U. S. DEPARTMENT OF AGRICULTURE.
DIVISION OF ENTOMOLOGY.
BULLETIN No. 9.

THE MULBERRY SILK-WORM;

BEING A

MANUAL OF INSTRUCTIONS

IN

SILK-CULTURE.

BY

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SEVENTH, REVISED EDITION.
WITH ILLUSTRATIONS.

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U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., March 20, 1888.

SIR: The sixth edition of Bulletin No. 9 of this Division, on the Silkworm, having been exhausted, I have the honor to present for publication a seventh edition, which is little more than a reprint of the sixth, with such slight changes as late experience has suggested.

Respectfully,

C. V. RILEY,
Entomologist.

Hon. NORMAN J. COLMAN,
Commissioner of Agriculture.

PREFACE TO THE SECOND EDITION.*

That there exists just now a very general and widespread interest in the subject of silk-culture in the United States is manifest from the recent large increase in the correspondence of the Entomological Division in relation thereto, and from the demand made for this Manual. To avoid the disappointment that is sure to follow exaggerated and visionary notions on the subject, it may be well here to emphasize the facts that the elements of successful silk-culture on a large scale are at the present time entirely wanting in this country; that the profits of silk-culture are always so small that extensive operations by organized bodies must prove unprofitable where capital finds so many more lucrative fields for employment; that extensive silk-raising is fraught with dangers that do not beset less ambitious operations; that silk-culture, in short, as shown in this Manual, is to be recommended only as a light and pleasant employment for those members of the farmer's household who either can not do or are not engaged in otherwise remunerative work.

The want of experience is a serious obstacle to silk-culture in this country; for while, as is shown in the following pages, the mere feeding of a certain number of worms and the preparation of the cocoons for market are simple enough operations, requiring neither physical strength nor special mental qualities, yet skill and experience count for much, and the best results can not be attained without them. In Europe and Asia this experience is traditional and inherited, varying in different sections both as to methods and races of worm employed. With the great variety of soil, climate, and conditions prevailing in this country, experience in the same lines will also vary, but the general principles indicated in this Manual should govern.

The greater value of labor here as compared with labor in the older silk-growing countries has been in the past a most serious obstacle to silk-culture in the United States, but conditions exist to-day that render this obstacle by no means insuperable. In the first place, comparative prices, as so often quoted, are misleading. The girl who makes only twenty or thirty cents a day in France or Italy does as well, because

* This preface was written in 1882, and some passages are omitted which had only a temporary interest and which might be misleading to-day.

of the relatively lower prices of all other commodities there, as she who earns three or four fold as much here. Again, the conditions of life are such in those countries that every woman among the agricultural classes not absolutely necessary in the household, finds a profitable avenue for her labor in field or factory, so that the time given to silk raising must be deducted from other profitable work in which she may be employed. With us, on the contrary, there are thousands—aye, hundreds of thousands—of women who, from our very condition of life, are unable to labor in the field or factory, and have, in short, no means, outside of household duties, of converting labor into capital. The time that such might give to silk-culture would, therefore, be pure gain, and in this sense the cheap-labor argument loses nearly all its force. This holds more particularly true in the larger portion of the South and West, that are least adapted to the production of merchantable dairy products or where bee-keeping and poultry-raising are usually confined to the immediate wants of the household.

The want of a ready market for the cocoons is now, as it always has been, the most serious obstacle to be overcome, and the one to which all interested in establishing silk-culture should first direct their attention. Ignore this, and efforts to establish the industry are bound to fail, as they have failed in the past. A permanent market once established, and the other obstacles indicated will slowly, but surely, vanish as snow before the coming spring. Owing to the prevalence of disease in Europe, there grew up a considerable demand for silk-worm eggs in this country, so that several persons found the production of these eggs quite profitable. Large quantities are yet shipped across the continent from Japan each winter; but this demand is, in its nature, transient and limited, and, with the improved Pasteur method of selection and prevention of disease, silk-raisers are again producing their own eggs in Europe. Silk-culture must depend for its growth, therefore, on the production of cocoons, and these will find no remunerative sale except where the silk can be reeled. I find no reason to change the views expressed relative to the part this Department might take in succoring silk-culture through Congressional aid; for, however just and desirable direct protection to the industry may be by the imposition of an import duty on reeled silk, no such protection has yet been given by Congress, and silk filatures can not be fully and profitably established without some fostering at the start. Under a heavy protective tariff our silk manufactures have rapidly grown in importance and wealth, until, during the year 1881 (according to the reports of W. C. Wyckoff, secretary of the Silk Association of America), raw silk to the value of $11,936,865 and waste silk and cocoons to the value of $769,186 were imported at the ports of New York and San Francisco, while our manufactured goods reached in value between $35,000,000 and $49,000,000. Now, the so-called raw silk thus imported to the value of nearly $12,000,000 is just as much a manufactured article as the woven goods, and its importation free of duty is as much an encouragement to foreign manufacturers and an impediment to home industry as the removal of the duty would be on the woven goods. The aid that Congress, through this Department, should, in my judgment, give to silk-reeling, and thereby to silk-production, may be supplied by private and benevolent means.

* * * * * * *

The obstacles which I have set forth are none of them permanent or insuperable, while we have some advantages not possessed by other countries. One of infinite importance is the inexhaustible supply of Osage Orange (*Maclura aurantiaca*) which our thousands of miles of hedges furnish; another is the greater average intelligence and ingenuity of our people, who will not be content to tread merely in the ways of the Old World, but will be quick to improve on their methods; still another may be found in the more spacious and commodious nature of the barns and outhouses of our average farmers. Every year's experience with the *Maclura* confirms all that I have said of its value as silk-worm food. Silk which I have had reeled from a race of worms fed on it, now for eleven consecutive years, is of the very best quality, while the tests made at the recent silk fair at Philadelphia showed that in some instances a less weight of cocoons spun by *Maclura*-fed worms was required for a pound of reeled silk than of cocoons from mulberry-fed worms.

C. V. R.

WASHINGTON, D. C., *February* 20, 1882.

PREFACE TO THE SIXTH EDITION.

The growing interest shown in the culture of silk, in the United States, is attested by the demands upon this Department for copies of this manual, which has hitherto been published as Special Report No. 11. Originally prepared as a brief manual, based on my own experience of the industry in America, the present demands of silk-growers, or rather of those desirous of becoming such, call for some further details, and in elaborating the work it has been thought best to include it among the bulletins of the Division. I have also divided the matter into chapters, and those on the implements which are necessary to, or facilitate, the work; those on diseases, reproduction, reeling, and the physical properties of raw silk embrace essentially new material, parts of Chapters V and VI being from my current annual report not yet distributed.

In Chapter VIII, in speaking of machinery I have omitted the detailed descriptions of special machines given in former editions and explained rather the mechanical principles that should be involved in all. A description of the Serrell Reel would have been very appropriate, but the inventor has been promised by the Commissioner that such should not be made public until all patents are secured. I shall hope to elaborate this chapter in some future edition.

It must not be forgotten that the original manual was never intended as an extended treatise on silk-raising or reeling, but was prepared to give, in a simple and most condensed way, information to those interested, and in a form applicable to the United States. It is gratifying to know that a number of other pamphlets on the Silk-worm have of late years been published, and that this manual has been quite freely used in their preparation. In one instance, in fact, an almost verbatim copy has been published and sold privately. I have found little or no occasion to alter opinions expressed in the manual, but in the present edition have revised the estimates of profits given in the Introduction to the original edition, leaving out those on egg production, because of the changed conditions since 1879, which have rendered such work, as a profitable business, obsolete in this country, and the production of sound and reliable eggs much more difficult and expensive.

Though particular pains were taken to impress upon readers the fact that the estimates of profits in silk-raising were based on definite market prices at that time, and that prices and profits must needs, as in all trades, vary from year to year, and though I especially omitted the cost of food, eggs, special buildings, etc., because the manual was addressed to those who would not have to incur these expenses (and I would not now recommend any one to embark in the industry who did not have these necessaries at command), yet these estimates have been criticised because silk-raisers have been unable to realize, in 1885, the profits which I considered attainable in 1879. For, though sharing the opinion of those directly connected with the silk trade, I then believed that the prices of raw silk and cocoons had reached as low a figure as they ever would, the belief proved subsequently unfounded, for fresh cocoons which in Europe sold in 1879 for 47 cents could be purchased, in 1885, for 35 cents per pound. Again, any estimates must needs be approximate only, as they will vary with the race.

This great alteration in the value of silk products has necessarily impaired the accuracy of the estimates given by me in the first edition of this pamphlet. I have therefore prepared another series of figures which are more nearly accurate to-day than the former ones, and are based on the French yellow race.

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

Average number of eggs per standard ounce of 25 grams, in ordinary yellow races, 37,500.

Number of fresh cocoons per pound, 300 to 400.

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

Maximum amount of fresh cocoons from 1 ounce of eggs, 93 to 125 pounds.

Allowing for deaths in rearing—26 per cent. being a large estimate—we thus get as the product of an ounce of eggs 69 to 92 pounds of fresh, or 23 to 31 pounds of choked, cocoons.

Two adults can take charge of the issue of from 1 to 3, say 2, ounces of eggs, which will produce 138 to 184 pounds of fresh, or 46 to 62 pounds of choked cocoons.

Price per pound of fresh cocoons (1885), 35 cents (300 cocoons per pound).

184 pounds of fresh cocoons, at 35 cents, $64.40.

Price per pound of fresh cocoons (1885), 25 cents (400 cocoons per pound).

138 pounds of fresh cocoons, at 25 cents, $34.50.

Price per pound of choked cocoons (1885), 80 cents to $1.15.

Value of above products, choked, $36.80 to $71.30.

APPROXIMATE COST OF REELING.

Estimated product of 6 non-automatic steam reels for the 300 working days of the year—1,200 pounds of reeled silk, and 300 pounds of waste silk.

Cost of production of 1,200 pounds of reeled silk, based on the Government experiments at New Orleans, in 1885:

Value of plant:		
Six reels	$500.00	
One steam engine	600.00	
Shafting and miscellaneous	400.00	
	1,500.00	
Interest and depreciation on plant, 20 per cent. per annum		$300.00
Raw material:		
5,076 pounds of choked cocoons, at $1		5,076.00
Labor (as shown at New Orleans), $1.12½ per pound of silk		1,350.00
Fuel, oil, etc		150.00
Total		6,876.00

Value of the above product:

1,200 pounds reeled silk, at $5.50	$6,600.00
300 pounds waste silk, at $1	300.00
Total	6,900.00

In studying these estimates the reader must, as I have said, bear in mind that the silk industry, like all industries, will have its ups and downs—its periods of buoyancy and depression. For the past few years it has been going through one of the latter. But late last fall an upward tendency was shown in prices for raw silk, which, if they remain firm, can not but influence for the better the value of cocoons.

In the preface to the second edition I mentioned the advantages to be gained by raising Silk-worm eggs, though I called attention to the fact that the market for them was in its nature limited and transient, and that European merchants were again producing their own seed by the aid of the improved Pasteur system of selection. Notwithstanding the facts there stated as to the limited nature of the egg market, silk-raisers have been disappointed, after having produced large quantities of eggs, in not finding a ready sale for them. But though the egg market is important in its place, it will readily be seen that it can be, when in a healthy state, no more extensive than is necessary to supply each season the wants of silk growers. In 1884, in France, about 2½ per cent. of the total crop was employed in the production of eggs. These figures, from a country where silk culture is established, furnish a foundation upon which to estimate. Every pound of cocoons which is sold at the filature puts money into the pockets of the silk-raising class; while every pound used in the production of eggs in excess of the amount actually required robs it of the money that it would otherwise receive. The only way to build up the industry, then, is, as I have so often insisted, to create, by the establishment of filatures, a durable and profitable market for cocoons. The production of eggs is simply an incident of comparatively little importance.

I have shown in said preface that silk-raising on an extensive scale is fraught with so many dangers that it is inadvisable to invest capital in such an enterprise. This is partly due to the fact that a large crop must necessarily be raised with the aid of hired labor, and a consequent investment of cash capital. A large rearing requires a large and (for success) a specially constructed building, which must necessarily lie idle for the greater part of the year. It has been found, too, that the average production of cocoons, per ounce of eggs, is much less for large than for smaller crops. Thus one ounce of eggs of good race will produce one hundred pounds of fresh cocoons; while for every additional ounce the percentage is reduced if the worms are all raised together, until for twenty ounces the average may 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 the worm in small broods, or of rearing on a moderate scale. As a result we see the great magnaneries disappearing from France and Italy, where in some establishments as many as 60 ounces were at one time annually raised. We find this statement confirmed by looking at the French official statistics for 1884, where it is stated that the cocoons produced in France during that year were raised by over one hundred and forty thousand families, who utilized therefor about two hundred and eighty thousand ounces of eggs, or an average of about two ounces per family.

To beginners I would repeat the advice so often given from this Office, to hatch the first season but a small quantity of eggs; not more than an eighth of an ounce. Experience counts in this as in other industries, and it will be found that, where only a small quantity of worms are being fed, there will be much more time to study their habits and wants. With a year's experience there will be a better chance of profit the second year.

It will not 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 none but skilled reelers can hope to produce a first-class article. Skill comes only after full apprenticeship and practice. 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. Though there is a ready market in the United States for large lots of good silk, it will not be found so easy to dispose of small lots of poorer quality.

Two years ago Congress appropriated $15,000 for the encouragement of silk-culture, and the appropriation was repeated for the present fiscal year. The appropriation was general in its nature, and the method of encouragement left with the Commissioner of Agriculture. In my Annual Reports for 1884 and 1885 details are given as to the work done by the Department under this appropriation, and various questions discussed and conclusions reached as to the outcome of the two years' experience. These need not be repeated here.

Owing to the conviction that the establishment of filatures and their successful operation was the *sine qua non* in putting the industry on a firm basis, a large portion of the money thus appropriated has been devoted to experiments in silk reeling. These experiments have shown that the quality of cocoons produced by American silk-raisers is not yet such as to enable this country to compete with others in the production of raw silk. The quality of a cocoon is most conclusively shown by the quantity of silk which may be unwound from it. A good average result, after the experience of European filatures, is the production of a pound of raw silk from 3.80 pounds of dry cocoons. The Government experiments at New Orleans showed a production of but 1 pound of silk from 4.23 pounds of dry cocoons. The cost of producing silk from a poorer quality of cocoons is proportionately much greater than where the cocoons are of better quality, and the difference is much greater than would be thought possible by one unacquainted with the industry. We have, therefore, much to accomplish from this point of view before we can hope to make the industry a profitable one in the United States. The cocoons which have been received at the Government stations during the past year have been, to a large extent, raised by persons who were inexperienced, and who were thus unable to produce a first-class cocoon. There is an inclination among these very persons to blame the industry if they do not receive, the first season, what they consider an adequate compensation for the time which they have expended upon the work. And yet these same individuals would not expect to be successful in any other enterprise until they had made themselves thoroughly acquainted, by practical experience, with the special work involved. It is not, therefore, surprising that with such a quality of raw material it has been impossible to produce silk without financial loss. Such a loss, in fact, as shown in my annual report as entomologist, for 1885, was incurred as the result of the experiments. We, however, performed these experiments with non-automatic machinery, and that even of an unimproved type. The loss was, however, so small that we have reason to believe that it can be more than counterbalanced by the use of improved plant. Automatic silk-reels are now being placed upon the market, which not only effect a slight saving in the quantity of raw material employed, but also a very large saving in labor, the cost of which in this country is the principal cause of our inability to compete with Europe and Asia. These new reels are also capable of producing, with comparatively unskilled labor, as good a grade of silk as can be made by the expert workwomen of France.

It will be seen by the estimates given above that silk-culture is not (and it never has been) 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."

The reader is reminded that the few quotations not otherwise credited are from the author's Fourth Report on the Insects of Missouri (1871). A number of foreign (more particularly French) terms are unavoidable in treating of silk-culture, as they have no actual equivalents in our language. These and the few technical terms used in the manual are made clear in the glossary.

Finally, I take pleasure in acknowledging the assistance given me in the preparation of this new edition by Mr. Philip Walker, who has acted as the chief agent of the division in the sericultural work during the past two years.

C. V. R.

WASHINGTON, D. C., *May*, 1886.

CHAPTER I.

PHYSIOLOGY AND LIFE-HISTORY OF THE SILK-WORM.

The Silk-worm 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 Silk-worm. 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 Silk-worm 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 results 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 Silk-worm must necessarily be very general in their character.

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

DIFFERENT STATES OR STAGES OF THE SILK-WORM.

THE EGG.—The egg of the Silk-worm 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.

Near one end a small spot may be observed. This is the *micropyle*, and is the opening through which the fecundating liquid is injected just before the egg is deposited by the female. After fecundation and before deposition the egg of some varieties is covered with a gummy varnish which closes the micropyle and serves to stick the egg to the object upon which it is laid. 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. The shell becomes quite white after the worm has made its exit by gnawing a hole through it, which it does at the micropyle. Each female produces on an average from three to four hundred eggs. In the standard ounce of 25 grams* there are about 50,000 eggs of the small Japanese races, 37,500 of the ordinary yellow annual varieties, and from 30,000 to 35,000 in the races with large cocoons. The specific gravity of the eggs is slightly greater than water, Haberlandt having placed it at 1.08.

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

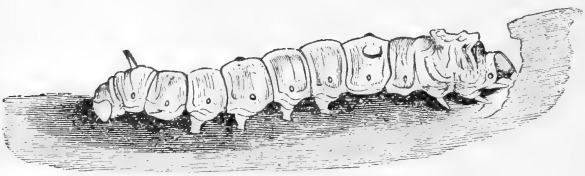

FIG. 1.—Full grown larva or worm (after Riley).

molts or sicknesses, the latter being the normal number. The periods between these different molts are called "ages," there being five of these ages, the first extending from the time of hatching to the end of the first molt, and the last from the end of the fourth molt to the transformation of the insect into a chrysalis.

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 twenty-five to forty days, depending upon the race of the worm, the quality of food, mode of feeding, temperature,

*$28\frac{1}{3}$ grams = 1 ounce avoirdupois.

etc.; but the same relative proportion of time between molts usually holds true.

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. After the first molt, and as the worm increases in size, these hairs and tubercles become less noticeable, and the worm gradually gets lighter and lighter, until, in the last stage, 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 forepart 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 which will form the cocoons.

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 softened 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 (Figs. 2 and 3) consists of an outer lining

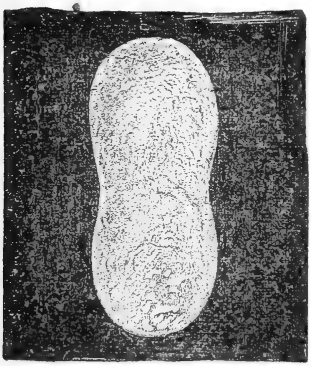

FIG. 2.—Constricted cocoon, with fine texture (original).

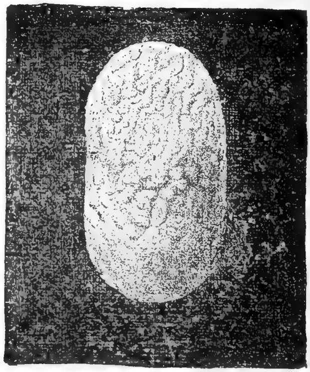

FIG. 3.—Non-constricted cocoon, with coarse texture (original).

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 around. 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, or even roseate.

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 the exit once effected, 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. 4.—Silk-worm moth, male (after Riley).

The moth is of a cream color, with more or less distinct brownish markings across the wings, as in Fig. 4. The males have broader antennæ or feelers than the females, and may be, by this feature, at once distinguished. Neither sex flies, but the male is more active than the female, and may be easily recognized by a constant fluttering motion of the wings, as well as the feature mentioned above. They couple soon after issuing, remaining coupled during several hours, and in a short time after separation the female begins depositing her eggs, whether they have been impregnated or not. Very rarely the unimpregnated eggs have been observed to develop.

VARIETIES OR RACES.

As before stated, domestication has had the effect of producing numerous varieties of the Silk-worm, 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; 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 the early spring, and the second, eight or ten days after the eggs are laid by the first brood. With Bivoltins 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 consideration 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. The principle difficulties encountered in raising other than the annual races arise from the excessive heat of midsummer, which causes disease, and the deteriorated quality of the leaves as explained in Chapter X. Silk-growers are therefore earnestly advised to attempt but one brood per annum except where, as in some parts of the Pacific coast, the summers are prolonged and equable.

Commercially cocoons are classed as yellow, white, and green, but through the intermingling of races these colors have become merged one into the other, and it is often difficult to define the line of demarkation. The same trouble exists in classifying varieties by the different countries or provinces from which they have originally come. Prior to the Silk-worm plague of twenty years ago in Europe there was a certain degree of exactness in the lines drawn between such races. Then, however, the indigenous races were to a large extent blotted out, and the egg merchants went first to Turkey, then to Asia Minor and Syria, and finally to China and Japan, in search of eggs that should be free from "the malady." Thus it was that there were brought into France and Italy a large number of races foreign to those countries. These were crossed together, and after the researches of Pasteur had made the resuscitation of the native races possible, they were crossed with these as well. Thus the identity of the old varieties was, in many cases, lost, or they obtained different names.

CHAPTER II.

WINTERING AND HATCHING THE EGGS.

As has been said in the last chapter, the egg of the Silk-worm changes color soon after oviposition. During this operation the contents undergo a chemical change, absorbing oxygen and giving off carbonic acid. This absorption of oxygen is very active during the first six days, after which it rapidly declines and continues at a very low rate during the months which precede hatching. The eggs should, therefore, be wintered in such manner that they have plenty of air; otherwise their development will be seriously interfered with. They must not be packed in thick layers, but should be spread out thinly. For these reasons the eggs at this Department are kept through the winter in boxes of perforated tin, the bottoms of which have a surface of 6½ square inches, each box containing not more than one quarter of an ounce of eggs.

The atmosphere in which the eggs are kept should neither be too dry nor too humid. M. Beauvais found a saturation of 50 per cent. to be the most suitable condition of the air, as when it is below that point the liquids of the eggs evaporate so rapidly as to require a highly saturated atmosphere for their incubation. Excessive moisture, on the other hand, will assist the formation of mold, which will quickly injure the contents of the egg. The eggs should be frequently inspected, and whenever such mold is discovered it should be quickly brushed off and the eggs removed to a drier locality.

Under natural conditions the egg undergoes a partial development as soon as laid, as shown by its changing color. After oviposition, and until subjected to cold, the eggs of the annual races are not capable of hatching out. This is the rule, although we often find in a batch of annual eggs a few accidental bivoltins that hatch some fifteen days after they are laid. The number, however, is very slight, and it has been determined that the temperature to which they are submitted in no way alters the result. During this period, which we call prehibernal, the eggs may be kept at any ordinary temperature, however warm, but once they are submitted to the cold of winter a certain change takes place in them, the nature of which has not yet been determined, and their subsequent warming may then result in hatching. As in our climate warm days are quite frequent in late winter, it is very necessary that the eggs be kept below the hatching temperature until the foliage on which the worms are to feed is developing and all danger from late frosts is at an end. The period of hibernation may be lengthened by keeping the eggs in a cool, dry cellar, with a northerly exposure, and in general this will suffice. But in such a case the temperature is more or less variable, and the embryo may be started in its development only to be checked by renewed cold. When kept at a uniform low temperature, after having once been cooled, development is imperceptible, and when afterward exposed to the proper hatching conditions, the resultant worms will prove more vigorous. If possible the temperature should never be allowed to rise above 40° F., but may be allowed to sink below freezing point without injury.

When small lots of eggs are to be wintered, they may be placed in ordinary boxes in the cellar, care being taken to observe the precautions noted above as to ventilation, humidity, and temperature. They should also be protected from rats, mice, ants, and other vermin. But where great quantities are to be stored, it will be well worth while to construct special hibernating boxes, where the requisite conditions may be regulated with nicety and precision.

A great 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 or hibernating boxes 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 it is necessary to do is to spread this same cloth over the bottom of the 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, if the weather be dry, 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.

It will be found that eggs which have been subjected to great cold during the winter will require a longer time in their incubation than those which have been kept at a higher temperature, and it is also true, as has been intimated above, that when the atmosphere in which the eggs have been retained has been excessively dry it will require con-

*Too much stress can not be laid on the importance of beginning the rearing of worms as early as possible, so that the excessive heat of summer may be avoided. Beginners are very apt to delay sending for eggs until after the leaves have put out, and there is not only more danger of the hatching of the eggs in transit, but the worms will be maturing during very warm weather.

siderable humidity to cause them to hatch. Such matters must be largely regulated by the experience of the individual raiser.

The desired conditions can be better regulated in specially constructed incubators than in an open room. A simple form of incubator is shown in Fig. 5. It consists of a tin cylinder with a perforated shelf and a

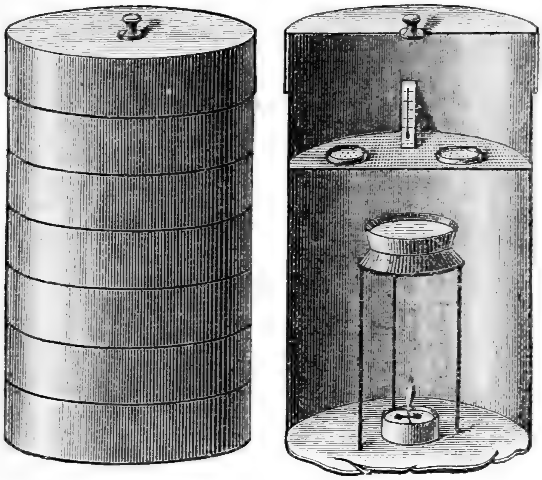

FIG. 5.—Incubator made of tin-ware (after Roman).

movable cover. Under the shelf is placed upon a tripod a small vessel of water, beneath which burns a small night-lamp. This apparatus may be made about eight times the size of the drawing. A similar and simple form of basket-ware incubator is shown in Fig. 6. This possesses

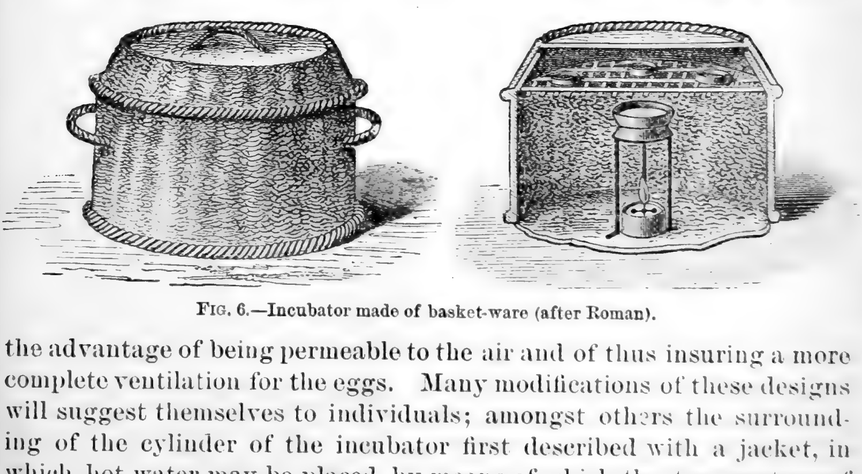

FIG. 6.—Incubator made of basket-ware (after Roman).

the advantage of being permeable to the air and of thus insuring a more complete ventilation for the eggs. Many modifications of these designs will suggest themselves to individuals; amongst others the surrounding of the cylinder of the incubator first described with a jacket, in which hot water may be placed, by means of which the temperature of the interior may be regulated with a considerable degree of nicety.

CHAPTER III.

IMPLEMENTS THAT FACILITATE THE RAISING OF SILK.

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 northeast exposure is the best, and buildings erected for the express purpose should 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 should be arranged with deep and numerous shelves, ranging one above the other from floor to ceiling, as shown in Fig. 7. The width of these shelves should not exceed 5 feet,

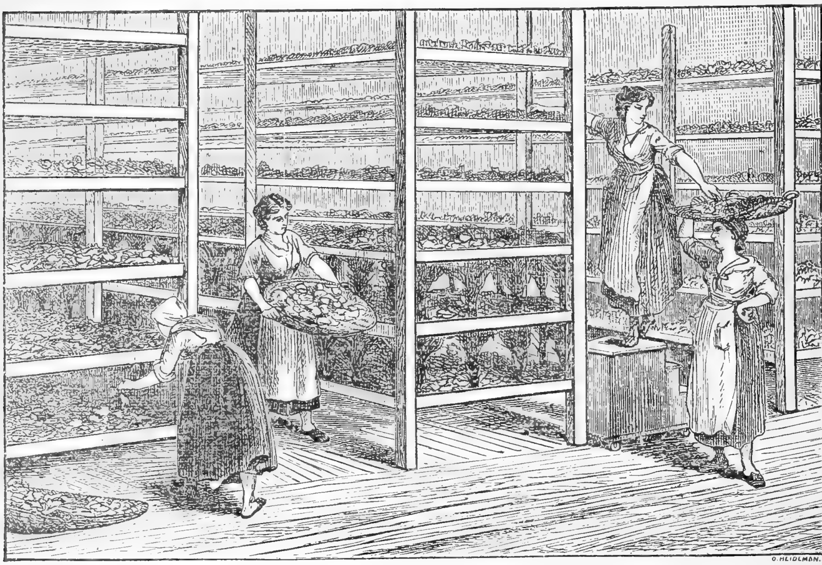

FIG. 7.—A modern magnanerie (after Gobin).

as those in charge must be able to reach from either side to the middle of each table. Bearing this in mind, the dimensions of these tables may be made to suit the room in which the worms are reared. The vertical distance between two shelves should not be less than 20 inches, but if this space is greatly increased it will be found inconvenient to obtain brush of sufficient length to form the arches upon which the cocoons are to be spun.

The form in which the tables are constructed is also immaterial, and should depend upon the resources of the owner. Where canes are abundant, as upon the Mississippi bottom, such a shelf as is shown in

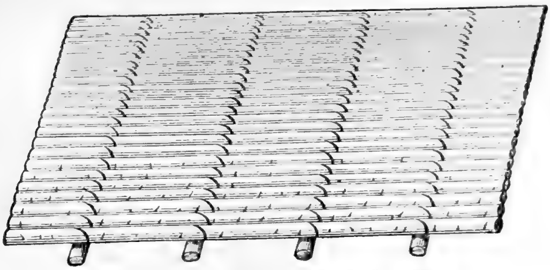

FIG. 8.—Shelf made of canes (after Roman).

Fig. 8 will be found inexpensive and satisfactory. To construct a shelf in this manner, say 5 by 8 feet, there should be selected for cross-pieces four stout canes about one inch through at the small end and 5 feet 4 inches long. Having procured a quantity of smaller canes, 8 feet long, lay out the four cross-pieces some eighteen inches apart, and, placing a cane across them, lash the whole together with stout cord. This is done by having an end of cord attached to each cross-piece, which, after it is carried over the smaller cane, is brought around the cross-piece and fastened by a slip knot, as will be better understood by reference to

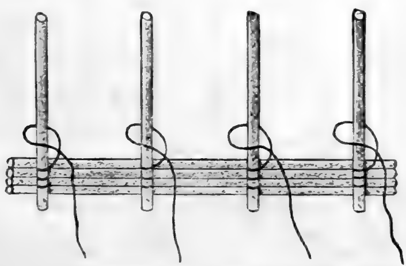

FIG. 9.—Construction of the cane shelf (after Roman).

Fig. 9. The second cane should be placed tip to butt with the first, and so on alternately. Fig. 10 shows a shelf formed with wire-work, which

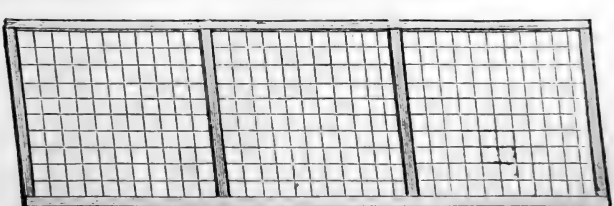

FIG 10. Wire-work shelf (after Roman).

makes a strong and light article. The form shown in Fig. 11 is essentially the same, being covered with wooden slats. Placing these diagonally increases the stiffness and diminishes liability to break.

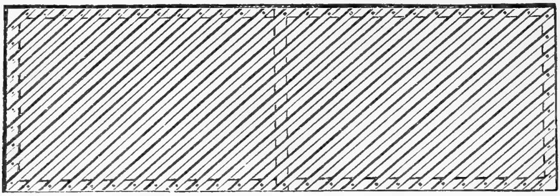

Fig. 11.—Frame covered with slats (original).

Where it is desired to have a neat and convenient standard, upon which a small quantity of worms may be reared, it may be constructed after the manner of that shown in Fig. 12, the shelves being made as

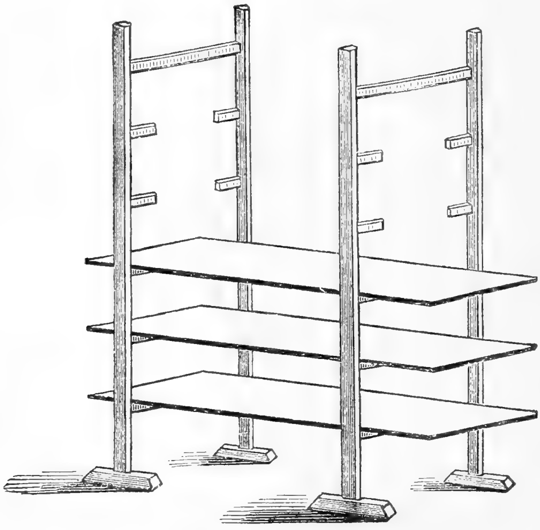

Fig. 12.—Standard for holding shelves (original).

shown in either of Figs. 10 or 11. The principal requisites in the construction of all the above articles are lightness and strength, and the shelves should be so constructed as to permit the free circulation of the air. All wood should be well seasoned, as green wood seems to be injurious to the health of the worms. The shelves above described must be covered with strong brown paper before being used, and it will be found to be more convenient in removing the litter if sheets of the same size as the table are employed.

In rearing Silk-worms great care should be observed in not handling them more than is absolutely necessary, and as, in clearing up the litter made by the larvæ, it is necessary to transport them from one table to another, several schemes have been adopted to accomplish this object. The first transfer made upon the birth of the worms is usually performed with the aid of ordinary mosquito netting, which is lightly laid over the hatching eggs. Upon this can be evenly spread freshly-plucked leaves or buds. The worms will rise through the meshes of the net, and cluster upon the leaves, when the whole net can be easily removed.

This netting has the disadvantage of sagging in the middle and lumping the worms. Netting of a coarser mesh may be used later in rearing, but it should be stretched on light frames. This method of transfer 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 ages of the worms, has been used. The material employed is a stout manila paper, and the perforations vary in size, as shown in Fig. 13. I have experienced some difficulty in the

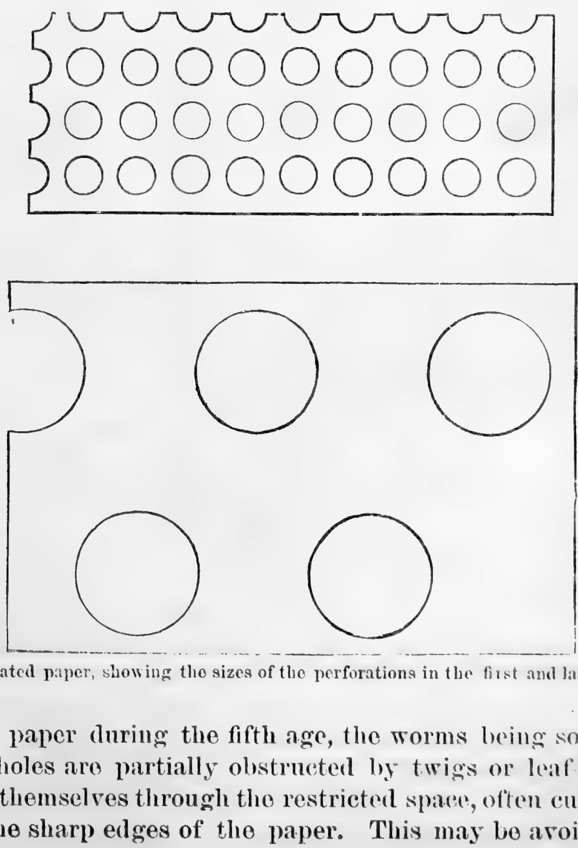

FIG. 13.—Perforated paper, showing the sizes of the perforations in the first and last ages (original)

use of this paper during the fifth age, the worms being so large that when the holes are partially obstructed by twigs or leaf stems they must force themselves through the restricted space, often cutting themselves on the sharp edges of the paper. This may be avoided by the use, during that age, of a lattice-work tray, such as is shown in Fig. 14.

To prevent this tray from pressing upon the worms beneath, it should be propped up by small blocks placed under the corners.

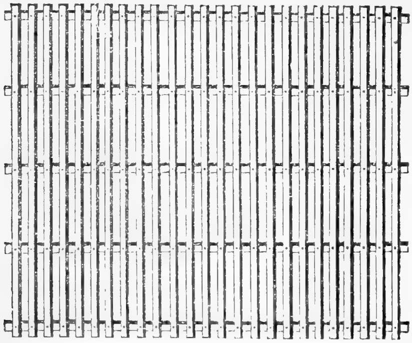

FIG. 14.—Lattice-work transfer tray (original).

When large pieces of perforated paper are used they should be handled by two persons. By cutting them into smaller pieces and using a transfer tray (Fig. 15) one person can perform the necessary work with ease. Such a tray is most conveniently made about 13 by 19 inches inside. When the paper, which should be made about one inch smaller each way, has been covered with leaves, and the worms have come through the perforations in search of their food, the whole may easily be slipped into the transfer tray, and as easily taken from it in depositing the worms on another table.

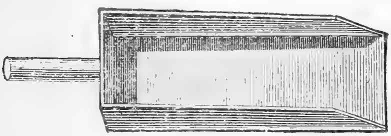

FIG. 15.—Transfer drawer (after Roman).

In gathering leaves for the worms it will be found convenient to employ a bag (Fig. 16), so arranged that it may be attached around the waist like an apron. Two such sacks may be made from an ordinary meal bag.

The worms should be made to spin their cocoons on brush so arranged as to form arches between the shelves, as is shown in Fig. 19.

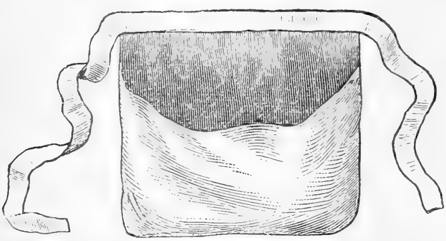

FIG. 16.—Bag for gathering mulberry leaves (after Roman).

For the same object the cocooning ladder shown in Fig. 17 was devised in 1842 by M. Davril. It consists of two central supports, across each side of which (Fig. 18) are nailed small strips of about one-quarter by one-half inch section, 1½ inches apart. The strips on one side are placed opposite the spaces between the strips on the other side. The ladder may be made about 30 by 15 inches, and the central supports about five-eighths inch thick. When in use the ladder is placed slantingly between the tables, with the central supports horizontal.

A thermometer is a very useful adjunct to the appliances above described.

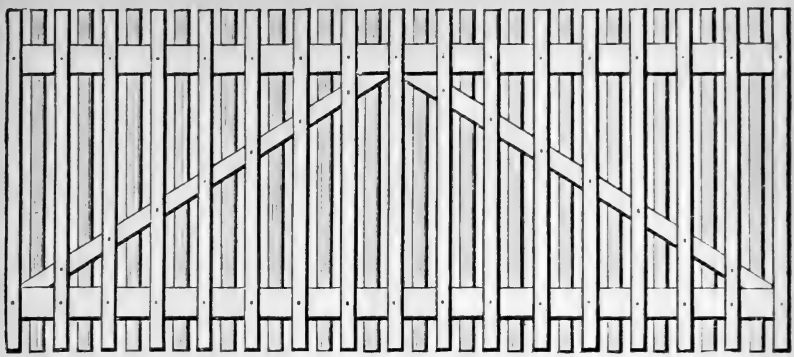

Fig. 17.—The Davril cocooning ladder.

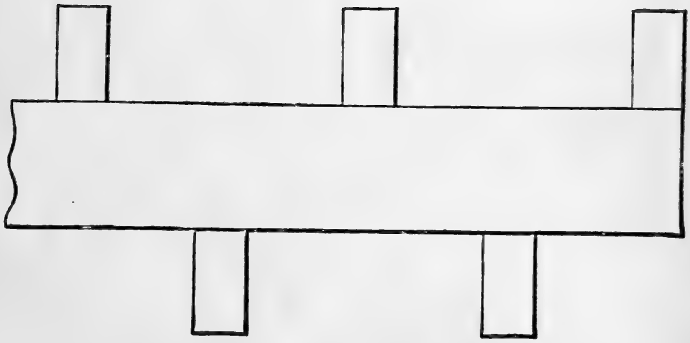

Fig. 18.—Partial end view of the Davril cocooning ladder (full size).

CHAPTER IV.

THE REARING OF SILK-WORMS.

The chief conditions of success in silk raising are (1) the use of good eggs; (2) proper care of the worms.

The means of obtaining pure eggs will be described in the next chapter, and we will here consider the second of the conditions.

Unless new, and especially where the worms raised with them the preceding season have suffered from any disease, all the implements and furniture used should be cleansed and purified by carefully scrubbing in soap and water. The walls of the room may, where convenient, be submitted to the same operation, and covered with a strong coat of whitewash. The room should then be tightly closed and thoroughly fumigated with burning brimstone during an entire day and night. It may then, after being well aired, be used for the rearing of Silk-worms.

The eggs when about to hatch, whether brought to this condition by the systematic processes described in Chapter II, or by ruder methods, should be spread out on clean paper in as thin layers as possible. Over them should be lightly laid small pieces of ordinary mosquito-netting. When the worms begin to appear there should be sparsely scattered over this netting a few buds or finely-cut leaves. The newly born larvæ will at once pass through its meshes in search of food, and the whole can then be easily removed to the table upon which they are to pass their first age.

It is recommended by many to feed the worms while in this 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 practised 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 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. Additional meals should be given during the day, according as the worms may seem to need them. It is only by experience that one can learn just what amount of food should be given to the worms. It may prove dangerous to feed them too copiously, as in the first ages the worms may become buried and lost in the litter, while later the massing of food in an attempt to satisfy their ravenous appetites may cause it to ferment and become productive of disease.

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 to feed wet or damp leaves to your worms. In case the leaves 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, grows more shiny, and soon the dark spot already described appears above the head. The larva at this time generally wanders to an unencumbered spot where it may shed its skin in quiet and often gets hidden and buried under the superimposed leaves. When the first worms show these signs of molting, food should be given more sparingly and the meals should cease altogether as soon as the most forward worms awaken. When the time for the molt is near, say during the fourth day, it will be well to clear away the litter so that the worms may pass the crisis on a clean bed.

Some will undoubtedly undergo the shedding of the skin much more easily and quickly than others, but no food 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, can not 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 or tray when about half of the worms have risen and replacing it by an additional one. The space allotted 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.

The second and third castings 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 to the elaboration of the silk.

It would, too, be found inconvenient if all the worms were to arrive at the spinning period together, as extra assistance would be required to place the brush on which they spin their cocoons.

At each successive molt the color of the worm has been gradually whitening, until now it is of a decided cream color. Some breeds, however, remain dark, and occasionally there is an individual with zebra-like markings.

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, etc. 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 predaceous 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 Silk-worm has.

So much depends upon the conditions of development mentioned above that it is impossible to state the exact quantity of food consumed by the Silk-worm during its life. It will not be far from the truth, however, to place the amount consumed by the issue of an ounce of healthy eggs, which matures in 35 days, at 6½ pounds during the first age, 20 pounds during the second, 65 pounds during the third, 200 pounds during the fourth, and during the fifth and last age 1,250 pounds. This makes a total of between 1,500 and 1,600 pounds. It need hardly be said that the food mentioned must be of the best quality. Were it poor, it would be impossible to give any figures at all.

Too much can not be said in favor of giving the larvæ plenty of room. Every worm should be free to move easily without incommoding its fellows. We should therefore allow the issue of an ounce of eggs during the first age, from 10 square feet at the beginning to 30 square feet at the end of the age, daily extending the space occupied by them by spreading their food over a greater table surface. In the second age, they should spread in the same manner so as to cover from 50 to 75 square feet, in the third from 100 to 160 square feet, and in the fourth from 200 to 320 square feet. Entering the last age, spread over 430 square feet of surface, they should gradually be extended until they occupy, at the spinning period, 640 square feet. It need hardly be said that when the worms have been decimated by disease the surface occupied by them need not be so extensive.

The litter of the worms should be cleared away by the use of netting or perforated paper, before and after each molt, and once at about the middle of the third age. 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 two last ages will suffer in the disease and mortality of his worms just as they are reaching the spinning point.

Summed up, the requisites to successful Silk-worm 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.

PREPARATIONS 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

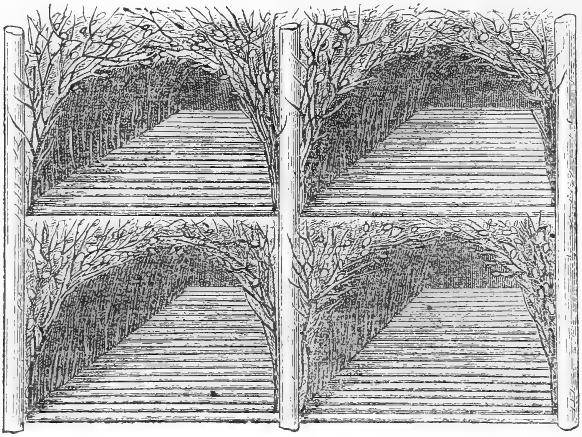

FIG. 19.—Method of constructing arches upon which the cocoons are spun (after Roman).

brush. The feet of each arch should be only about a foot apart. The Davril cocooning ladder, described in Chapter III, may be used with advantage in the place of the brush arches.

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 semi-fluid 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 removed from the inner cocoons or pods, and the latter sorted 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 can not 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 provision for eggs 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. The precautions to be taken in choosing cocoons for reproduction are set forth in Chapter VI.

Kept at a temperature of about 70° F., new silk cocoons lose, through the giving off of humidity by the chrysalides, a material proportion of their weight. According to Dandolo the loss in 100 pounds during the first ten days amounts to about 7½ per cent.* The amount of humidity in the atmosphere naturally affects this result. The loss continues until the cocoons are thoroughly dry, when it will be found that they have lost two-thirds of their original weight.

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* Dandolo states that 100 pounds of cocoons will suffer the losses indicated by the following table:

	Pounds.
Weight when taken from the brush and after the floss has been removed	100.0
Weight one day after	99.1
Weight two days after	98.2
Weight three days after	97.5
Weight four days after	97.0
Weight five days after	96.6
Weight six days after	96.0
Weight seven days after	95.2
Weight eight days after	94.3
Weight nine days after	93.4
Weight ten days after	92.5

CHAPTER V.

ENEMIES AND DISEASES OF THE SILK-WORM.

As regards the enemies of the Silk-worm 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." This is produced by a Tachinid called by Rondani *Ujimyia sericaria*, and the life history of which has been carefully worked up by Prof. C. Sasaki of Japan (Journal Science College, Imp. Un., Tokio, Japan, 1886, Vol. I, part I).

There are, however, several forms of disease against which it is necessary to guard and of which it is therefore necessary that silk-raisers should have an intimate knowledge. Through the multitude of local names given to these diseases abroad, one would suppose that there were as many diseases to which the Silk-worm is subject. But Pasteur, after studying the subject very carefully, concluded that all may be considered as varieties of four principal diseases, viz: the *muscardine*, *pébrine*, *flacherie*, and *grasserie*.*

The *gattine*, one of these varieties, is considered by Pasteur as a mild form of the pébrine,† but Maillot, in a later work,‡ considers it as a species of the flacherie.

These diseases are found to some extent intercurrent, though at all times one (at least one of the first three) has been more prevalent than the others, generally amounting to a plague. So in 1849 we find M. Guérin-Méneville studying, on the part of the French Academy, the then prevalent disease, the muscardine. This was soon followed, in the fifties, by a veritable scourge in which the pébrine was the leading feature, with flaccidity (*flacherie*) quite frequently found. The same learned body appointed Pasteur to study the causes of these diseases, and after two years of patient research he devised a means, which will hereafter be described, of successfully preventing the return of the pébrine. This made way for flaccidity, which is to-day the dread of silk-raisers, for although it does not reach the importance of a plague, its effects are distinctly visible upon the national crops of cocoons in France and Italy, and I have never known it to be absent from worms reared by me almost every year for nearly two decades in this country. The grasserie has never attained any such importance, but occurs in rare instances only.

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* Pasteur, "*Études sur la maladie des vers à soie,*" Vol. I, p. 225.

† Pasteur, "*Études,*" etc., Vol. I, p. 12.

‡ Maillot, "*Leçons sur le vers à soie du murier,*" p. 109.

MUSCARDINE.

The first of these, the *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 silk-worm raisers, including such good authorities as F. E. Guérin-Méneville and Eugène 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. W. B. Carpenter, an eminent microscopist, 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.

As the sole means of disseminating the disease are the spores which only appear several hours after the death of the worm, the most rational means of preventing the spread of muscardine is by carefully taking from the tables all dead worms as soon as they are discovered, and if the disease seems to have gained a foothold in the magnanerie it will be well to remove the litter oftener and give the worms more

**Guide à l'éleveur de vers à soie.*

space. The spores retain their power of communicating disease for at least three years; hence the importance of cleansing and fumigating as described in the last chapter.

PÉBRINE.

External symptoms.—"The disease, pébrine, shows itself outwardly by the dwindling away of the worms and their inequality of size; eating little, they do not grow as large as when in their normal state. At the end of a few days black spots frequently make their appearance on the skin, resembling punctures or burns; the anal horn, the prolegs, the soft parts between the rings, are especially subject to these spots."*

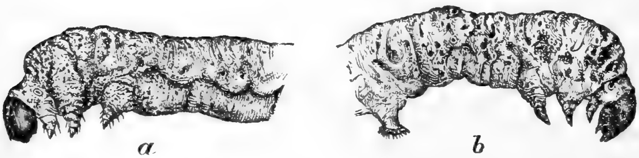

Fig. 20.—Silk-worms spotted with pébrine, twice natural size (after Pa teur).

Fig. 20 "represents, at twice the natural size, the anterior part of the body of sick worms covered with such spots. In one of the worms, *a*, they are just becoming visible, and the eye should be aided by a magnifying glass to render them distinct; the other, *b*, shows them farther advanced, easily recognizable with the naked eye, if the worm be examined with a little attention. Finally, Fig. 21 shows one ring spotted with pébrine, magnified to six diameters. For this cut was chosen a worm bearing two kinds of marks, one with clear-cut edges, the others surrounded with a halo. The first are wounds, the others the true spots belonging to the disease and serving as an indication of its existence, if not always, at least under many circumstances. The halos in question have generally a yellowish tint. They must be observed through a magnifying glass to be well seen."†

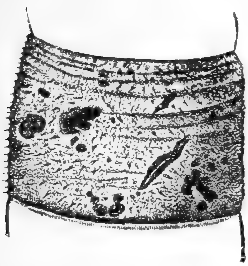

Fig. 21.—Joint of a Silk-worm showing wounds and spots of pébrine, six times natural size (after Pasteur).

These spots disappear with the shedding of the skin at each molt only to reappear again within a few days. Worms bearing them are figured in plate I, A, B, C, and D. In addition to these symptoms it is noticed that the prolegs do not seem to attach themselves easily to objects. In the chrysalis the abdomen is very much swollen and the rings stretched. In a highly-diseased moth the wings are wrinkled as when they emerge

* Maillot, *Leçons*, etc., p. 96.

† Pasteur, *Études*, etc., p. 15.

from the cocoon, and are often covered with bloody pimples, which become black on drying. Part of the body and the wings have a leaden color; but this must not be confounded with a certain natural brownness which some healthy moths exhibit, and which extends over the whole body; but it is only with highly diseased subjects that these exterior signs become visible, and to find the symptoms of the disease we are often obliged to resort to a microscopical examination of the interior of the insect.

Internal symptoms.—"In the interior of the body microscopic observation reveals the presence of innumerable corpuscles of an ovoid shape (Plate II), filling the cells of the walls of the stomach, those of the silk glands, the muscles, the fatty tissues, the skin, the nerves—in a word, all the portions of the body. There are often so many of them that the cells of the silk glands become swollen and white, and appear to the naked eye to be sprinkled over with chalky spots; the silky liquid always remains exempt from this parasite, but it is much less abundant than when the worm is in a healthy state."*

In 1849, M. Guérin-Méneville first noticed these floating corpuscles in the bodies of the diseased worms. They 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 included in the class *Sporozoa* of the *Protozoa*, and referred by Balbiani to the order *Microsporidiæ*.

These corpuscles are found in the Silk-worm in all its stages—in the egg, larva, chrysalis, and moth. It was for a long time a mooted question as to whether they were the true cause or the mere result of the disease; but the praiseworthy researches of Pasteur have demonstrated that pébrine is entirely dependent upon the presence and multiplication of these corpuscles. The disease is both contagious and infectious, because the corpuscles which have been passed with the excrement or with other secretions of diseased worms may be taken into the alimentary canal of healthy ones when they devour leaves soiled by them, and because it may be inoculated by wounds inflicted by the claws of other worms. The malady may be carried to a distance with the corpusculous dust coming from infected magnaneries, and such dust holds the power of communicating disease from one season to another.

When the "seed" is thus diseased it hatches irregularly and incompletely, and the larvæ often perish before or during the first molt. When the corpuscles are taken into the intestines, as above described, the malady usually becomes apparent, through some of the external symptoms mentioned, at the end of four or five days. M. Pasteur determined that if the worm partook of the soiled food after the fourth molt it would make its cocoon, but that corpuscles would be found in profusion in the chrysalis and moth. If, on the other hand, the worm is thus ex-

* Maillot, *Leçons*, etc., pp. 96, 97.

posed to contagion just before spinning, the chrysalis will show the parasites only during its last days, while they will be abundant in the moth.

From the mother moth the corpuscles pass into the egg and give rise to the diseased "seed" already remarked upon. Disease in the male will not, however, affect its progeny. The egg is formed while the insect is still in the chrysalis state, and it has been ascertained that where the corpuscles become abundant only during the last days of this stage they enter into the seed to a very small degree only, if at all. For this reason eggs are sometimes found to be entirely pure, though the issue of a highly pébrinous parent. The development and multiplication of these corpuscles, though ordinarily very rapid, is insignificant in the egg until the formation of the larva begins. It will be easily understood that, though the parasite may exist in the vitellus of the egg, its detection may be extremely difficult. But when the development of the embryo has commenced, the number of corpuscles grows also, so that just before, or, better still, just after the time of hatching they may be found by hundreds upon a casual observation. Upon a microscopical examination at this time, Vittadini, in 1859, founded his system of selection, examining samples of eggs just at the time of hatching and rejecting those lots which showed the corpuscular disease.

At that epoch it was believed that the corpuscles existed even in the healthy moth when well advanced towards its natural death. But Pasteur showed this theory to be fallacious, proving, as we have said above, that the corpuscle is only present when the moth is diseased. He showed that, where the moth is free from the parasite, the egg, too, would be exempt, and that, as a rule, where the corpuscles exist in the moth, then its issue will probably be corpusculous also. There is, to be sure, even then a chance of its purity, as mentioned above—that is, where the corpuscles become abundant in the chrysalis only after the formation of the egg. But here, too, it is highly probable that the malady will have so affected the general health of the parent as to make her issue more apt to succumb to disease, as in the case of flaccidity. Therefore it is laid down as a rule, and upon this rule the Pasteur system of selection rests, that if, upon microscopical examination of the mother moth, the corpuscles of pébrine are found, then her eggs and issue will also be pébrinous, and should be destroyed.

The details of the Pasteur system of selection will be given in the next chapter.

FLACCIDITY (*flacherie*).

External symptoms.—When, after the worms have passed their fourth molt, and are eating well and regularly, they have all the appearance of perfect health and vigor, and the silk-raiser feels full confidence in the success of his crop, some will often be seen to crawl to the edges of the trays, and lie there languid and without motion. But for the loss of their wonted activity and the cessation of their naturally voracious appetite, one would still think the worms in perfect health, for they yet retain all the outward perfection of form that we have remarked above (Plate I, Fig. G). In color they have, perhaps, become somewhat more rosy, especially if the disease is in a violent form. On touching them, however, we find them soft, and even in this seemingly live condition they are often dead. Had the worms been carefully observed at this time, it would have been seen that the beating of the dorsal vessel was gradually becoming slower, and that it finally stopped altogether. A green drop appears at the mouth and the worm secretes a dirty liquid, which soils the anal orifice and gradually closes it.

Before many hours are passed the skin begins to shrivel and draw in around the fourth and fifth joints of the body, viz: those two lying between the set bearing the legs proper and the set bearing the prolegs (Plate I, Fig. F). Later, at this restricted point, the body begins to turn brown (Plate I, Fig. E), then black, and the whole worm is soon in an advanced state of putrefaction. Then, and even before the death of the worm, a sour odor is perceptible in the magnanerie, due to the fatty volatile acids exuded by the victims to the disease. Should the malady strike the insects at a later period, when they are ready to spin their cocoons, the same languishing air will be observed; they will show a reluctance to crawl up into the arches, and will be seen to gather around their bases, seeking some place which it requires no exertion to attain to spin their cocoons. Many of those which reach the branches stretch themselves out motionless on the twigs and die there. They are to be seen later hanging by their prolegs in different states of putrefaction (Fig. 22). When these symptoms are observed we may be sure that the worms are attacked by flaccidity (*flacherie*).

Fig. 22.—Silk-worms at the spinning period, after death by flaccidity (after Pasteur).

Internal symptoms.—A microscopic examination of the intestines of the sick worm will show masses of undigested food, and the coats of the intestines will be found to be opaque. Here, too, the microscope reveals the parasites ordinarily attending putrefaction, chief among which is a bacillus, seen sometimes with and sometimes without a bright nucleus. There also exists a special form of ferment, not unlike that which accompanies the formation of vinegar (*Mycoderma aceti* Pasteur), which is found in short chains, the links of which are almost spherical

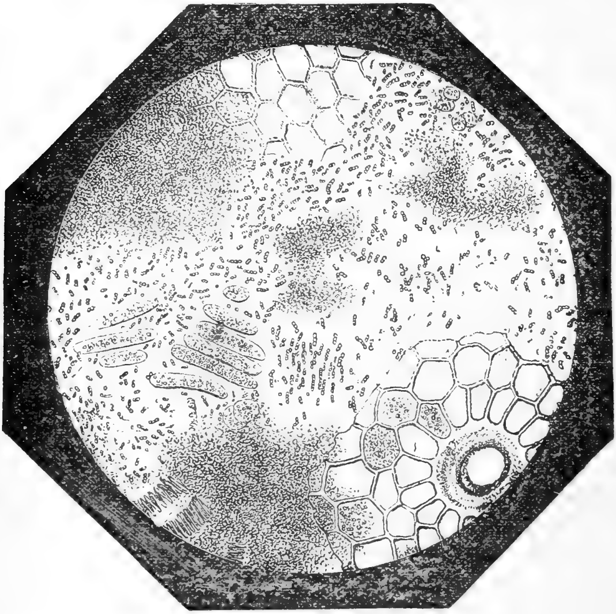

FIG. 23.—Chain ferment, taken from the stomach of a flaccid chrysalis. Magnified 400 times (after Pasteur).

in form (Fig. 23).* These two parasites are sometimes found together and sometimes separately. When the bacillus is abundant death quickly follows its appearance, and the disease, spreading rapidly, will sometimes destroy a whole school in a single day. At times this bacillus appears so short a time before the spinning of the cocoon that the worms are able to mount into the branches, and even make their cocoons and become chrysalides. Then, however, the disease overcomes them, and their putrefaction produces foul cocoons. This case is, however, more rare, and in general the bacillus is not often found in the chrysalis. When the ferment alone appears the disease progresses differently. The worms then show the same languor on the approach of the spinning period, and the same indisposition to make their cocoons; but even then they mount the branches, perform their work of spinning, are transformed into chrysalides, and these into moths which may have a fine appearance. The silk crop may even be exceptionally good; but where this state has existed, when the worm has been without its usual

* The distance from center to center of the links of these chains is about 1 μ (=0.001^{mm}=0.00004 inch).

agility at the spinning time, where it has shown this apparent laziness, then, though the cocoons be of the firmest and the moths the finest, there will exist a weakness, a constitutional debility, that will show itself in the next generation. This is the only way in which flaccidity is hereditary, in this predisposition of the worm to succumb to disease on account of the affection which weakened but which did not kill the parent.

Such are the symptoms attending flaccidity in Silk-worms, and from them M. Pasteur evolved the theory that the disease was caused by the fermentation of the food in the intestinal tube of the larva, which was followed by diarrhea and the closing of the anal orifice, as already mentioned. Confirming this theory of food fermentation is the fact that the same parasite (Fig. 23) which is found in the intestines of flaccid larvæ also exists in a fermented broth of mulberry leaves. Digestion thus arrested, the worm ceases to eat and becomes languid. The gases evolved by the processes described burst the walls of the intestines and cause the death of the victim. Such is the Pasteur theory, followed, as a rule, by the French scientists.

Italians, on the contrary, believe with Verson and Vlacovich, who claim to have observed "that in the flaccid worm the micro-organisms are not at times to be found; that it has been proved that in the beginning there occurs a tumefaction of the membrane of the intestines, and that this membrane, as the disease advances, disappears here and there, and finally altogether. According to them flaccidity consists primarily of a lesion of the membranous walls of the intestines, which would generally be followed by the development and multiplication of the micro-organisms which Pasteur considered the primitive cause of the disease. It is a fact, nevertheless, that all acknowledge, that in most cases flaccidity is accompanied by bacilli and ferments in great numbers in the intestinal tube."*

Flaccidity generally appears after some sudden change in the weather or temperature, as, for instance, a thunder shower, or a hot, heavy day. It is apt, too, to follow the feeding of wet or fermented food. If the shelves go too long without cleaning and begin to mildew; if the worms are too crowded on the table and their natural respiration interfered with, flaccid subjects will soon appear in the school. These, by their unhealthy excrement, soil the food of their neighbors, who quickly follow them in the path of disease. It is thus that flaccidity becomes highly infectious.

No very satisfactory means have been proposed for combating this malady when once it appears. It would be well, on the discovery of the first victims, to take the worms remaining healthy into another apartment and give them more space and plenty of air. Attentive care may then save the crop, though by no means with certainty.

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* Perroncito, *I Parassiti*, p. 35.

To avoid the disease one should carefully follow the fundamental rules already laid down (Chapter IV), though even then circumstances may be against the silk-raiser and the crop be lost through no apparent fault of his.

GRASSERIE.

This disease is of little importance, and has therefore received but little attention from scientists. It is thus described by Maillot:*

"In the middle of a school of worms in good condition it is not rare, as a molt approaches or just before the spinning begins, to find here and there some worms which crawl slowly, and have a shining, stretched, thin skin; the body is of a bright yellow in the yellow, and of a milky white in the white races; a troubled liquid transudes through the skin; soiling the food and the worms over which the diseased subjects pass. * * * A moist, cold, stagnant air seems to favor the occurrence of grasserie. The disease is not contagious, * * * nor does it appear that it can be transmitted by heredity. From this point of view there is nothing to be feared, unless a great number die of the malady, in which case it will be imprudent to use the stock for reproduction."

Victims of this disease should be removed as soon as discovered, as they are apt to crawl into the branches and soil the cocoons spun by other worms.

Prefacing the next chapter we may draw the following conclusions from what has been said: Grasserie is never hereditary, as the victim never dies later than in the chrysalis state, and the disease can never originate in the moth. This is equally true of muscardine, provided the moths be not mingled with worms covered with the spores of the Botrytis. In such a case the moth might also catch the disease and its general debility decrease the vigor of its progeny. Flaccidity is hereditary in an indirect manner, a debility springing from the affection of the parent rendering its issue more apt to succumb to disease. And finally, pébrine is hereditary in its true sense, the corpuscles passing from the mother through the egg to the next generation. In the production of eggs, then, we need look for flaccidity and the pébrine only, the other diseases not entering into the consideration.

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* *Leçons, etc.*, p. 111.

CHAPTER VI.

REPRODUCTION.

It has been said in Chapter IV that the first condition of success in raising Silk-worms is to "procure good eggs." The object of the present chapter is to describe the most approved processes of producing such eggs.

Were it not for the diseases to which the Silk-worm is subject, the old, simple processes of egg production might still be followed, and even now, unless the egg producer is able and ready to undertake the microscopical examination required by the Pasteur system, it is needless to observe the more complex rules for the isolation and examination of the moths.

The simple process formerly employed in all sericultural countries consisted in stringing the cocoons and letting the moths couple, as in the modern process. A sheet was then hung up with the lower edge so turned as to form a trough into which any badly gummed eggs might fall. After uncoupling, the females were placed upon the sheet and permitted to lay their eggs promiscuously. The only precaution taken against disease was in the selection for reproduction of lots of cocoons whose larvæ had shown no signs of any malady, and which were themselves of first quality. From what has been said it will at once be seen that pébrine contracted after the fourth molt and the slow form of flaccidity due to the presence of chain-ferment are not thus guarded against. The modern system has a deeper, more scientific basis, and aims to guard against these.

The Pasteur system of microscopical selection.—As we have seen, pébrine and flaccidity are the only diseases which it is necessary to guard against in selecting eggs. If pébrine or flaccidity have appeared in a positive form in the larvæ, either through the external or internal symptoms described in the last chapter, no further examination need be resorted to, as the stock will evidently be unfit for reproduction. The most important and positive sign of the latter disease to be looked for is languor at the spinning time. If a greater degree of certainty is desired, or if the egg-producer has not had the opportunity of observing the rearing of the worms, a miscroscopical examination of the chrysalis may be resorted to. In flaccidity this examination should be confined to the stomach, where the chain-ferment to be sought for is more easily found. M. Pasteur gives the following directions for extracting this organ:

"Cut away the walls of the thorax of the chrysalis with fine scissors, after the manner shown in Fig. 24, so as to reveal the stomach *s*. Draw this out with a pair of tweezers. The restricted part of the digestive tube, which unites the stomach with the urinal sack *u*, should then be cut. The anterior part of the digestive tube now alone holds the stomach in place, and this easily gives way. Lay the small ball thus withdrawn on a glass slide and scratch away the very soft, fatty envelope which covers the interior. Of this interior substance take a piece as big as the head of a pin, wash it with a drop of distilled water, and, placing it upon a slide with a cover glass over it, examine it with a microscope magnifying about four hundred diameters. With a little experience this work may be done very rapidly. It would be well to take out at the same time the stomachs of, say, twenty chrysalides, and lay them on as many glass slides. * * *

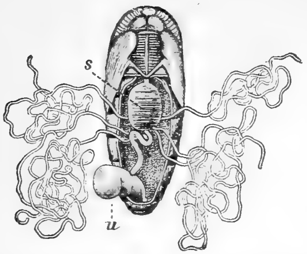

FIG. 24.—Anatomy of the chrysalis, showing method of extracting the stomach (after Pasteur).

"The first few days after the formation of the chrysalis the contents of the stomach are generally very liquid, which makes their extraction inconvenient. It is better to make these observations seven or eight days after the spinning begins, when the matter will be found to have more consistence. * * * Fig. 23, page 38, shows the appearance of the ferment found in flaccid chrysalides under a magnifying power of 400 diameters. It is associated with the débris of leaves, morsels of the trachea, and chlorophyl cells. These matters ordinarily accompany the little ferment in the stomach of the chrysalis, because of the incomplete digestion of the leaf whenever it is submitted to fermentation."*

No parasite indicative of flaccidity has been discovered other than this ferment, which is not found in the adult insect; and if the transformation into the moth is permitted, all opportunity will be lost for detecting the disease.

In pébrine, on the contrary, the corpuscle is found in the moth as well as in the chrysalis. We might, therefore, wait for a final examination of the moth to be made after oviposition. But, in case disease is then found, it will be too late to stifle the cocoons, and the emergence of the moths will have ruined them for certain commercial purposes. For this reason it is important to detect the disease, if it exists, at as early a stage of the work as possible. If the larvæ have shown no external signs of the pébrine, it would be well to microscopically examine a few of the last worms to spin. The corpuscles will be found in these laggards, if anywhere.

Isolation and examination of the moths.—If left to themselves the insects remain in the chrysalis state for from two to three weeks in our ordi-

* Pasteur, *Études*, etc., Vol. I, p. 233.

nary summer weather. Their development may, however, be hastened or retarded by increasing or lowering the temperature. This fact is taken advantage of to obtain a few adult insects which may be microscopically examined before the whole lot becomes fully developed.

I was very much pleased with the method employed by M. Maillot, which I had an opportunity of examining at Montpelier, in 1884, and I here give a description of it in his own words:

"Three or four days before the cocoons are taken from the branches we take, here and there, from the early spinners as well as the late, several hundred cocoons; as, for example, five hundred from a lot of 90 pounds. This sample should be placed in an oven or warm room, where it will be kept day and night at a temperature of from 100° to 110° Fah., and a high degree of humidity. In this way the formation of the moth is hastened. As during this time the cocoons of the lot itself remain at a temperature of from 75° to 90°, and often during the night at even lower temperatures, we shall still have time to stifle them if the lot is discarded, or to string them into chains if, on the contrary, it proves healthy.

"Every two days we take ten chrysalides from the sample and examine them microscopically for corpuscles. If we find them in the first eight or ten days, no matter in how small quantities, we can be sure that the proportion of pebrinous moths will be considerable. When the chrysalides are mature, which is easily seen by their eyes becoming black and the eggs harder to break under the pestle, and also by some of them turning into moths, we proceed to the definite examination. We crush one by one the moths which have come out and the chrysalides which remain and search for corpuscles; the per cent. which is thus found will not differ materially from that which exists in the whole lot."*

The examination of the chrysalides here mentioned may be made in the manner already described when searching for the ferment of flaccidity and at the same time. But if we are looking for the pébrine only we need simply crush the whole chrysalis in the manner hereafter described for the moth.

Proceeding now with stock of which the purity has been ascertained by one or more of the different methods of observation above described, 200 cocoons should be selected for each ounce of eggs that it is desired to produce. In making this selection great care should be exercised in taking only cocoons that are fine in texture and firmly made. This fineness is one of the prerequisites of a first-class cocoon. What is meant by this difference in texture will be seen by an examination of Figs. 2 and 3, page 14, the former being fine and the latter coarse. The firmness of the cocoon, depending as it does on the amount of silk which it contains, is an indication of the vigor of the worm, and another item to be considered in selecting stock for reproduction. Rules have been

*Maillot, *Leçons*, etc., p. 250.

given for the determination of the sex of the inclosed insect, and among them, perhaps the most common, is the assertion that those that are constricted in the middle (Fig. 2) contain males, while those not constricted (Fig. 3) contain females. This, however, may be regarded as an indication rather than a fixed rule, and there are races in which the cocoon is almost uniformly constricted and others where the reverse is true. But this careful selection for sex is comparatively unimportant, and we consider it wiser to choose the cocoons in relation to their firmness and texture, and trust to chance to bring as many male moths as female. Double cocoons, where two worms have spun together, should never be used in egg-making.

The proper cocoons having thus been selected, they should be strung upon stout threads about 3 feet long. Care should be taken not to prick the chrysalides with the needle while passing it through the end of the cocoon in making the chains. These chains should then be hung in a cool, darkened room while waiting for the moths to emerge. They should not be placed near any object which would be soiled by the secretions emitted by the moths on their emergence from their cocoons.

Previous to this emergence there should be prepared for each ounce of eggs to be produced about one hundred small bags of fine muslin (cheese cloth makes a good material), made in the following manner: Cut the cloth in pieces 3 by 6 inches, then fold one end over so as to leave a single edge of about three-quarters of an inch, as shown in Fig.

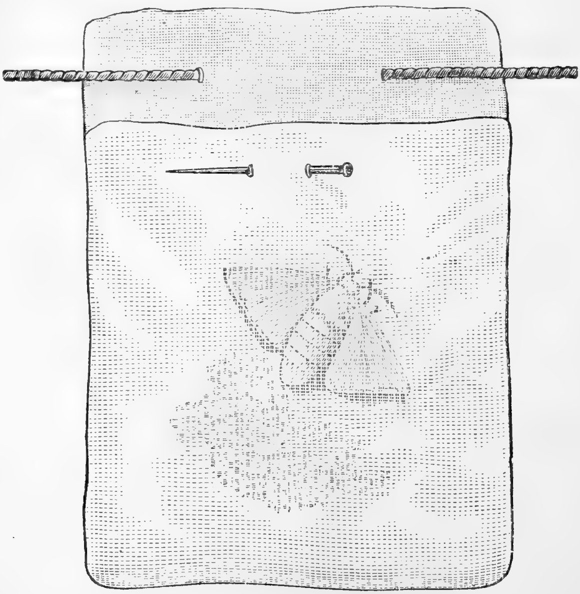

FIG. 25.—Cell used in the Pasteur system of egg-laying (after Roman).

25. This should be sewn up into a bag with the upper end open, and then turned inside out so that the seams will cause the sides to bulge. Thus completed they are called "cells." The cells should be strung

on a cord stretched across the room. Some trouble having been experienced in keeping the moth from crawling out of the cell at either side of the pin, which is the method of closing it shown in the cut, the scheme shown in Fig. 26 was adopted last year in the Department.

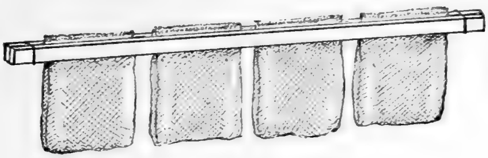

FIG. 26.—Method of clamping cells (original).

This consists in clamping the bags in fours between two sticks of wood, rough sawn, about one-half by one-quarter inch through and 14 inches long. They are bound together by rubber bands and may be laid across parallel wires stretched across the room at about 13 inches apart. M. Pasteur suggests that a simple piece of cloth about four inches square be used instead of the sack. The moth lays her eggs on this and is then retained by being fastened to the cloth, the corner of which is turned up over her and a pin passed through it and over her wings (Fig. 27).

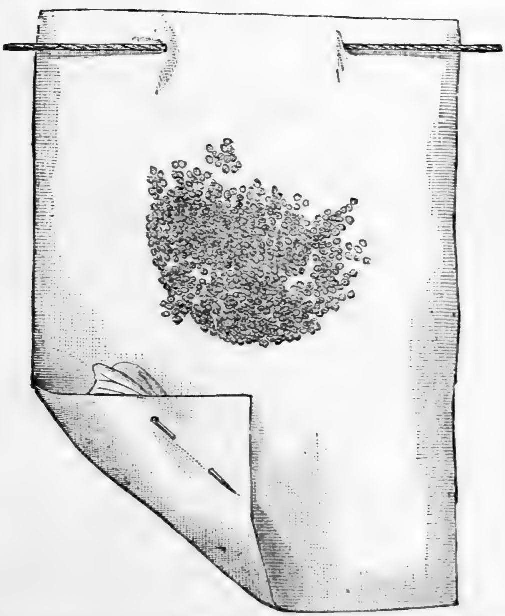

FIG. 27.—Cell used in the Pasteur system of egg-laying (after Pasteur).

Some trouble has been experienced by this process, as the eggs, if not properly gummed to the cloth, will sometimes fall off and be lost, and the moths, not being confined as in the sacks, will wander to other cloths and get their eggs mixed with those of other moths, which would be detrimental to the microscopical selection to be hereafter described. It has the advantage, however, of enabling the microscopist to avoid the labor of turning the sacks.

The moths emerge from the cocoons, as a rule, from 5 to 8 o'clock in the morning. At the latter hour many of them will be found coupled and clinging to the chains. These should be carefully taken by the wings and placed upon a table by themselves, the single moths being placed upon another table where they will couple if the sexes are evenly divided. They should then be transferred to the first table as the fluttering of the male moths is apt to disturb the couples. These should be left together until 4 or 5 o'clock in the afternoon, when they may be separated by drawing them gently apart by the wings. The females should then be placed in the cells or upon the cloths already described, where they will at once commence their egg-laying, completing it in about thirty-six hours. Most of the males may then be thrown away, though it may be wise to keep a few of the more active ones to compensate for any superabundance of females in the issue of the following day. But little difficulty will be encountered in distinguishing the sexes, the males being noticeable by their smaller abdomens, more robust antennæ, and by their greater activity.

When the eggs have been laid, the microscopical examination of the moths should be made with a view to ascertaining whether or no they are afflicted with pébrine. The entire moth should be ground up with a few drops of distilled water* in a small glass mortar (1 ounce is a convenient size). A drop of this water is then taken with a medicine dropper and placed upon a glass slide with a cover glass over it. It is then microscopically examined with a power greater than three hundred diameters. Plate II shows a field very highly charged with the corpuscles of pébrine. When the moths are not examined until some time has elapsed after their death, they will be found to contain other germs peculiar to putrefaction. These do not indicate any disease that would affect the egg or its issue; nor does their presence imply any lack of vigor in the parents. They are simply post-mortem parasites. Great care should be taken in cleansing the mortar, pestle, and other implements before making an examination, by washing them in an abundance of water and rinsing them thoroughly with distilled water. In making the above examination only the corpuscles of pébrine need be looked for. The bacilli and the ferments of flaccidity are rarely found in the moth.

* The amount remaining in the mortar after rinsing is sufficient.

CHAPTER VII.

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 following apparatus has been used by Mr. Walker at the Department:

It consists of a tin reservoir, about one-third filled with water. Slightly above the surface of the water is a movable perforated partition, B, intended to prevent spattering during ebullition. The upper portion contains a perforated pan for holding the cocoons, while all is tightly closed by a cover. Cocoons may be thoroughly stifled by exposure in this apparatus, over boiling water, for twenty minutes. It will be seen, too, that much the same apparatus may be contrived by the use of a deep kettle, into which is set an ordinary colander full of cocoons. It is well to avoid, however, so filling the kettle with water that it will splash upon the cocoons in boiling, as they should only be subjected to the action of steam. The apparatus is 12 inches in diameter and 13 inches deep, and will stifle from 3 to 4 pounds of cocoons at a time.

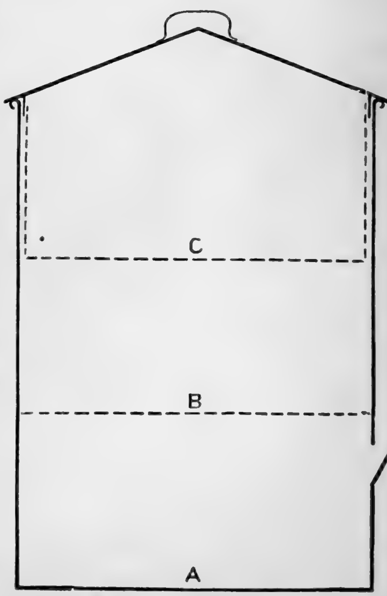

FIG. 28.—Simple stiffling apparatus.

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 chrysalides are all dead. Where the choking is well done there is little loss, only about 1 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 stirring, the chrysalides 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. Two or three days of such exposure are sufficient. But, as strong wind may 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 the chrysalis most surely. The glass cover should be slightly raised to permit the escape of the excessive moisture which evaporates from the cocoons, and care should be had to keep out the ants.

CHAPTER VIII.

SILK-REELING.

Spun, reeled, and thrown Silk.—From the cocoon the silk is by different processes transformed into spun or reeled silk. The former is generally made from pierced cocoons or silk waste, and serves in the manufacture of inferior classes of tissues. The method of manufacture consists in cleaning and macerating the raw material, after which it is carded and made into thread somewhat after the manner of cotton. The process of producing reeled silk, which will be hereafter treated at length, consists, in general, of softening the gluten of the cocoons in hot water and then taking the ends of the constituent threads of several of them together and winding these threads from the cocoons upon a reel.

By virtue of the next process of manufacture to which this material is submitted it becomes *thrown silk*. Thrown silk is classified as organzine and tram. It is made either from spun or reeled silk. Tram consists of two or three threads of reeled (or spun) silk twisted together at about 75 to 100 turns per running meter (67.5 to 90 per yard). It is used in making the warp in weaving. Organzine, used in the woof, is produced by twisting two threads together at about 500 to 600 turns per running meter, and then taking two of the threads thus made and twisting them together in the opposite direction at about 400 to 500 turns. It is, in the language of the trade expression, "cable laid."

It is the object of this work to deal only with one of these classes; that is to say, reeled, or, as it is commonly called, raw silk. Although the former name indicates more exactly than the latter the processes to which the raw material has been previously submitted, yet the term "raw silk" has acquired a special meaning by trade usage and applies only to reeled silk.

The process of Silk-reeling.—The cocoons should have been roughly sorted before they were spread out in the cocoonery, the double and feeble specimens having been laid aside. They should now be sorted so that cocoons of the same color and shade may be reeled together, for the use even of cocoons of the same color but of different shades will give a streaked skein of silk. They should, too, be sorted as to their texture. Those of fine texture, among ordinary cocoons, are considered first choice and are used to produce the finest qualities of raw silk. They are more easily unwound than those of coarser texture which are called satiny cocoons. This satinage appears to be due to the fact that the successive layers of the cocoon are insufficiently gummed together. As a result the water penetrates quickly into its center while it is being reeled and causes it to sink to the bottom of the basin, which interferes with the process of unwinding. Towards the end a satiny cocoon comes off in flocks, making a dirty silk.

A comparison of the cocoons shown in the cuts on page 14 may convey an idea of the difference of texture mentioned, Fig. 2 being fine, and Fig. 3 of coarse grain. In addition to the above features some regard must be paid to the reeling of cocoons of the same size together. An extended experience is needed to make a rapid cocoon-sorter, and it is work that should be followed without intermission, that the knack necessary to quickness may not be lost.

The process of reeling cocoons, while extremely simple, is still one that requires an amount of skill to acquire which the experience of several months is necessary. The cocoons are first plunged into boiling water, whereby their gluten is softened in such a manner as to render the unwinding of the filaments an easy matter. This done, they are brushed with a small broom, to the straws of which their fibers become attached. The bundle of filaments is then taken and they are unwound until each cocoon shows but one clean thread. These three operations are called "cooking," "brushing," and "cleansing." All of these operations can be accomplished mechanically.

The elements of the mechanism of all modern silk-reels are essentially the same. They are shown in Fig. 29, and consist, in general, of a basin,

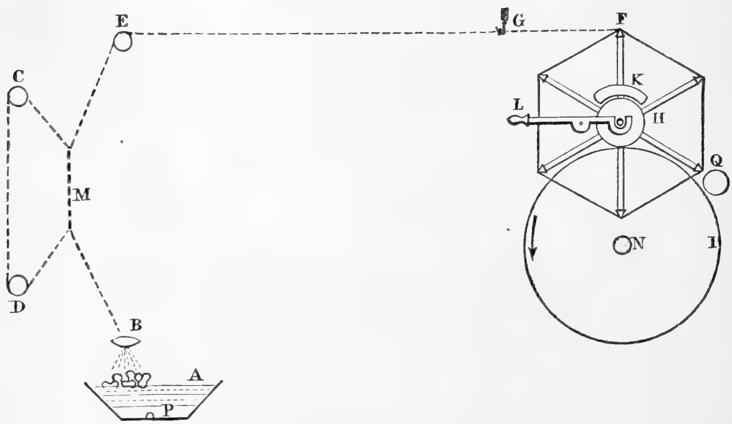

FIG. 29.—Elements of the mechanism of a modern silk reel (original).

A, in which is a perforated steam-pipe, *P*, by means of which the water in the basin may be heated. A few inches above the surface of the water is placed a perforated agate, *B*. The cocoons having undergone the three operations mentioned, the ends of the filaments of four or more of them are twisted together into a thread, which is passed through the hole in the agate. From this it runs through the "croisure" *M*, which will be hereafter explained, and over the guide *E* to the reel at *F*. Between *E* and *F* the thread passes a guide, *G*, moving to and fro (in a line perpendicular to the plane of the paper), which distributes it in a broad band over the surface of the reel. This facilitates the drying of the silk, without which the gluten would bind together the threads of the skein as it does those of the cocoons, and thus ruin its commercial value. In winter it is often necessary to use supplementary means to effect this drying. Perhaps one of the best is by passing a large steam-pipe near the reel, as at *Q*. The shaft of the reel carries at one end a friction-wheel, *H*, which rests on the large friction-wheel *I* that constantly revolves on the shaft *N*, and thus motion is imparted to the reel. In order to stop the reel it is only necessary to raise the wheel *H* from its bearings by means of the lever *L*. This movement presses the wheel against the brake-shoe *K*, and its motion is at once arrested.

As has been said above, the thread is passed between the agate and the reel through the croisure. The making of the croisure consists in twisting the thread around itself or another thread so as to consolidate its constituent filaments and wring the water from it and thus aid in its drying. The mode of the formation of this croisure forms the principal distinguishing mark between the French and Italian systems of reeling. The former is called the "Chambon system." Each reeler manages two threads. These are passed through separate agates, and after being brought together and twisted twenty or thirty times around each other are again separated and passed through guiding eyes to the reel. The other system, called "tavellette,"* consists in passing the thread up over a small pulley *C*, down over another *D*, and then twisting it around itself, as shown at *M*, in Fig. 29, and thence to the reel.

The cocoon filament is somewhat finer in the floss or beginning, thickens at the point of forming the more compact pod, and then very gradually diminishes in diameter until it becomes so fine as to be incapable of standing the strain of reeling. Therefore a thread which is made up of five new filaments becomes so small when the cocoons from which it is drawn are half unwound as to require an addition. This addition might also be made necessary by the rupture of one of the constituent filaments. It is here that the skill of the operator is called into play. When her experience tells her that the thread needs nourishing from either of these causes she takes the end of the filament of one of the cocoons which lie prepared in her basin, and, giving it a slight snap or whiplash movement with the index finger, causes it to wind around or adhere to the running thread of which it from this moment becomes a constituent part. This lancing, as it is called, of the end of the filament, although in hand reeling performed in the manner described, is also accomplished mechanically, several devices having been invented for this purpose.

*The trade name of the small pulley mentioned.

They consist, in general, of a mechanism which causes a small hook to revolve in a horizontal plane about the running thread, and to twist around it any end of the filament that may be placed in the path of the hook. The reeler, seeing that a new filament is needed, holds the end of one in the way of the attaching device and it is automatically caught.

The temperature of the water used while reeling the cocoons varies from 140° to 175° F. The more cocoons have been cooked the lower will be the temperature required. It is customary, however, to work in the neighborhood of the maximum limit. 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.

It is highly important that the silk be kept as clean as possible. It lacks cleanness when the filament ends are badly attached in lancing, when the figure 8 loops, of which the cocoon is composed, come off one or more at a time instead of unwinding continuously, or when the thread after breaking is not neatly knotted. All these faults show in weaving and injure the value of the silk.

According to Dandolo the fresh cocoons consist, by weight, of:

	Per cent.
Chrysalides	84.20
Castings	0.45
Silken pods	15.35

It is from this 15.35 per cent. that the reeler draws her silken thread. But a large proportion of even this is lost, so that there is recovered but 8, 9, or rarely 10 per cent. of the original weight of the cocoons. From this it will be seen that it takes from 10 to 12½ pounds of fresh cocoons, or 3⅓ to 4⅙ pounds of dry ones to make a pound of silk. A more usual working average, with good stock, is in the neighborhood of 3¾ pounds of dry cocoons per pound of silk. If cocoons are of poorer quality they necessarily produce less silk and their commercial value falls off in far greater proportion than their power of silk production.

CHAPTER IX.

PHYSICAL PROPERTIES OF REELED SILK.

Certain physical properties are of great importance in determining the commercial value of reeled silk. They are its cleanliness, already mentioned; its mean size; the irregularities in its size; its ductility, or, as it is wrongfully but universally called, its elasticity; its tenacity, and the amount of soluble gum which it contains.

The mean size of a skein is determined in the following manner: One thousand yards of the thread is wound off on a reel, supplied with a counter called an *éprouvette*, and made into a little skein termed an *échevette*. This échevette is then weighed and the number of sixty-fourths of a dram which it is found to equal becomes the size number of the thread. This process is called the sizing, or, colloquially, the "dramming" of silk.

In Europe the same system is employed, but the units are a length of 476 meters (400 old French ells) and a small weight called the *denier*. One dram silk in America is equivalent to a thread of 17⅓ deniers in France.

Until recently there has been no means of determining the irregularities in size existing in a silken thread, but manufacturers were content to approximate it by weighing four échevettes per sample skein. The difficulty in making this determination is owing to the fact that the thread is not round, but flattened, being, in fact, in its simple state, two filaments joined into one, and when several of these naturally compound filaments are combined to make a commercial thread the matter becomes still more difficult. Mr. E. W. Serrell, jr., of New York, has, however, overcome these obstacles by relying on another property of a silk filament, which is, that the distance which a given length will stretch under a given tension is inversely proportionate to the mean cross-section of this length. This is the underlying principle of his serigraph, which will now be described. The mode of testing with this machine is as follows: The end of the thread is brought from the reel or bobbin on which it is wound, around a drum (Fig. 30 *A*), thence over

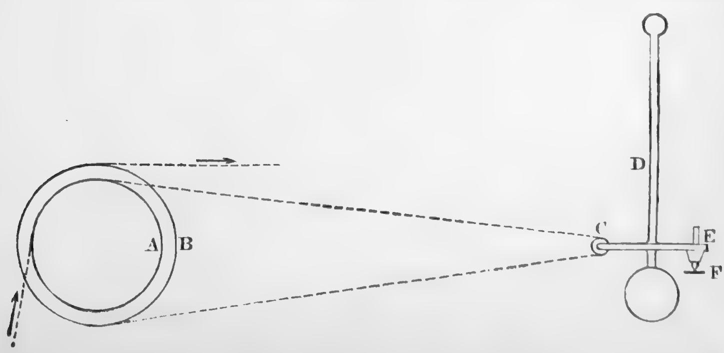

Fig. 30.—The principle of the Serigraph (original).

a pulley, *C*, and back around another drum, *B*, mounted on the same axis as *A*. From the drum *B* it is wound on a reel. The drum *B* is larger than *A*, so that the former winds on the thread somewhat faster than it is paid off by the latter. In thus stretching the thread we apply a force to the pulley *C* tending to draw it from its normal position. This pulley is attached to the base of a pendulum, *D*, which, under the action of the force mentioned, is drawn from the perpendicular. The weight of this pendulum overcoming this applied force to an extent inversely proportional to the mean section of the length of thread submitted to the test, the position of equilibrium taken by the pendulum depends upon that mean section. This length of thread is the piece between the two drums *A* and *B*, and as, through the constant action of the machine, successive lengths of thread occupy the position indicated, the pendulum oscillates through a course which depends upon the irregularities of the thread. These irregularities are graphically recorded by a pencil, *E*, attached to the pendulum, upon a band of paper, *F*, constantly moving under its point. In the commercial form of the machine the mechanism for driving the reel is so constructed as to stop automatically when a standard échevette has been wound upon it, and this échevette may then be sized in the manner above described.

The elasticity and the tenacity of raw silk are determined by the use of the serimeter. This machine is composed of a dynamometer above, a graduated circle indicating the tension corresponding to the point at which the index stops. On the lower extremity of this dynamometer is a knob to which the thread to be tested may be attached. At 50 centimeters below this knob, in the same vertical line, is another knob attached to a counterweight which is on the inside of the case of the instrument and which also bears a pointer moving along a graduated scale on the outside of the case. This weight is held in place by a detent which is terminated on the outside of the case by a faller, on which it is only necessary to press lightly to cause the detent to let go the counterweight and permit its index to slide along the scale; these stop instantly, on the other hand, when the faller is released and retakes its initial position.

The silk thread attached to the two knobs mentioned passes over this faller, and, as it tends to pull it from its normal position, the detent lets go the counterweight and the thread stretches until rupture takes place, when the descent of the counterweight is automatically stopped. It is then only necessary to read the indication of the dynamometer to ascertain the weight which caused the rupture. By doubling the distance passed over by the sliding index, we have the stretch per meter or per cent. of elasticity.

The elasticity or ductility of silk is about 15 to 20 per cent., being nearly four times superior to that of cotton. It is about the same as brass and slightly greater than iron; hair has only half the ductility of silk.

"The tenacity of silk thread is well known; a thread of raw silk of 10 deniers easily supports a weight of 50 grams* without breaking. Direct relations exist between the tenacity of silk, the country in which it originates, its hygrometric state, the processes by which it was reeled, etc. Relations not less interesting may be found between the elasticity and the ductility." †

In the silk which constitutes the cocoon as made by the worm we find three classes of material. They consist of a waxy substance soluble in boiling water, of a gluten soluble in certain acids and alkalies, and especially in a solution of soap, and of the fibrine which constitutes the base of the thread. In the yellow silks there is also a slight quantity of coloring matter. Robinet found from 4 to 5 per cent. of the waxy substance, which, being soluble in boiling water, disappears in the process of reeling. We therefore find in reeled silk the gluten, or, as it is technically called, *grès*, and the fibrine. Before this silk can be properly dyed it is essential that a certain portion of this gluten be removed. This operation is usually performed by boiling it in a solution of soap. At the Conditioning Works at Lyons, France, this boiling off, as it is called, consists of two operations. The silk is first submitted for thirty minutes to ebullition in a solution containing an amount of soap equal in weight to about 25 per cent. of the weight of the silk boiled off. This silk is then wrung, in order to free it from the soap and the dissolved gluten, and then resubmitted to the same operation of boiling. As a result of these tests, it is found that white French silks contain 19.68 per cent. of gluten and the yellow silks 22.84 per cent. Silks coming from Italian filatures contain an amount of gluten slightly in excess of these figures, while the Chinese silks exceed them by more than 2 per cent.

The silk thread is highly hygrometric, containing under ordinary conditions 10 to 12 per cent. of water, while a thread of raw silk is capable of absorbing 21 to 26 per cent. Humidity augments the ductility of silk and slightly diminishes its tenacity.

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* 100,000 times the weight of a piece 50 centimeters long.

† Adrien Perret, "*Monographie de la Condition des Soies de Lyon.*"

CHAPTER X.

FOOD-PLANTS.

The traditional food-plant of the Silk-worm 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 Silk-worm 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 kinds which are most used are the Black (*M. nigra*) and the different varieties of the White (*M. alba*). The first is inferior to the others as Silk-worm food.

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.

The *rosea*, *japonica*, and the *multicaulis*, varieties of the same species, are also used with excellent success.

A species of Mulberry new to this country has lately been introduced into the Western States by the Mennonites. This is the Russian Mulberry (*M. tartarica*). It is very hardy and its leaves make excellent Silk-worm food.*

The Mulberry grows readily, being easily propagated by cuttings or layers or from the seed. The white Mulberry, in particular, grows well

*A tree of a genus allied to the Morus is the *Broussonetia papyrifera*, commonly called the Paper Mulberry. It is found quite generally throughout the South, but its foliage is *not* suitable for Silk-worm food. The Paper Mulberry is usually a some what larger tree than the Mulberry and its leaves are subject to a considerable diversity of form, being mainly ovate and toothed on the margin; frequently with lobes on one or both sides of the leaf. They are quite rough to the touch on the upper surface, much more so than the Mulberry, and on the under surface they are softly hairy. The trees are of two kinds, male and female. The male tree, early in the spring before its leaves are developed, has tassels something like those of the willow. They soon drop off after shedding pollen. The female flowers then go on developing during the summer until they make small round balls from which, when ripe, the seeds stand out. These seeds are covered with a gummy substance and are very small, being about the size of those of the raspberry. The female trees are little known in this country, as only the male trees have been introduced into the United States.

I refer to this tree because of the frequency with which inquiries are made by Southern correspondents as to whether the Paper Mulberry can be used as Silk-worm food. The tree is very generally used for shade and ornament in Southern cities, where it attracts attention by the gnarled and knotted character of its trunk.

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 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.

It must not be forgotten that in the propagation of plants only true species can be reproduced from the seed. The varieties of the White Mulberry mentioned above can only be obtained from cuttings or layers.

The fresh mulberry leaf contains a large amount of water of vegetation, and of certain mineral and organic matters. Of water, it is only necessary that there should be sufficient to enable the worm to easily digest its food, and all that is in excess of this quantity is apt to be injurious and productive of disease. In order to avoid this difficulty, food-trees should be planted in a light loam, and especial care taken to prevent excessive irrigation. It has been found, too, to be important that the tree should be so planted as to receive as much sunlight as possible, experiments having shown that, other conditions being equal, the leaves of such a tree contained but 55 per cent. of water, while in the case of one lighted by the sun until 1 o'clock only there was 64 per cent., and in one which received only diffused light, 73 per cent.

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* The better plan is to have two sets of trees, using each set but once in two years. When pruned a tree is then allowed to grow for one year without touching its leaves, which are only picked for the second season. The life of the tree will thus be materially prolonged, and the crop of leaves be more abundant than with annual pickings.

Of the mineral matter contained in the leaf, only certain portions are appropriated by the worm; these are phosphoric and sulphuric acid, potash, and magnesia. Its silica and sulphate and carbonate of lime are not useful in nutrition. In studying the leaf of the Mulberry at different seasons it is found that early in the spring certain varieties possess these nutritive mineral substances to a greater extent than others, but that as the season advances they become less abundant, while the proportion of silica and lime increases. It is important, then, if from this point of view only, that we should rear our Silk-worms as early in the season as possible. A great many experimenters have occupied themselves with the value of the different varieties of Mulberry with a view to ascertaining which would give the best alimentary results under ordinary conditions. As a result, it is generally advised that the seedling White Mulberry be fed at the beginning of an education and the *rosea* during the later ages. The *multicaulis* possesses many of the advantages of these varieties, though less rich in nutritive elements than either of them.

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 Silk-worm 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 other diseases.

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 Silk-worms on this plant; and if care be had in this respect, and the same judgment used in selecting from trees or hedges well exposed to sunlight, as suggested for Mulberry, there will be no appreciable difference in the silk crop from Osage Orange as compared with that from Mulberry.

The thorns of this plant make it somewhat more difficult to pick its leaves than those of the Mulberry, and I should not advise its cultivation merely as Silk-worm food.

What is said of the Osage Orange is based upon a very extended experience, and I would not only emphasize the fact of the value of this plant, but also of the necessity of the careful selection of Maclura leaves, especially during the last two ages of the worm. I have found that after the third age time is saved by using the twigs, first taking care to clip off the spines, which is rapidly done by means of a pair of scissors. In using twigs instead of leaves, the tender tips of the current year's growth should be cut off with the spines. I have found this method of feeding to have decided advantages (though contrary to all custom in Europe, where the twigs and branches of the Mulberry are too valuable to be constantly pruned), for it not only allows more air to circulate as the food accumulates, but it gives the worms, as they grow in size, an opportunity of clambering about, which they do not have to the same extent where leaves alone are used. In adding the new meal there is, also, where twigs are used, less danger of the transfer paper pressing injuriously upon the worms beneath.

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 hatching and first molt, between any two molts, or between the last larval molt and spinning.

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.

Bacillus: A microscopical vegetable organism, often causing disease.

Bivoltins: Those races producing two broods in one year.

Bombycidæ: The family of moths, commonly known as "spinners," to which the Silk-worm 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.

Chlorophyl: The green coloring matter of leaves.

Chrysalis: The third or restful state of the insect, or that between the worm and the moth, inclosed 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 where cocoons are dried after being choked.

Corpuscle: A microscopic parasitic organism causing the disease, pébrine.

Croisure: The twist to which the silk thread is submitted in reeling.

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

Detent: A stop which locks and unlocks the wheels in clock-work.

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

Échevette: A small skein of silk of a determined length, the weight of which determines its size number.

Epizootic: A term having the same significance with lower animals as epidemic with man.

Éprouvette: A reel supplied with a counter upon which échevettes are measured.

Faller: A small lever, over which a thread runs, and which, upon the breaking of the thread, falls, thus stopping the mechanism through the action of a detent to which it is attached,

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

Ferment: Micro-organism causing fermentation.

Fibrine: An organic compound forming the base of the silk filament.

Filature: The French name for reeling establishment.

Flaccidity: A Silk-worm disease characterized in the text, Chapter V.

Flacherie: The French name for flaccidity.

Floss silk: Silk made from the loose material of the outer cocoon and from pierced cocoons, etc. It is carded and spun like cotton or wool.

Fresh cocoons: Cocoons that have not been choked.

Gattine: An old name for a mild phase of the disease known as pébrine. Maillot thinks that it is a form of flaccidity.

Grasserie: A Silk-worm disease allied to jaundice. It is described in Chapter V.

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.

Japonica: A variety of the White Mulberry.

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

Larva: The second or worm state of the insect.

Lepidoptera: Name of the order to which the Silk-worm belongs.

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

Magnanerie: The name applied to the room or building used for the rearing of worms.

Micropyle: The opening in the egg of the Silk-worm moth through which the fecundating liquid enters.

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

Mori: The scientific specific name for the Silk-worm.

Morus: The botanical generic name of the Mulberry.

Multicaulis: A variety of the White Mulberry.

Muscardine: A Silk-worm disease of a fungus nature, characterized in the text, Chapter V.

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

Organzine: Highly twisted thrown silk used in the woof in weaving.

Ovipositing: Laying the eggs.

Pébrine: A Silk-worm disease characterized in the text, Chapter V.

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: Scientific name for the floating corpuscles in the bodies of worms affected by pébrine.

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

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

Rosea: A variety of the White Mulberry.

Seed: The eggs in bulk.

Sericaria: A generic name proposed by Latreille, and to which the Silk-worm 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.

Tavellette: A small pulley used in the Italian system of reeling.

Thrown silk: Silk which has been submitted to the operations following spinning or reeling. It is classed as tram and organzine.

Trachea: The breathing-tube of an insect.

Tram: Slightly twisted thrown silk used in the warp in weaving.

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

Trevoltins: Those races of Silk-worms of which there are three broods in one year.

Vitellus: The yolk of an egg.

Whites: Those varieties having white cocoons.

Yellows: Those varieties having yellow cocoons.

EXPLANATION TO PLATES.

PLATE I.

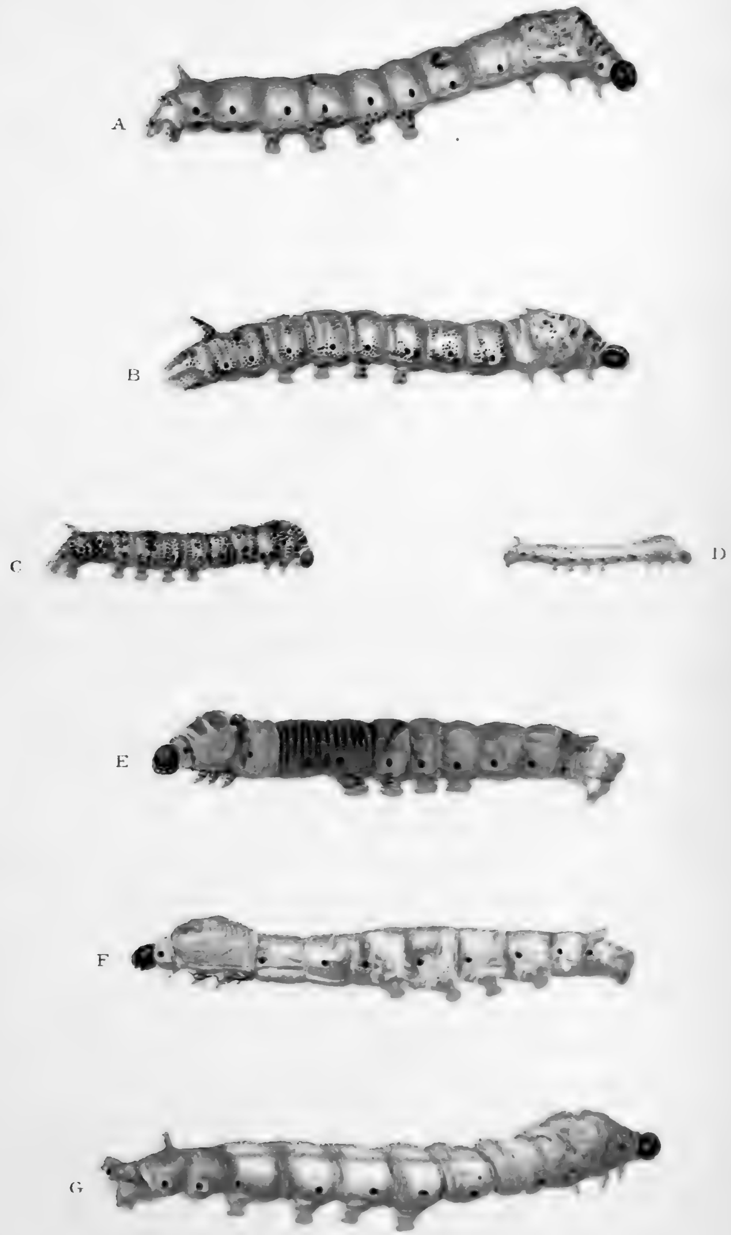
SILK-WORMS AFFECTED BY PÉBRINE AND FLACCIDITY (AFTER PASTEUR).

A, B, C, D, Silk-worms affected with pébrine, showing the spots of the disease. On the eighth joint of the worm A will be seen a wound which is distinguishable by its clear-cut edges.

E, F, G, worms, after death from flaccidity. G shows the worm just after death, still retaining all of its outward perfection of form. At F the worm has begun to shrivel, while at E the blackening caused by putrefaction is shown.

PLATE II.

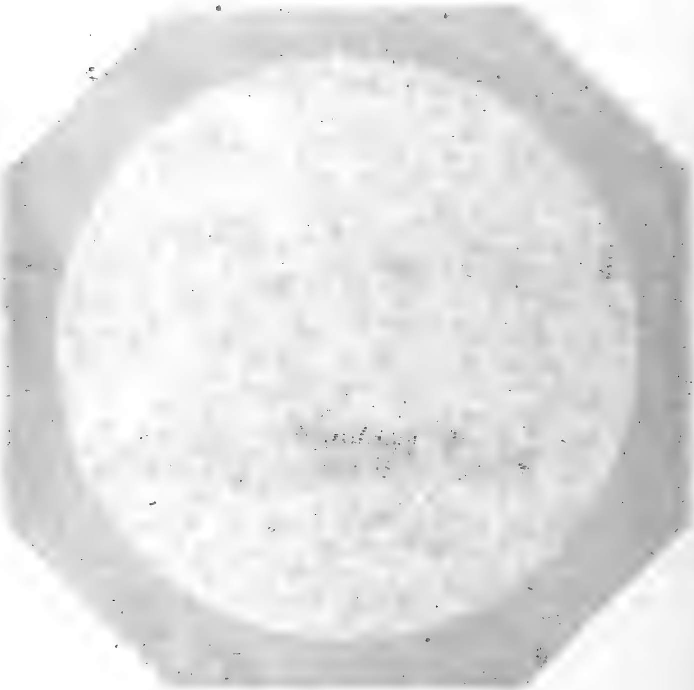
PÉBRINE CORPUSCLES OF SILK-WORM MOTH HIGHLY MAGNIFIED (AFTER PASTEUR).
(The white ovoid bodies are these corpuscles.)

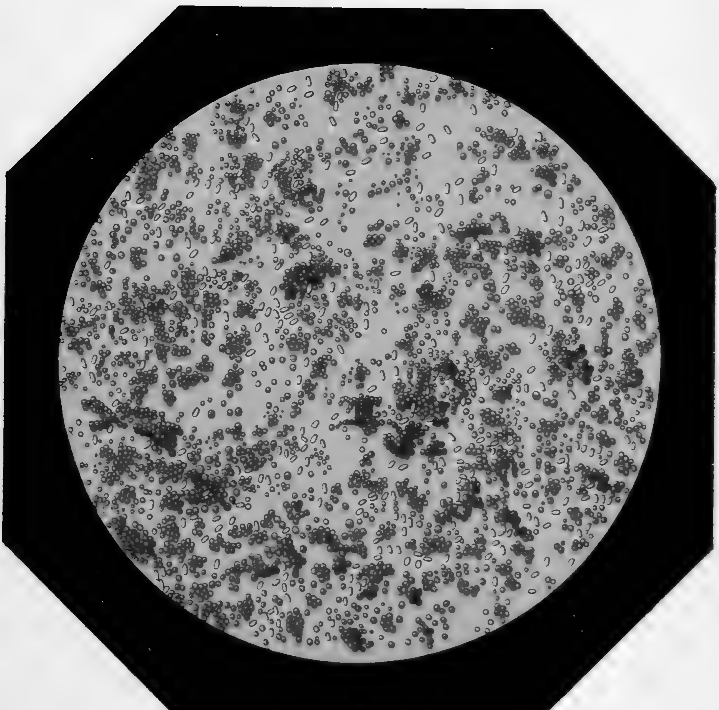


A Hoen & Co. Lith. Baltimore

SILKWORMS AFFECTED BY PEBRINE AND FLACCIDITY.

(after PASTEUR)





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PEBRINE CORPUSCULES OF SILKWORM MOTH.

highly magnified

(after PASTEUR)

INDEX.