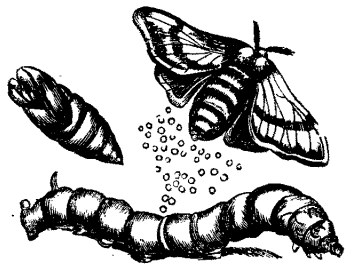
SILK AND SILKWORM. The name *silk* is derived, by the not unusual substitution of *l* for *r*, from Lat. *sericum* (Gr. *serikon*), so called as coming from the country of the Seres or Chinese. The SILKWORM is the caterpillar of the SILKWORM MOTH, of which there are numerous species belonging to the genus *Bombyx* and other genera of the family *Bombycidæ*, lepidopterous insects of the section popularly known by the name Moth (q. v.). The *Bombycidæ* have a very short and rudimentary proboscis, living for a very short time in their perfect state, and taking little or no food; the body is thick and hairy; the wings are large and broad, either extended horizontally when at rest, or inclined like the sides of a roof; the antennæ are pectinated. The caterpillars feed on the leaves and other tender parts of trees or other plants; the chrysalids are enclosed in a cocoon of silk, which gives to some of the species a great economical importance. The most important is the COMMON SILKWORM (*Bombyx mori*), a native of the northern provinces of China. The perfect insect is about an inch in length, the female rather larger than the male; the wings meeting like the sides of a roof; the colour 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 much longer. The eggs are numerous, about the size of a pin's head, not attached together, but fastened to the surface on which they are laid



Silkworm Moth (*Bombyx mori*), in its various stages.

by a gummy substance, which, when dry, becomes silky. They are laid in the end of summer, and are hatched in the beginning of next summer. The caterpillar is at first very small, not more than a quarter of an inch in length, but rapidly increases in size, till, when full grown, it is nearly three inches long. It is of a yellowish gray colour. The head is large. On the upper part of the last joint of the body is a horn-like process. The skin is changed four or five 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 fore part, and the caterpillar then, by continually writhing its body, without moving from the spot, thrusts it backwards; but silkworms frequently die during the change of skin. A very rapid increase of size takes place whilst the new skin is still soft. The natural food of the silkworm is the leaves of the white mulberry, but it will also feed on the leaves of some other plants, as the black mulberry and the lettuce. When so fed, however, it produces silk of inferior quality. The silk-producing organs are two large glands (sericteria) containing a viscid substance, which extend along 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 its cocoon, the silkworm ceases to eat, and first produces the loose 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, which, however, being bent, is completely enclosed in it. The cocoon is about the size of a pigeon's egg. 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 often exceeds 1100 feet in length. The time of the silkworm's life in the caterpillar state is generally about eight weeks. About five days are occupied in the spinning of the cocoon; after which about two or three weeks elapse before the cocoon bursts and the perfect insect comes forth. The natural bursting of the cocoon is, however, injurious to the silk, and the silkworm rearer prevents it by throwing all the cocoons into boiling water, except those which he intends to keep in order to the maintenance and increase of his stock. These he selects with care, so that he may have about an equal number of male and female insects, the females being

known, even in the chrysalis state, by their larger size. The cocoons intended for the production of moths are placed on a cloth in a somewhat darkened room, of which the temperature is near, but does not exceed 72° F.; and the moths, when produced, shew no inclination to fly away, but remain on the cloth, lay their eggs, and die there. It is an interesting peculiarity of this valuable species of moth, that neither in the caterpillar nor in the winged state does it shew that restless disposition which belongs to many others, the caterpillars remaining contentedly in the trays or boxes in which they are placed, feeding on the leaves with which they are there supplied, and at last only seeking a proper place to assume the chrysalis form on small bundles of twigs which are placed for that purpose above the trays; the perfect moths, in like manner, abiding almost in one spot, and scarcely caring to use their wings. Owing to this peculiarity it is capable of being reared and managed in a way which would otherwise be impossible.

The silkworm is liable to various diseases, particularly to one by which great numbers are often destroyed, and which is either caused or characterised by the growth of a small fungus known as *Silkworm-rot*, or *Muscardine* (q. v.).

Of the other species of silkworm, many are rapidly increasing in commercial importance. The following is an enumeration of the chief silk-producing insects; those in Italics are not as yet employed in manufactures:

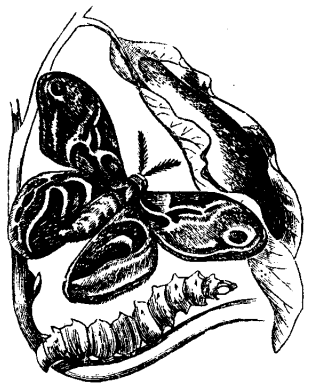
Bombyx mori.—The common silkworm, native of India, and reared in other parts of the world.
B. cræsi.—Crosses have been obtained between this and B. mori, yielding excellent silk, at Mussooree.
B. textor.—Native of Mussooree.
B. sinensis.—China.
B. Huttoni.—Silk collected in Mussooree.
B. Horsfieldi.—Native of Java.
Attacus atlas.—Native of India, and said to yield some of the 'Tusseh Silk.'
A. Guerini.—Native of Bengal.
A. ricini.—Native of Assam.
A. cynthia.—The 'Eria,' or 'Arrindy' silkworm, native of India, now extensively raised in Hong-kong, Nepaul, Mussooree, Java, and to some extent in Southern Europe. It feeds on the leaves of the Ailanto (q. v.) tree.
Antheræa Mezankooria.—The Mezankooria silk-moth.
A. Paphia.—The true Tusseh or Tussur Moth, native of Darjeeling, and other parts of Upper India. It is produced very extensively, and is chiefly collected in the jungle districts by the Sahars and other half-wild castes who live in the jungles. The cocoons are so carefully concealed in the leaves, that much care is required to discover them, the only indication being the dung of the caterpillar under the trees. The tusseh silk is easily wound off from the cocoons in the same way as that of the common silkworm.
A. Assama.—The Moonga, or Moogha, native of Assam.
A. Pernyi.—North China.
A. Perrottetti.—North China.
A. Roylei.—Mussooree.
A. Helferi.—Darjeeling.
A. Jana.—Java.
A. Frithii.—Darjeeling.
A. Larissa.—Java.
The preceding seven are all called Tusseh moths.
Actias Selene.—Darjeeling.
Saturnia pyretorum.—China.
S. Grotei.—Darjeeling.
Lœpa Katinka.—Java.
Neoris Huttoni.—Mussooree.
Caligula Tibeta.—Mussooree.
C. Simla.
Salassa Lola.—South-east Himalaya.
Cricula triferrestrata.—Java.

It will be seen by the above list that hitherto very few of the silk-moths have been turned to man's profit. The first in importance after the common silkworm is the true *Tusseh*, next, the *Moonga*, the silk from both of which can be wound off the cocoon; and then the *Eria*, which cannot be wound easily, and is therefore generally carded.

Silk appears not to have been well known to the ancients; although several times mentioned in the translations of the Bible, the best authorities deny that it is in the original, or that it was known to the Hebrews. Among the Greeks, Aristotle is the first who mentions it, and he only says that 'Pamphile, daughter of Plates, is reported to have first woven it in Cos;' and from all the evidence which has been collected, it would appear that the natives of Cos received it indirectly (through the Phœnicians and Persians) from China. The silken webs of Cos found their way to Rome, but it was very long before they were obtainable except by the most wealthy. The cultivation in Europe of the worm itself did not take place until 530 A. D., when, according to an account given by Procopius, the eggs were brought from India (China) to the Emperor Justinian by some monks.

In China, the cultivation of silk is of the highest antiquity, and according to the greatest Chinese authorities, it was first begun by Si-ling, the wife of the Emperor Hoang-ti, 2600 years B. C., and the mulberry was cultivated for the purpose of feeding them only forty years later.

Since its introduction to Europe, it has always formed a great branch of industry in Italy, Turkey, and Greece, and it has been cultivated to some extent in France, Spain, and Portugal. In England, too, from time to time, laudable efforts have been made to cultivate it, especially by Mrs Whitby of



Ailanto Silkworm (reduced), shewing the Cocoon of Silk attached to a Leaf.

Newlands, Mr Mason of Yately in Hampshire, and Lady Dorothy Neville of Dangstein in Hampshire; but their partial success has not encouraged others to pursue this branch of industry, which requires a warmer and less variable climate and cheaper labour than we can command.

The quantity of silk raised in the world is enormous. Great Britain imports annually in the unmanufactured state: 'Raw' silk, about 6,500,000 lbs.; 'waste,' or knubs and husks, about 3,500,000 lbs.; besides undyed 'singles,' about 5700 lbs.; tram, about 7000 lbs.; organzine, about 39,000 lbs.; and dyed singles and tram, about 3000 lbs.; organzine, about 10,000 lbs. Singles, tram, and organzine are terms applied to the thread after it has undergone certain operations (to be afterwards described). The total quantity is thus about 10,000,000 lbs., of

the value of £5,000,000; and in addition to this we import manufactured silk goods to the value of about twelve millions and a half sterling; so that the importance of this little insect to Great Britain alone is represented annually by about £17,500,000. It requires 1600 worms to raise a pound of silk.

Rearing of Silkworms.—It is of the first consequence in the production of silk that one of the species of mulberry should be cultivated, and that it should be so favourably situated as to climate, that its foliage is in readiness for feeding the young worms when they are first hatched from the eggs. The species best adapted is the white mulberry, *Morus alba*. The extreme lateness of season at which the black mulberry produces its leaves, prevents its employment generally, besides which it will not bear the loss of its leaves so well. It is said that in some parts of China the silkworm is easily reared upon the trees in the open air. So little has it a tendency to wander far from the place of its birth, if food be at hand, that it only requires a warm dry atmosphere to bring it to perfection; but usually, even in China, and in all other countries, it is thought desirable to raise the silkworm in properly arranged buildings, and to supply it with mulberry leaves gathered from day to day. In India, China, and other tropical countries, the eggs hatch readily at the proper time by the natural heat; but in Southern Europe, artificial heat is almost always required; formerly, the heat of fermenting dung was found serviceable, and the warmth of the human body was also used, the eggs being carried in little bags in the bosom of the cultivators; but now they are regularly hatched by stove-heat, beginning with a temperature of 64° F., which is gradually increased through ten days to 82°, at which it is maintained until the eggs are hatched. Experience has shewn that the operation is facilitated by washing the eggs in the first place with clean water; and some cultivators also wash them in wine, the value of which is very questionable. Washing is found to remove a certain gumminess and other impurities from the eggs, which would otherwise impede the hatching. When the silkworms have been regularly developed as above described, it is usual to place above the trays various little contrivances for the caterpillar to spin within: many of the Italian growers employ an ingeniously simple arrangement, which lasts many seasons, and when not in use, occupies very small space. It consists of a number of thin slips of wood, about an inch and a half broad, and all cut sufficiently long to reach across the trays. They are each cut at intervals of an inch half through, as in fig. 1, so that one will fit into another, as in fig. 2; and when complete, they all form a series of cells, which, set in a tray (fig. 3), form the very best receptacles for the silkworm to spin in. When not in use, the whole arrangement can be compressed into very small compass, as in fig. 4, for convenience of storage. Others use little cones of paper, or small twigs, amongst which the cocoons are spun.

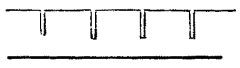


Fig. 1.

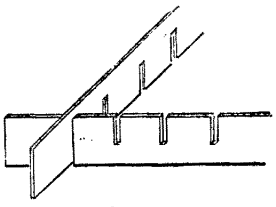


Fig. 2.

In feeding the worms, care is taken so to distribute the food on the shelves or in the trays that the insects shall not crowd together; and for this reason, the most careful cultivators chop the leaves small, and strew them very evenly about. Great care is taken not to let the worms of one hatch mix with

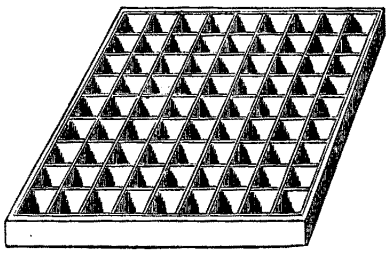


Fig. 3.

those of another, unless of exactly the same age, otherwise the stronger insects would deprive the younger of their food. Many other niceties of

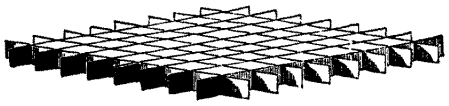


Fig. 4.

attention are required, which altogether render the successful rearing of silkworms a matter of much anxiety and labour.

Preparation of Silk.—When the cocoons are completed, which is known by the absence of any sound within, they are carefully sorted, and a certain number are kept for laying. The sexes are readily known by the difference of shape as well as of size, the female being plumper, as in fig. 5, and the male (fig. 6), besides being 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 enclosed chrysalis, otherwise they would all become *perforated* by the insect eating through; they are then prepared for winding by first removing the flossy covering, which is often somewhat hard and compact. The cocoons are placed in basins of water, kept warm by charcoal fires, or, in the larger establishments, by steam. This softens and dissolves the natural gum which coats the silk, and makes the various coils of silk adhere together in the cocoon. The operator then takes a small branchy twig, and stirs them about in the water. This is sure to catch hold of any liberated ends which may be floating in the water. From three to five of these ends are taken and twisted together with the fingers, so as to unite them into one thread, which is passed through a polished metal or glass eye in the reeling-machine, which is so far from the hot-water basin as to give the softened gum on the silk time to dry in its passage from the basin to the reel. In large *filatures* or silk establishments, complex machinery is used for winding; but reeling apparatus of the greatest simplicity is used by the Chinese, East Indians, and

Fig. 5.

Fig. 6.

others with almost equal effect, when carefully done, except in the amount of work accomplished. In all cases, however, the principle is the same, and is very simple, as shewn in fig. 7, in which *a* shews the small pan of warm water holding the cocoons,

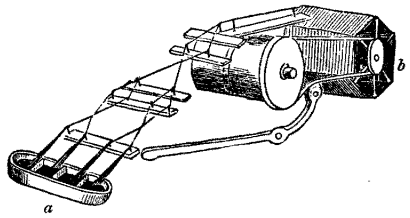


Fig. 7.

the threads from which are gradually united, and wound on the reel *b*. Great care and skill are required in reeling silk from the cocoons, because, although the reeler starts with four or five cocoons, not only are their individual threads apt to break, but they are not all of the same length, so that one will run out before the others. These matters are carefully watched; and as often as a thread breaks, or a cocoon runs out, another thread is joined on, and is made to adhere to the compound thread on the reel by its natural gumminess. Each cocoon generally yields 300 yards of thread, so that it takes 1200 or 1500 yards to make 300 yards of the filament of raw silk, by which name the reeled silk is always known. The raw silk is made up into hanks of various sizes. That from China and Japan is tied in packages of six hanks each, technically called *books*, and sometimes the ends of these books are covered with silken caps very curiously formed out of a single cocoon, so managed as to form a filmy cap sufficiently large to cover a man's head. The method used by the Chinese to accomplish this is quite unknown in Europe. These caps or bags, when closed, are sometimes nearly a foot square, and much of the wadding used by the Chinese dressmakers for padding is made by placing these bags upon each other to the required thickness.

Notwithstanding the care taken in reeling the silk from the cocoons, and forming several threads into one, it is not ready for the weaver, but has to undergo the processes called collectively *throwing*. In this country, this is a special trade, the *silk throwster* usually conducting it in large mills with extensive machinery, where the above processes are all carried on, generally by steam-power. The silk reaches the throwster in hanks as imported. These are put into clean soap and water, and carefully washed, ties having been placed at intervals, to prevent the silk entangling. After being dried by hanging in

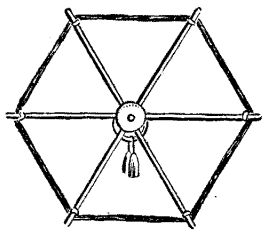


Fig. 8.

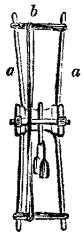


Fig. 9.

the drying-room, they are placed on large skeleton reels called *swifts* (fig. 8), so adjusted that they will hold the hanks tightly. Fig. 9 is a front view of a *swift*, and shews that the spokes, *a*, *a*, are in pairs. They are made of thin pieces of lancewood, and each pair are rather nearer together at the axle than at the circumference, where they are connected together by a small band of cord, *bb*. These bands are so tied that they will slip down easily to admit of the hanks being placed; then, by pushing the cords upwards, the hank can be stretched to its fullest extent. This is necessary to compensate for the varying lengths of the hanks received from different countries.

When the *swifts* are set in motion, the silk is carried from the hanks to bobbins, upon which it is wound for the convenience of further operations. The bobbins are then taken from the *winding* to the *cleaning* machine, when they are placed on fixed spindles, so that they will turn with the slightest pull; and the thread is passed through a small apparatus attached to the machine, which is specially called the cleaner, and consists essentially of two polished smooth-edged blades of metal (*a*, *a*, fig. 10), attached to a part of the frame of the machine, *b*. They are held together by the screw *c*, and are slightly opened or closed by the other screw, *d*, so that the thread can be put between them down to the small orifice, *e*, and then, by tightening the screw, preventing its return, after passing through this small hole, which is the gauge of the thread, and which removes any irregularities or adherent dirt. The silk next passes over a glass or metal rod, and then through another small hole, much larger than that of the *cleaner*, and usually made of glass, on to the bobbin, upon which it is wound by the action of the machine. The next process is *twisting* the cleaned thread, by which it becomes better adapted for being combined with other threads. *Doubling* is the next process, and this consists in running off a number of bobbins of *twisted* silk on to one bobbin of a larger size, which is put into the *throwing*-machine, when the ends of the *doubled* silk are passed through a smooth hole on to a large reel, which rewinds it into hanks, but twisting the threads into a fine cord as it goes from the bobbins to the reel. This operation of *throwing* derives its name from the Saxon *thrawan*, to whirl or twist. After this, the hanks have to be again wound on reels and bobbins for the weaver, the former for the warp, and the latter for the weft. For many purposes, only some of these operations are required. Thus for common and light fabrics, such as *Persian*, *gauze*, &c., only the two first are needed—viz., the *winding* and *cleaning*, and the material is called *dumb-singles*. If it has been *wound*, *cleaned*, and *thrown*, it is called *thrown-singles*, and is used for weaving common broad stuffs, or plain silks and ribbons. If *wound*, *cleaned*, *doubled*, and *thrown*, it is called *tram*, and is used for the richer silks and velvets, but only for the weft or shoot; and if *wound*, *cleaned*, *spun*, *doubled*, and *thrown*, it is called *organzine*, and is used for the warps of fine fabrics.

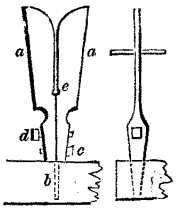


Fig. 10.

Before winding the cocoons, a flossy portion has to be removed; and after all has been wound off, another portion remains, like a compact bag; these are collected and sold under the name of *waste-silk*, and to these are added the fragments of broken threads, which accumulate in considerable quantities during the reeling and throwing operations. Formerly, very little use was made of waste-silk; not a little of it was employed by engineers and others for mere cleaning purposes; although, as early as

1671, a proposition was made by a manufacturer named Edmond Blood to make it available by carding it with teasels or rowing-cards. He took out a patent for this invention, but apparently did not bring it into use. Another patent was taken out by Mr Lister of Bradford, which has done wonders; now the waste is all spun into yarn, thereby greatly economising the use of silk, as the quantity of silk-waste always greatly exceeds the amount of good silk reeled off. The processes employed in the production of silk-yarn from the waste differ little from those for spinning other materials. See SPINNING.

The silk-manufactures of Britain are chiefly located in Spitalfields, London, at Macclesfield and Congleton in Cheshire, at Derby, and in Glasgow. The dyeing of silk is done chiefly in the neighbourhood of London, at Nottingham, and at Manchester; and considerable quantities of silk goods are sent from India to be printed with patterns in London and other parts of England. These goods are chiefly the corah and bandana pocket-handkerchiefs, and Indian waist and turban scarfs.