SILKWORM. The silkworm of commerce is the caterpillar of *Bombyx mori*, a moth of the family Bombycidæ, a group commonly known as the family of silkworm moths. The caterpillars of all the species of this group have the silk glands largely developed, and many produce large quantities of silk in making cocoons. The Bombycidæ have a short and rudimentary proboscis, live only a brief period in their perfect state, and take little or no food; the body is thick and hairy, the wings large and broad, the antennæ pectinated. The caterpillars feed on the leaves and other tender parts of trees or other plants; the chrysalids are inclosed in a cocoon of silk. The common silkworm is a native of either the northern provinces of China or of Bengal. The perfect insect is about an inch in length, the female rather larger than the male, the color whitish, with a broad pale-brown bar across the upper wings. The females generally die very soon after they have laid their eggs, and the males do not survive long. The eggs are numerous, bluish in

color, about the size of a pin's head, not attached together, but fastened to the surface, on which they are laid by a gummy substance which, when dry, becomes silky. They are laid about the end of June and are hatched about the middle of the following April or at the time when the leaves of the mulberry unfold.

The caterpillar is at first small—a quarter of an inch in length—but rapidly increases in size till, full grown, it is nearly 3 inches long. It is usually yellowish gray in color, but some varieties are much darker. The skin is changed four times during the growth of the caterpillar. Before each change of skin it becomes lethargic and ceases to eat, whereas at other times it is very voracious. When the skin is ready to be cast off, it bursts at the forepart, and the caterpillar then, by continual writhing, without moving from the spot, thrusts it backward. Silkworms frequently die during this change. A rapid increase of size takes place while the new skin is still soft. The natural food of the silkworm is the leaf of the white mulberry, but it will also feed on the leaves of some other plants, as black mulberry and lettuce, and in the United States it is frequently fed on the Osage orange. When so fed, however, it produces inferior silk. The silk-producing organs are two large glands (sericteria) containing a viscid substance, which extend along a great part of the body and terminate in two spinnerets in the mouth. These glands become very large when the change to the chrysalis or pupa state is about to take place.

When about to spin a cocoon, the silkworm ceases to eat and first produces the rough fibre which forms the outer part of the cocoon, and then the more closely disposed and valuable fibre of its interior. In this process the position of the hinder part of the body is little changed, but the head is moved from one point to another, and the cocoon when finished is much shorter than the body. Each fibre of silk, when examined by a microscope, is seen to be double, being equally derived from the two silk-producing organs of the caterpillar. A single fibre ranges from 800 to 1000 yards in length. The time of the silkworm's life in the caterpillar state is about four weeks. About three days are occupied in the spinning of the cocoon, after which about two or three weeks elapse in the chrysalis stage before the perfect insect comes forth.

Diseases. The silkworm is liable to various diseases, particularly to muscardine, pébrine, flacherie, gattine, and grasserie. Muscardine (q.v.), commonly known as silkworm rot, is due to a fungous growth within the caterpillar. A worm so affected becomes dull white, sluggish, and soon dies. A few days after death it becomes hard, red, and floury. The cause of the disease was discovered by an Italian, Bassi, and the fungus is called *Botrytis bassiana*. Pébrine, unquestionably bacterial, is an hereditary disease and probably contagious and infectious. It is the most fatal of silkworm diseases. By 1847 its ravages in France compelled the French to get their silkworm eggs from Italy. The disease spread to Italy, and then the eggs were procured from the Danube, then from China, and in 1865 healthy eggs could be obtained only from Japan. Pasteur showed that selection and isolation of healthy moths is the only remedy. With the methods of isolation and care against contamination such as are at present practiced, France now supplies her own market and exports 300,000 ounces of silkworm eggs annually. In worms affected with flacherie the food ferments in the alimentary tract and sustains vibrios and certain fungi. This disease is probably induced by improper care of the eggs. Gattine is probably only a modification of flacherie. The cause of grasserie (q.v.) is unknown. It is the least fatal of silkworm diseases. To keep silkworms healthy they must be reared in a suitable and constant temperature. Humidity, ventilation, and cleanliness must be strictly and constantly attended to. Lime is used for whitewashing the walls and buildings in which worms are reared, and sulphur fumes for sterilizing trays.

Culture of Silkworms. The leaf of the white mulberry (*Morus alba*) is apparently the natural food of the domestic silkworm. There are many horticultural varieties of this plant, some much better adapted than others to commercial silk culture, and some better suited to certain localities. The *Morus moretti*, the *Morus multicaulis*, and the black mulberry (*Morus nigra*) are also used. The red mulberry (*Morus rubra*) does not make good food, and the paper mulberry (*Broussonetia papyrifera*) is also valueless. The best varieties of mulberries are propagated by means of seeds and by cuttings. The trees should be planted well apart and should be pruned so as to form a short trunk and a close low head. Silkworm eggs are kept through winter at a low temperature, the embryo beginning to take form when the temperature rises above 50° F. The receptacle in which they are stored should be ventilated, the air should not be moist, and great care should be taken to keep them out of the reach of mice and insects. The eggs are hatched in an artificial incubator or by natural heat. When an incubator is used the temperature should be gradually increased until 73° F. is reached. The whitening of the eggs denotes the nearness of hatching. The eggs should then be covered with sheets of tulle or finely perforated paper, sprinkled with finely cut white mulberry leaves. The young caterpillars will at once mount to the leaves and should be fed eight to ten times during 24 hours. After each feeding the lower sheet of paper or tulle should be removed with the frass. About the sixth day they will begin to molt and pass into the second stage. As the worms increase in size, paper in which the perforations are larger should be used, and the same general directions followed for each stage until the fifth has been reached.

The worms have now grown to nearly full size, are very voracious, and it is difficult to satisfy their appetite. After five days in the fifth stage they are ready to spin. In making preparations for spinning, dry brush, bundles of straw or shavings or finely split-up wood may be used. The brush or straw should be placed upright between the feeding shelves, in rows about 16 inches apart, the tops spread to form arches and allow the worms plenty of room to spin. The temperature during spinning should be 75° F., and the humidity throughout the rearing about 65°. The rearing room should be well ventilated, and before introducing the worms should be disinfected with chloride of lime or sulphur. One ounce of eggs contains approximately 40,000, and the space required may be estimated by allowing 1 square yard for this amount at birth, on the fourth day

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2 square yards, for the second stage 4 square yards, three days later 8 square yards, for the third stage 16 square yards, and for the fourth stage 32 square yards, and for the fifth stage 60 square yards. Plenty of space is desirable, since when crowded the worms will not be so robust. A mean temperature of about 74° F. is the best. There are many commercial varieties of the silkworm graded according to the size, color, and quality of the cocoon. When the cocoons are completed, which is known by the absence of any sound within, they are carefully sorted and a certain number kept for laying. The sexes are readily known by difference of shape as well as of size, the female being plumper; the male, much smaller, having a central depression and sharper extremities. The French growers sort them into nine varieties, those which are less compact or in which the worm has died—a fact known by external indications—being separated from the good ones. When the sorting is finished the cocoons are placed in an oven with a gentle heat, which kills the inclosed chrysalis, otherwise they would all become perforated by the insect eating through. The cocoons are then ready for the first stage in the manufacturing process, which consists in the removal and winding of the fibrous covering as described under SILK.

Other Silkworms. It is supposed by some entomologists that the original wild silkworm from which descended the silkworm of commerce is a species known as *Theophila huttoni*, which occurs in Japan, the northwest Himalaya, and Assam. The moth is of the same size as that of *Bombyx mori*, light brown, with the characteristic markings on the wings. The larva almost precisely resembles the domestic silkworm, but has a pair of small black thorns on the back of each segment of the abdomen. It seems very unlikely, however, that this species could have been the ancestor of *Bombyx mori*, since it lacks palpi, which are present in the *Bombyx*.

Oriental people have utilized the cocoons of a number of species of bombycid moths in the manufacture of silk goods. The so-called tussah, tusseh, or tusser silkworm is *Antheræa mylitta*. a species occurring in China, India, and Ceylon. In Upper India this silk is extensively produced, and the cocoons are collected in the jungle districts by the Sahars and other half-wild castes who live in such places. Other silkworms which are said to be used in the manufacture of tussah silk are *Antheræa pernyi*, from China; *Antheræa assama* (*Saturnia perottetti* and *Antheræa mezankooria* are synonyms of this species), a native of Assam and there called moonga or moogha; *Antheræa roylei*, from India; *Antheræa helferi*, from Sikkim; *Antheræa jana*, from Java; *Antheræa frithii*, from Sikkim, Bhutan, and Darjeeling; and *Antheræa larissa*, from Java. The very large and beautiful *Attacus atlas*, from India, Ceylon, Burma, and Java, is said to produce cocoons used for tussah silk.

The wild silkworms which have received the most attention in Europe, however, are *Antheræa yamamai*, from Japan, commonly known as the yamamai silkworm; *Antheræa pernyi*, from China; and *Philosamia cynthia*, from Japan, China, the Himalaya, Assam, and Java, which has been introduced into Europe and which has been acclimatized in the eastern United States. Its larva is commonly known as the ailanthus silkworm, while the yamamai and pernyi silkworms are commonly known as oak silkworms.

The yamamai silkworm is commonly raised in Japan, and its cocoon is large, heavy, handsome, and of a yellowish-green color. It is readily reeled, and its silk ranks commercially next to that of the domestic silkworm. The silk is strong and valuable. It bleaches well and may then be dyed. Fewer threads are required to make a strand than with *Bombyx mori*, and the cocoons unwind with perfect ease by the ordinary process. The life of the worm lasts from 50 to 80 days, and it feeds on all kinds of oak, but prefers those of the white-oak group. The pernyi silkworm has been cultivated in Europe with better success than the yamamai. It develops more rapidly, is double-brooded, and passes the winter in the chrysalis state. The cocoon is not so valuable, though ranking probably third best among the different silkworm cocoons. The ailanthus silkworm is utilized extensively in north China. It has been known in Europe since the middle of the last century and has been cultivated there as well as in the United States with perfect success. The cocoons, however, cannot be reeled successfully, and their silk is utilized principally by carding processes.

In the United States several species of silkworm moths occur, and their caterpillars spin an abundance of silk of a strong and durable quality. The American silkworm (*Telea polyphemus*) is a large moth of a buff color, whose caterpillar feeds upon the leaves of many trees, including oak, willow, hickory, maple, apple, sycamore, and many others. The cocoon is formed of strong silk, which when unwound has a glossy fibre. It is oval and closed at both ends, dense, and generally fastened to a leaf or leaves, with which it sometimes falls to the ground. The fibres are intermixed and cemented with a gummy substance which when dry gives the cocoon a chalky appearance. The principal difficulty in reeling the cocoon is in the hard matter which binds the threads. This, however, may be softened, and no doubt the cocoon could be improved by a process of continued selection. The insect has one generation each year in the Northern States, two in the Southern States, and passes the winter in the chrysalis state.

The large luna moth (*Tropæa luna*) is a beautiful species of a delicate green color, with long tails to the hind wings, whose larva feeds on several forest trees and whose cocoon is less dense than that of the polyphemus moth. The cocoons of these two species have the same general characteristics as those of the yamamai silkworm. Another native North American silkworm (*Callosamia promethia*) resembles in many respects the ailanthus worm. Its cocoon, like that species, is open and is in the same way difficult to reel. It feeds on ash, sassafras, wild cherry, maple, lilac, birch, and other trees. The largest of the American silkworms is the larva of *Samia cecropia*, a beautiful moth of a grayish-brown color marked with reddish and yellow spots and bands. The large green larva, which bears six coral-red tubercles on its thorax and smaller blue tubercles on its abdomen, feeds upon the apple and other rosaceous plants, as well as upon hazel, hickory, maple, willow, and honey locust. The cocoon is peculiar in being apparently double. There is a thick, wrinkled outer layer which resembles strong

brown paper and which covers an inner oval cocoon composed of the same kind of silk, but closely woven like that of the mulberry silkworm. Nearly related to this species are *Samia gloveri*, of the Rocky Mountain region; *Samia columba*, of the North Atlantic States; and *Samia rubra*, from the Pacific States. In Mexico there are several large silkworm moths of the Saturnian group which produce quantities of silk, but it has not been commercially utilized or experimented with. There is another group of moths belonging to the family Psychidæ, in which the larva makes a large bag of silk which it carries about with it to protect its soft body from the attacks of birds. A common American example is the bagworm (q.v.) or basket worm. This silk has not been utilized except in China.

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