and the abdomen of the male gently pressed with the other. The males may then be laid aside in a box, as there may be use for them before all the moths have appeared. After all the females are impregnated, however, they may be thrown away. These last, as soon as separated, should be placed for a few minutes upon sheets of blotting-paper, where they will free themselves of a quantity of greenish-yellow fluid. From the blotting-paper they should be transferred to trays lined with cloth upon which the eggs are to be laid. This cloth should be of the smoothest sort of woollen stuff rather than of linen or paper, if it is desired to remove the eggs at a future time, as they will stick so fast to the latter that it will be difficult to remove without bruising them. Upon these trays they may be placed in rows, and will immediately commence depositing. It is advisable to tip up the trays at one end so that they incline a little, as the moths are then more apt to lay their eggs uniformly. They should also be kept in the dark, in accordance with the nocturnal habit of the moth. The temperature of the room should be kept at about 75°, and plenty of air given during oviposition. All of the thoroughly impregnated eggs will be laid in about 24 hours, and the moth should be removed after that length of time. She may continue depositing a short time longer, but the eggs should be kept by themselves and not mixed with the others. It will be well, also, if the best and purest breed be desired, to keep the eggs of those moths which were coupled with males that had been used before, separated from the eggs laid by those which were coupled with virgin males. "The eggs are best preserved on the cloth where originally deposited, as they are protected by a natural coating of varnish, and, being fastened, the worms, when hatching, eat their way out better. For commercial purposes, however, they are usually detached during the winter by immersing the cloth containing them in cool soft water for a few moments; the moisture being then drained off by means of blotting-paper, and the eggs gently removed with a paper-knife. They are then washed in soft water, thoroughly dried, and put away for keeping. All eggs which swim on the surface are considered bad and discarded. The Japanese producers sell their eggs on cards or cartoons made of coarse silk. The cards are placed in wooden frames, the rims of which are varnished, so that the moths—disliking the varnish—are made to confine their eggs upon the cards, which are consequently covered in a very regular and uniform manner."

The egg retains the characteristic color of the unimpregnated ones—light yellow—for 12 or 15 days, when it gradually acquires the gray, lavender, or greenish tint of impregnation. The moths live but a few days after having perpetuated their kind.

REELING.

"If the mere rearing of the worm and the production of the cocoons is simple, the reeling of the silk is by no means so, as the greatest skill is required to accomplish the work properly, and the value of a hank of silk depends as much on the skill of the reeler as upon the quality of the original thread. In the best cocoons the silk will measure upwards of a thousand feet in length, and, though it appears single, it is in reality composed of two threads, which are glued together and covered as they issue from the spinneret of the moth with a glossy varnish, which enables the worm to fasten the silk where it wills, and which is soluble in warm water."

In countries where there are steam-reeling establishments, it is generally more profitable for the small raiser to sell his cocoons, and not go to the trouble and expense of reeling by hand; but, unfortunately, there is no market for choked cocoons in this country, and the raiser will be under the necessity of reeling his own silk, if he wishes to make the most of them. It will be desirable, then, in this paper, to state the facts and principles which should govern the unwinding and reeling, for the benefit of those who may wish to use single basins and reels worked by hand. In the great reeling districts of France, everything is brought to such perfection in the *filatures*, or reeling establishments, by the aid of steam, that the hand-reels have there almost gone out of use. But most of the silk is unwound by hand-power in China, and excellent silk may be made by dexterous management with a good hand-reel.

"Raw silk is classified into organzine, tram, and floss. Organzine is considerably twisted and is the choicest. Tram is made from inferior cocoons and is but slightly twisted. Floss is made of the loose silk, carded and spun like cotton or wool.

"The thread of silk as it unwinds from the cocoon is valueless for manufacturing purposes, several of them combined going to make the staple of commerce. The persons employed in unwinding silk are mostly women, one standing or sitting before each basin, of which she has entire charge. The basin is made of copper, and, in the large establishments, the water in each basin is heated by steam, at the control of the operator. The cocoons are plunged into the water, when it is near the boiling point, and moved about so that the gum which fastens the threads becomes uniformly and thoroughly softened. They are then beaten with a small birchen broom, having the tips split, so that the loose threads readily fasten to them. After beating a short time, the operator gets all the cocoons fastened, and, taking the bundle of threads, shakes the cocoons till each hangs but by a single one. She now takes up five or more threads (*brins*), according to the quality of silk wanted, unites them, and introduces the combined staple or strand (*fil*) into a little glass eye on one side of the basin. She then forms a second similar strand and introduces it into a second eye on the other side. The strands are then brought together, twisted several times, separated above the twist, and introduced into two other glass eyes or ringlets through which they are led, one to each end of the reel or *tambour*, which is kept revolving in a steady, rapid manner, and to which is also given a certain back-and-forth side motion. The great object in reeling is to get the threads uniform, rounded, well joined, properly freed from moisture, and so crossed on the reel that they will not stick or glaze, as it is termed. These objects are attained by the twisting and the to-and-fro lateral movement of the reel, as also by properly regulating the distance between reel and basin. The uniformity of the thread depends on the skill of the operator, who must supply a new thread as soon as one begins to give out. This is called nourishing the silk, and is done by dexterously casting, with the thumb, the new thread upon the combined strand, to which it immediately adheres. In this she must use much judgment, for the silk of a cocoon gradually gets lighter and finer as it approaches the end, and the uniformity of strand does not entirely depend on the uniformity in number of the individual threads forming it. Whenever the silk rises in locks the temperature of the water is known to be too hot, and when it unwinds with difficulty the temperature is, on the contrary, too low. The operator is supplied with a skimmer with which to remove all chrysalides and refuse silk; also, with a basin of cold water in which to cool her fingers, which are being constantly dipped in the hot basin. This constitutes the whole operation of unwinding, but before the skeins, as they come from the reel, are ready for the manufacturer they must undergo still further manipulation. The staple is first passed through a cleanser, consisting of a clasp lined with cloth, which catches any loose silk or other matter that may be adhering to it. It is then further cleansed and purged by being passed through four similar cleansers (*purgeurs*), then twisted about 500 times to the yard, then doubled and again twisted about 400 times to the yard. It is finally run on to reels about 1½ feet in diameter, and taken off and twisted in a peculiar knot or hank. Through all these operations the oscillating to-and-fro lateral motion is kept up, so as to produce the diagonal crossing of the strands, and it will be readily understood that each staple is, in the end, composed of ten or more of the simple threads first spun by the worm.

"The loose or flock silk, together with all which, from one cause or another, cannot be reeled, is soaked in water for three days, boiled for one half hour in clear lye, washed in rain-water, and when dry, carded, and spun it makes an inferior floss silk."

In order to better illustrate these principles, we have introduced figures of three reels. Fig. 5 is the old Piedmontese reel, which for many years held its supremacy, and which has been the foundation of numerous improved reels. It is formed of four bars or arms, and is usually about a yard in circumference. One of these bars is provided with hinges so that it may fold inwards towards the center when it becomes necessary to slacken the silk in order to carefully remove it from the reel. The lateral movement so necessary in order that the consecutive circles shall not stick together is gained in rather a clumsy manner by means of cogs. The strands after being twisted several times at *c*, in order to round and smooth the threads by friction, are passed over the guides *b b*, which are inserted in the traversing bar *a*. To this bar

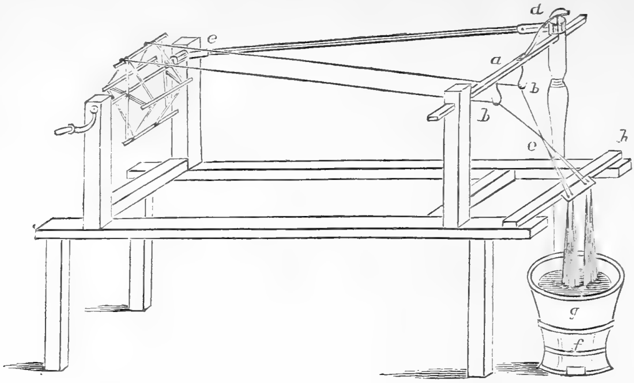

Fig. 5.—Piedmontese reel.

the lateral movement is imparted by a pin connected with the outer circumference of the cog-wheel *d*. This is connected at *e* with the cog revolving with the shaft of the reel. *f* represents a charcoal-furnace under the copper basin *g*. The cross-bar *h*, to which are attached the glass eyes through which the threads from the cocoons first pass, is usually widened into a shelf, upon which to place the broom and the cold water for the reeler's fingers.

Figs. 6 and 7 represent, respectively, a plane view, seen from above, and a longitudinal vertical section of an old French reel differing somewhat from the Piedmontese, and the principles of which are employed in all the improved reeling establishments of to-day.

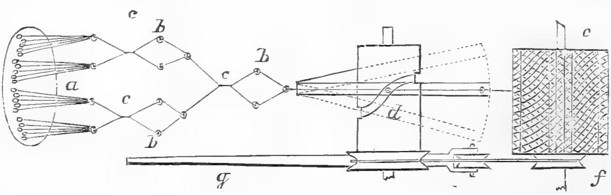

Fig. 6.—Plane view of old French reel.

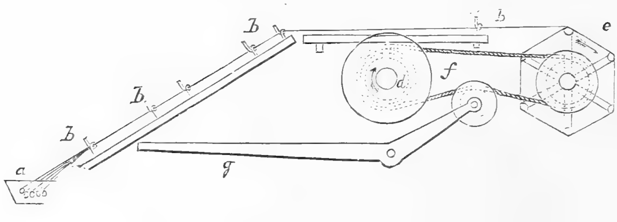

Fig. 7.—Section of old French reel.

a. The oblong water-basin heated by a charcoal-furnace or by steam, and frequently divided by partitions.

b b. Hooked wires or eyelets to guide several threads and keep them apart.

c c. Points where the threads are twisted upon each other to clean their surfaces and compactly round them.

d. Cylinder on shaft, with a spiral groove in its surface, in which fits a pin from the traversing-bar, thus giving the lateral movement to the thread which goes through a guider on the front end of the bar, which moves through the arc of a circle.

e. The reel.

f. Pulleys which transmit by a belt the rotary motion of the cylinder *d* to the reel *e*, that connected with the reel being the smaller of the two.

g. Friction lever, for tightening or slackening the endless cord, in setting or stopping the winding operation. There is usually a series of such reels in one apartment, driven by the same motive power, but each of them, as has been shown, can be stopped at pleasure. In case the reels are driven by a steam-engine, stop-cocks and pipes are so arranged that the water in every basin can be instantly or gradually heated by steam. If desired to run the reel by hand, a handle can be placed upon the shaft of the cylinder *d*, or of the reel *e*.

Figure 8 represents a hand reel, of much the same style as the last, set up and ready for work. This machine was illustrated in the American Artisan for February, 1874, in the course of an article by W. V. Andrews, of Brooklyn. It is as good a hand reel as is now in use, though it is made on the same principle as the old French reel of forty years ago.

a. Tin basin with copper bottom for holding the water in which the cocoons are boiled, fitting tightly over the tray *b*.

b. Square tin tray for reception of cocoons, &c.

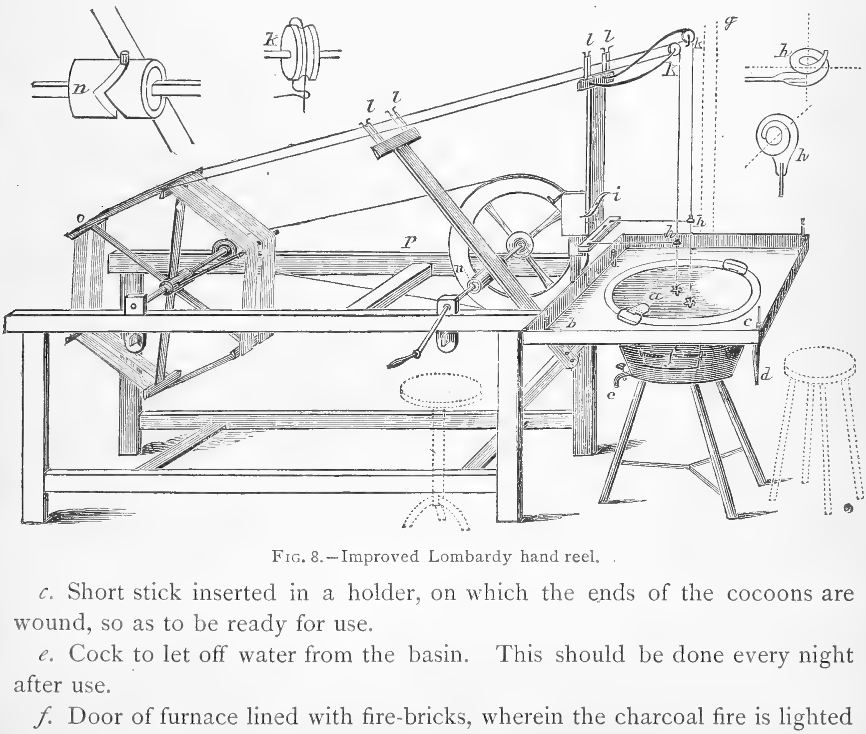

FIG. 8.—Improved Lombardy hand reel.

c. Short stick inserted in a holder, on which the ends of the cocoons are wound, so as to be ready for use.

e. Cock to let off water from the basin. This should be done every night after use.

f. Door of furnace lined with fire-bricks, wherein the charcoal fire is lighted to heat the water in *a*.

g. Flue-pipe to carry off fumes; this, as supplied, is short; the length and direction in which it may be carried varying in every case. It is necessary that all the charcoal fumes should be carried either into a chimney or into the open air.

h h. Glass eyes on wire holders, through which the threads from the cocoons pass upward to the pulleys at *k.* It is of importance that the glass eyes should be so placed that the threads pass upward in a straight line from the water to the pulleys at *k*, and also from the pulleys to the top of the wheel at *o* (except so far as when diverted laterally by the long guider at *l l*); friction is thus reduced to a minimum, and the elasticity of the thread preserved.

i. A former arrangement for twisting the threads one upon the other; this is now discontinued as unnecessary, since the twist given to the threads at *k* and continued downward to the point *h* effects its purpose with a minimum of friction, and produces a superior thread. This twist is effected by the very simple method of passing one thread round the other, as shown in the small drawing of the pulley *k.*

k k. Rollers or pulleys revolving on bent wire stands, over which the threads pass.

l l. Porcelain tubes on wire holders, between which the threads pass to reach *o.* Glass eyes may be substituted for the first pair of these tubes with equal advantage.

n n. A grooved arrangement by means of which the long guider working to and fro distributes the thread to the reel "in the cross." Unless the thread is thus wound "on the cross," it cannot be unwound at the mills when required to be thrown, and is, therefore, unsalable.

o. The top of the reel on which the silk is wound. One of the arms is furnished with the screw-hinge attached, by means of which the length of the arm is diminished to take off the silk.

p. Handle of the machine. (The letter in the cut is in the wrong place.)

The adult reeler sits on the stool in front of the cocoons, and the other stool is occupied by the child who turns the crank.

FOOD PLANTS.

The traditional food plant of the Silkworm is the Mulberry (botanical genus *Morus*). There are two species of Mulberry indigenous to the United States, namely, the Red Mulberry (*Morus rubra*) and the Small-leaved Mulberry (*Morus parvifolia*), neither of which is suitable Silkworm food. I have tried in vain to rear the worms upon *rubra*, but they either refuse its leaves entirely or dwindle and soon die upon it. The imported species which are most used are the white (*M. alba*), the *Multicaulis*, and the black (*M. nigra*). This last is inferior to the other two as Silkworm food.

The Mulberry grows readily, being easily propagated by cuttings or layers or from the seed. The White Mulberry, in particular, grows well from cuttings, and this is perhaps the readiest and most economical method of planting to secure a stock.

The cuttings should be started in rows, 3 or 4 inches apart, in ground prepared by deep plowing and harrowing. They should be about 6 inches long, and should be cut just before an eye in every case. They should be almost entirely buried. The quickest way to get a supply of leaves is to grow dwarfs. Set out the young trees from the nursery in rows 10 to 15 feet apart, and 6 to 8 feet between the rows, and form the crown of the tree by cutting down to a foot or so from the ground. The height of the tree and its form are easily regulated by pruning, and upon this process depend not only the vigorous growth of the tree, but also the ease with which the leaves may be gathered when desired. The pruning may be done in February or March, either every year or every other year. All dead twigs and dried bark should be removed and the limbs kept as smooth as possible, as this greatly facilitates picking. The best time for planting is in the fall, from frost until December, and in the spring, from March until May.

For growing standard high trees, a practical raiser gives the following directions: The cutting should remain two years in the nursery without pruning. The third year it is cut down close to the ground and transplanted. The finest shoot is then allowed to grow, and in good land it will reach a height of 8 or 10 feet in one season. The fourth year it is cut back to 6 feet or thereabouts. Then, the three or four terminal buds only being allowed to grow, all others are removed as often as they appear, by passing the hand along the stem.

The *Moretti*, a variety of the White Mulberry, is profitably grown in the form of a hedge, and the large size of its leaves makes it a very desirable variety.

Osage Orange.—The cultivation of the Osage Orange (*Maclura aurantiaca*) is so well understood in this country that there is no need of giving detailed instructions on the subject. Very generally used as a hedge plant in those sections of the country which are particularly adapted to silk culture, its leaves may at once be obtained without any special investment of capital. Indeed, as the hedges need trimming, the cutting off of the new year's growth, as the leaves may be wanted for feeding purposes, is a saving rather than an expenditure. Those who use this plant as Silkworm food must, however, bear in mind that the shoots from a hedgerow become very vigorous and succulent by the time the worms are in the last age. These more milky and succulent terminal leaves should be thrown aside and not used, as they are apt to induce flaccidity and disease.

In avoiding these more tender leaves, and using only the older and firmer ones, especially when the worms are large, consists the whole secret of the successful rearing of Silkworms on this plant; and if care be had in this respect there will be no appreciable difference in the silk crop from Osage Orange as compared with that from Mulberry.

Should the worms, from whatever cause, hatch before either Mulberry or Osage Orange leaves can be obtained, they may be quite successfully fed, for a few days, upon well-dried lettuce leaves. It will, however, be worse than a waste of time to attempt to feed them entirely on these leaves, or, in fact, on any other plants than the two here recommended.

GLOSSARY OF TERMS USED.

Age. The interval between any two molts.

Alimentary canal. The food-canal; a straight, simple tube, running from one end of the body to the other, and which it is impossible to subdivide into gullet, stomach, and intestine

Alkaline. Having the opposite reactions to an acid.

Anal horn. The horn upon the posterior end of the body of the worm.

Annuals. Those races which produce but one brood in a year.

Antennæ. The feathery feelers upon the head of the moth.

Bivoltins. Those races producing two broods in one year.

Bombycidæ. The family of moths, commonly known as "spinners," to which the Silkworm moth belongs.

Botrytis bassiana. The fungus causing muscardine.

Brin. The French term for a single thread from the cocoon.

Carneous. Flesh-colored.

Choked cocoons. A term applied to those cocoons in which the chrysalis has been killed.

Chrysalis. The third or restful stage of the insect, or that between the worm and the moth; enclosed in the cocoon.

Cocoon. The silken covering with which the worm surrounds itself before passing into the chrysalis state.

Cocoonery. The name applied to a room or building used for the spinning of worms.

Dacey. A Bengalese race of worms producing eight broods each year.

Dorsal vessel. The heart, extending from one end of the body to the other, just under the skin of the back.

Epizoötic. A term having the same significance with lower animals as *epidemic* with man.

Fil. The French term for the combined threads as they come from the reel.

Filature. The French name for a reeling establishment.

Floss silk. Raw silk made from the loose material of the outer cocoon and from pierced cocoons, &c. It is carded and spun like cotton or wool.

Gattine. An old name for a mild phase of the disease known as pébrine.

Grasserie. A Silkworm disease allied to jaundice.

Green cocoons. A name frequently applied to fresh or unchoked cocoons. Should be avoided, except where it has reference to cocoons of a green color.

Greens. A name applied to those races making cocoons of a greenish tint.

Integument. Skin or outer covering.

Labium. The under lip upon which is situated the spinneret.

Larva. The second or worm stage of the insect.

Lepidoptera. Name of the Order to which the Silkworm belongs.

Lusettes. A name applied to the worms which die from being unable to molt.

Magnanerie. Cocoonery.

Moretti. A variety of the White Mulberry discovered in 1815 by Professor Moretti, of Pavia.

Mori. The scientific specific name for the Silkworm.

Morus. The botanical generic name of the Mulberry.

Multicaulis. A species of *Morus* often called the Chinese Mulberry.

Muscardine. A Silkworm disease of a fungus nature, characterized in the text.

Spinneret. A tube projecting from the lower lip, and through which the silk issues.

Organzine. The choicest kind of raw silk, made from the best cocoons, and considerably twisted.

Ovipositing. Laying the eggs.

Panhistophyton. Name given by Lebret to the floating corpuscles in the bodies of worms affected by *pébrine.*

Pébrine. A Silkworm disease characterized in the text.

Pod. The compact portion of the cocoon, which is used for reeling purposes.

Polyvoltins. A term applied indiscriminately to all races which produce more than one brood in a year.

Pro-legs. The ten non-jointed legs under the sixth, seventh, eighth, ninth, and last joints of the body of the worm.

Psorospermiæ. Ordinary name for the floating corpuscles in the bodies of worms affected by pébrine.

Purgeur. The French word for *cleanser*—a clasp lined with cloth, through which the skeins of raw silk are passed to remove loose silk and foreign particles.

Quadrivoltins. Those races which produce four broods in one year.

Raw silk. Silk reeled from the cocoons before being spun and woven.

Seed. The eggs in bulk.

Sericaria. A generic name proposed by Latreille, and to which the Silkworm is referred by modern writers.

Sickness. The period of molting.

Spiracles. The breathing-holes of the insect; one row of nine down each side of the body.

Spores. The germinating seed of fungi.

Tambour. The French for *reel.*

Tram. Raw silk reeled from inferior cocoons and but slightly twisted.

Transformation. The change from one state to another, as from worm to chrysalis or from chrysalis to moth.

Trevoltins. Those races of Silkworms of which there are three broods in one year.

Whites. Those varieties having white cocoons,

Yellows. Those varieties having yellow cocoons.