wasted men of Syracuse hide their diminished faces far within their helmets, and carefully shade their pallor lest hope should arise for the enemy. In the avoidance of rhetorical artifice and epigrammatic antithesis Silius stands in marked contrast to Lucan. Yet he can be pointed; so of Fabius, "laudum cladumque quieta Mente capax"; and of Scævola, "Aspera semper amans et par cuicumque periclo"; and of Africa, "Altrix bellorum bellatorumquè virorum Tellus, nec fidens nudo sine fraudibus ensi." Looking at Silius merely as a poet he may not deserve high praise; but, as he is a unique specimen and probably the best of a once numerous class, the preservation of his poem among the remains of Latin literature is a fortunate accident.

The poet's full name, Ti. Catius Silius Italicus, is preserved in an inscription (*C. I. L.*, vi. 1984). The poem was discovered in a MS., possibly at Constance, by Poggio, in 1416 or 1417; from this now lost MS. all existing MSS., which belong entirely to the 15th century, are derived. A valuable MS. of the 8th or 9th century, found at Cologne by L. Carrion in the latter part of the 16th century, disappeared soon after its discovery. Two *editiones principes* appeared at Rome in 1471; the principal editions since have been those of Heinsius (1600), Drakenborch (1717), and Ernesti (Leipsic, 1791). A useful *variorum* edition is that of Lemaire (Paris, 1823). The recent *lucubrationes* on Silius are mostly small pamphlets, enumerated by Engelmann (*Bibl. Script. Class.*, 1878). (J. S. R.)

SILK

SILK is a fibrous substance produced by many insects, principally in the form of a cocoon or covering within which the creatures are enclosed and protected during the period of their principal transformations. The webs and nests, &c., formed by spiders are also of silk. But the fibres used for manufacturing purposes are exclusively produced by the mulberry silk-moth of China, *Bombyx mori*, and a few other moths closely allied to that insect (see vol. iv. p. 596). Among the Chinese the name of the silkworm is "si," Corean "soi"; to the ancient Greeks it became known as *σήρ*, the nation whence it came was to them Σῆρες, and the fibre itself *σηρικόν*, whence the Latin *sericum*, the French *soie*, the German *Seide*, and the English *silk*.

The silk industry originated in China; and according to native records it has existed there from a very remote period. The empress Se-ling-she, wife of a famous emperor, Hwang-te (2640 B.C.), encouraged the cultivation of the mulberry tree, the rearing of the worms, and the reeling of silk. This empress is said to have devoted herself personally to the care of silkworms, and she is by the Chinese credited with the invention of the loom. A voluminous ancient literature testifies not only to the antiquity but also to the importance of Chinese sericulture, and to the care and attention bestowed on it by royal and noble families. The Chinese guarded the secrets of their valuable art with vigilant jealousy; and there is no doubt that many centuries passed before the culture spread beyond the country of its origin. Through Corea a knowledge of the silkworm and its produce reached Japan, but not before the early part of the 3d century. One of the most ancient books of Japanese history, the *Nihongi*, states that towards 300 A.D. some Coreans were sent from Japan to China to engage competent people to teach the arts of weaving and preparing silk goods. They brought with them four Chinese girls, who instructed the court and the people in the art of plain and figured weaving; and to the honour of these pioneer silk weavers a temple was erected in the province of Setsu. Great efforts were made to encourage the industry, which from that period grew into one of national importance. At a period probably little later a knowledge of the working of silk travelled westward, and the cultivation of the silkworm was established in India. According to a tradition the eggs of the insect and the seed of the mulberry tree were carried to India by a Chinese princess concealed in the lining of her headdress. The fact that sericulture was in India first established in the valley of the Brahmaputra and in the tract lying between that river and the Ganges renders it probable that it was introduced overland from the Chinese empire. From the Ganges valley the silkworm was slowly carried westward and spread in Khotan, Persia, and the states of Central Asia.

Most critics recognize in the obscure word *dmeshek*, Amos iii. 12, a name of silk corresponding to the Arabic *dimakṣ*, late Greek *μέταξα*, English *damask*, and also follow the ancients in understanding *meshi*, Ezek. xvi. 10, 13, of "silken gauze." But the first notice of the silkworm in Western literature occurs in Aristotle, *Hist. Anim.*, v. 19 (17), 11 (6), where he speaks of "a great worm which has horns and so differs from others. At its first metamorphosis it produces a caterpillar, then a bombylius, and lastly a chrysalis,—all these changes taking place within six months. From this animal women separate and reel off the cocoons and afterwards spin them. It is said that this was first spun in the island of Cos by Pamphile, daughter of Plates." Aristotle's vague knowledge of the worm may have been derived from information acquired by the Greeks with Alexander the Great; but long before this time raw silk must have begun to be imported at Cos, where it was woven into a gauzy tissue, the famous *Coa vestis*, which revealed rather than clothed the form.

Towards the beginning of the Christian era raw silk began to form an important and costly item among the prized products of the East which came to Rome. Allusions to silk and its source became common in classical literature; but, although these references show familiarity with the material, they are singularly vague and inaccurate as to its source; even Pliny knew nothing more about the silkworm than could be learned from Aristotle's description. The silken textures which at first found their way to Rome were necessarily of enormous cost, and their use by men was deemed a piece of effeminate luxury. From an anecdote of Aurelian, who neither used silk himself nor would allow his wife to possess a single silken garment, we learn that silk was worth its weight in gold.

Notwithstanding its price and the restraints otherwise put on the use of silk the trade grew. Under Justinian a monopoly of the trade and manufacture was reserved to the emperor, and looms, worked by women, were set up within the imperial palace at Constantinople. Justinian also endeavoured, through the Christian prince of Abyssinia, to divert the trade from the Persian route along which silk was then brought into the east of Europe. In this he failed, but two Persian monks who had long resided in China, and there learned the whole art and mystery of silkworm rearing, arrived at Constantinople and imparted their knowledge to the emperor. By him they were induced to return to China and attempt to bring to Europe the material necessary for the cultivation of silk, which they effected by concealing the eggs of the silkworm in a hollow cane. From the precious contents of that bamboo tube, brought to Constantinople about the year 550, were produced all the races and varieties of silkworm which stocked the Western world, and which gave trade, prosperity, and untold wealth to great communities for more than twelve hundred years. The necessity for again going to the East for a supply of silkworm eggs has only arisen in our own day.

Under the care of the Greeks the silkworm took kindly to its Western home and flourished, and the silken textures of Byzantium became famous. At a later period the conquering Saracens obtained a mastery over the trade, and by them it was spread both east and west,—the textures becoming meantime impressed with the

patterns and colours peculiar to that people. They established the trade in the thriving towns of Asia Minor, and they planted it as far west as Sicily, as Sicilian silks of the 12th century with Saracenic patterns still testify. Ordericus Vitalis, who died in the first half of the 12th century, mentions that the bishop of St Evroul, in Normandy, brought with him from Apulia in southern Italy several large pieces of silk, out of the finest of which four copes were made for his cathedral chanters. The cultivation and manufacture spread northwards to Florence, Milan, Genoa, and Venice—all towns which became famous for silken textures in mediæval times. In 1480 silk weaving was begun under Louis XI. at Tours, and in 1520 Francis I. brought from Milan silkworm eggs, which were reared in the Rhone valley. About the beginning of the 17th century Olivier de Serres and Laffémas, somewhat against the will of Sully, obtained royal edicts favouring the growth of mulberry plantations and the cultivation of silk; but it cannot be said that these industries were firmly established till Colbert encouraged the planting of the mulberry by premiums, and otherwise stimulated local efforts.

Into England silk manufacture was introduced during the reign of Henry VI.; but the first serious impulse to manufactures of that class was due to the immigration in 1585 of a large body of skilled Flemish weavers who fled from the Low Countries in consequence of the struggle with Spain then devastating their land. Precisely one hundred years later religious troubles again gave the second and most effective impetus to the silk-trade of England, when the revocation of the edict of Nantes sent simultaneously to Switzerland, Germany, and England a vast body of the most skilled artisans of France, who planted in these countries silk-weaving colonies which are to this day the principal rivals of the French manufacturers. The bulk of the French Protestant weavers settled at Spitalfields, London,—an incorporation of silk throwsters having been there formed in 1629. James I. used many efforts to encourage the planting of the mulberry and the rearing of silkworms both at home and in the colonies. In 1825 a public company was formed and incorporated under the name of the British, Irish, and Colonial Silk Company, with a capital of £1,000,000, principally with the view of introducing sericulture into Ireland, but it was a complete failure, and the rearing of the silkworm cannot be said ever to have become a branch of British industry.

In 1522 Cortes appointed officials to introduce sericulture into New Spain (Mexico), and mulberry trees were then planted and eggs were brought from Spain. The Mexican adventure is mentioned by Acosta, but all trace of the culture had died out before the end of the century. In 1609 James I. attempted to reinstate the silkworm on the American continent, but his first effort failed through shipwreck. An effort made in 1619 obtained greater success, and, the materials being present, the Virginian settlers were strongly urged to devote attention to the profitable industry of silk cultivation. Sericulture was enjoined under penalties by statute; it was encouraged by bounties and rewards; and its prosecution was stimulated by learned essays and rhapsodical rhymes, of which this is a sample:—

> Where Wormes and Food doe naturally abound
> A gallant Silken Trade must there be found.
> Virginia excels the World in both—
> Envie nor malice can gaine say this troth!

In the prospectus of Law's great *Compagnie des Indes Occidentales* the cultivation of silk occupies a place among the glowing attractions which allured so many to disaster. Onward till the period of the War of Independence bounties and other rewards for the rearing of worms and silk filature continued to be offered; and just when the war broke out Benjamin Franklin and others were engaged in nursing a filature into healthy life at Philadelphia. With the resumption of peaceful enterprise, the stimulus of bounties was again applied—first by Connecticut in 1783; and such efforts have been continued sporadically down almost to the present day. Bounties were last offered by the State of California in 1865–66, but the State law was soon repealed, and an attempt to obtain State encouragement again in 1872 was defeated. About 1838 a speculative mania for the cultivation of silk developed itself with remarkable severity in the United States. It was caused principally through the representations of Samuel Whitmarsh as to the capabilities of the South Sea Islands mulberry (*Morus multicaulis*) for feeding silkworms; and so intense was the excitement that plants and crops of all kinds were displaced to make room for plantations of *multicaulis*. In Pennsylvania as much as $300,000 changed hands for plants in one week, and frequently the young trees were sold two and three times over within a few days at ever-advancing prices. Plants of a single year's growth reached the ridiculous price of $1 each at the height of the fever, which, however, did not last long, for in 1839 the speculation collapsed; the famous *Morus multicaulis* was found to be no golden tree and the costly plantations were uprooted.

The most singular feature in connexion with the history of silk is the persistent efforts which have been made by monarchs and other potentates to stimulate sericulture within their dominions, efforts which continue to this day in British colonies, India, and America. These endeavours to stimulate by artificial means have in scarcely any instance resulted in permanent success. In truth raw silk can only be profitably brought to the market where there is abundant and very cheap labour,—the fact that China, Japan, Bengal, Piedmont, and the Levant are the principal producing localities making that plain.

The Silkworm.

The mulberry-feeding moth, *Bombyx mori*, which is the principal source of silk, belongs to the *Bombycidæ*, a family of *Lepidoptera* in which are embraced some of the largest and most handsome moths (see vol. iv. p 596). *B. mori* is itself an inconspicuous moth (figs. 1 and 2) of an ashy white colour, with a body in the case of the male not half an inch in length, the female being a little longer and stouter. Its wings are short and weak; the fore pair are falcate, and the hind pair do not reach to the end of the body. The larva (fig. 3) is hairless, of an ashy grey or cream colour, attains to a length of from 3 to $3\frac{1}{2}$ inches, and is slender in comparison with many of its allies. The second thoracic ring is humped, and there is a spine-like horn or protuberance at the tail. The common silkworm produces as a rule only one generation during the year; but there are races in cultivation which

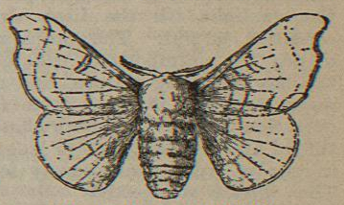

FIG. 1.—*Bombyx mori* (male).

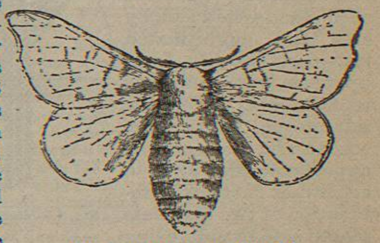

FIG. 2.—*Bombyx mori* (female).

are bivoltine, or two-generationed, and some are multivoltine. Its natural food is the leaves of mulberry trees. The silk glands or vessels consist of two long thick-walled sacs running along the sides of the body, which open by a common orifice—the spinneret or seripositor—on the under lip of the larva. Fig. 4 represents the head (*a*) and feet (*b*, *b*) of the common silkworm, while *c* is a diagrammatic view of the silk glands. As the larva approaches maturity these vessels become gorged with a clear viscous fluid, which, upon being exposed to the air immediately hardens to a solid mass. Advantage is taken

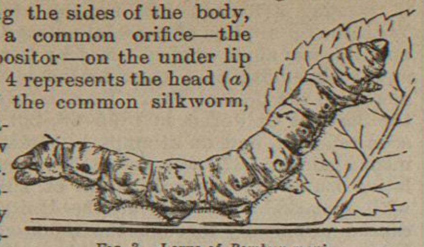

FIG. 3.—Larva of *Bombyx mori.*

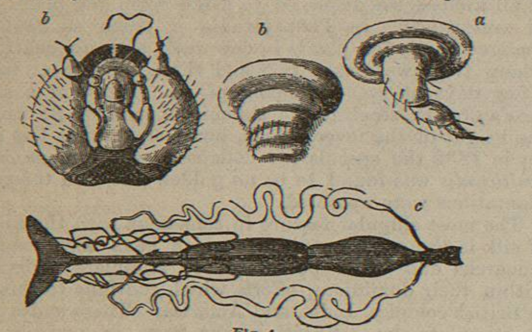

Fig. 4.

of this peculiarity to prepare from fully-developed larvæ silkworm gut used for casting lines in rod-fishing, and for numerous other purposes where lightness, tenacity, flexibility, and strength are essential. The larvæ are killed and hardened by steeping some hours in strong acetic acid; the silk glands are then separated from the bodies, and the viscous fluid drawn out to the condition of a fine uniform line, which is stretched between pins at the extremity of a board. The board is then exposed to the sunlight till the lines dry and harden into the condition of gut. The preparation of gut is, however, merely an unimportant collateral manufacture. When the larva is fully mature, and ready to change into the pupa condition, it proceeds to spin its cocoon, in which operation it ejects from both glands simultaneously a line or thread about 4000 yards in length, moving its head round in regular order continuously for three days or thereby. The thread so ejected forms the silk of commerce, which as wound in the cocoon consists of two filaments—one from each gland—laid side by side and agglutinated into one fibre (Fr. *bave*) by their own adhesive constituents. Under the microscope, therefore, cocoon silk presents the appearance (fig. 5) of a somewhat flattened combination of two filaments placed side by side, being on an average from ·033 to ·036 mm. broad by ·020 to ·025 mm. in thickness. The cocoons are white or yellow in colour, oviform in shape, with often a constriction in the middle (fig. 6). According to race, &c., they vary considerably in size and weight, but on an average they measure from an inch to an inch and a half in length, and from half an inch to an inch in diameter. They form hard, firm, and compact shells with some straggling flossy filaments on the exterior, and the interior layers are so closely and densely agglutinated as to constitute a parchment-like mass which resists all attempts at unwinding. The whole cocoon with its enclosed pupa weighs from 15 grains for the smaller races to about 50 grains for the breeds which spin large cocoons. From two to three weeks after the completion of the cocoon the enclosed insect is ready to escape; it moistens one end of its self-made prison, thereby enabling itself to push aside the fibres and make an opening by which the perfect moth comes forth. The sexes almost immediately couple; the female in from four to six days lays her eggs, numbering 500 and upwards; and, with that the life cycle of the moth being complete, both sexes soon die.

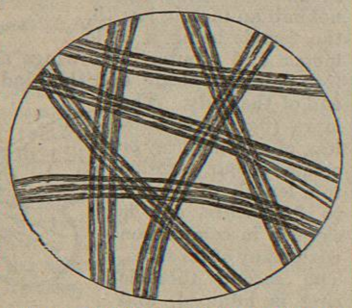

FIG. 5.—Microscopic appearance of Silk of *Bombyx mori.*

FIG. 6.—Cocoon of *Bombyx mori.*

Sericulture.

The art of sericulture concerns itself with the rearing of silkworms under artificial or domesticated conditions, their feeding, the formation of cocoons, the securing of these before they are injured and pierced by the moths, and the maturing of a sufficient number of moths to supply eggs for the cultivation of the following year. The first essential is a stock of mulberry trees adequate to feed the worms in their larval stage. The leaves preferred in Europe are those of the white-fruited mulberry, *Morus alba*, but there are numerous other species which appear to be equally suitable. The soil in which the mulberry grows, and the age and condition of the trees, are important factors in the success of silkworm cultivation; and it has been too often proved that the mulberry will grow in situations where, from the nature of the leaf the trees put forth and from other circumstances, silkworms cannot be profitably reared. An elevated position with dry friable well-drained soil produces the best quality of leaves. Throughout the East the species of mulberry cultivated are numerous, but, as these trees have been grown for special purposes at least for three thousand years, they show the complex variations peculiar to most cultivated plants.

The eggs of the silkworm, called *graine*, are hatched out by artificial heat at the period when the mulberry leaves are ready for the feeding of the larvæ. These eggs are very minute—about one hundred weighing a grain; and a vast number of hatched worms may at first be kept in a small space; but the rapid growth and voracious appetite of the caterpillars demand quickly increasing and ample space. Pieces of paper punctured with small holes are placed over the trays in which the hatching goes on; and the worms, immediately they burst their shell, creep through these openings to the light, and thereby scrape off any fragments of shell which, adhering to their skin, would kill them by constriction. The rearing-house in which the worms are fed (Fr. *magnanerie*) must be a spacious, well-lighted, and well-ventilated apartment, in which scrupulous cleanliness and sweetness of air are essential, and in which the temperature may to a certain extent be under control. The worms are more hardy than is commonly supposed, and endure variations of temperature from 62° to 78° F. without any injury; but higher temperature is very detrimental. The lower the temperature at which the worms are maintained the slower is their growth and development; but their health and vigour are increased, and the cocoon they spin is proportionately bigger. The worms increase in size with astonishing rapidity, and no less remarkable is their growing voracity. Certain races moult or cast their skin three times during their larval existence, but for the most part the silkworm moults four times—about the sixth, tenth, fifteenth, and twenty-third days after hatching. As these moulting periods approach, the worms lose their appetite and cease eating, and at each period of change they are left undisturbed and free from noise. The worms from 1 oz. of graine—numbering, say, 40,000—consume in their first stage about 6 lb of picked leaf, in the second 18 lb, in the third 60 lb, fourth 180 lb, and in their final stage 1098 lb,— in all 1362 lb of mulberry leaf; but from that is to be deducted about 590 lb of unconsumed fragments removed in the litter, giving of leaf really consumed 772 lb. An ounce of graine so treated may yield from 80 to 120 lb of cocoons, 85 per cent. of which consists of the weight of chrysalides and 15 per cent. of pure cocoon. The growth of the worms during their larval stage is thus stated by Count Dandolo :—

	Weight per 100.	Size in Lines.
Worms newly hatched	1 gr	1
After 1st moult	15 ,,	4
,, 2d ,,	94 ,,	6
,, 3d ,,	400 ,,	12
,, 4th ,,	1628 ,,	20
Greatest weight and size	9500 ,,	40

When the caterpillars are mature and ready to undergo their transformation into the pupa condition, they cease eating for some time and then begin to ascend the brushwood branches or echelletes provided for them, in which they set about the spinning of their cocoons. Crowding of positions must now be guarded against, to prevent the spinning of double cocoons (*doubions*) by two worms spinning together and so interlacing their threads that they cannot be reeled. The insects complete their cocoons in from three to four days, and in two or three days thereafter the cocoons are collected, and the pupa killed to prevent its further progress and the bursting of the shell by the fully developed moth. Such cocoons as are selected for the production of graine, on the other hand, are collected, freed from the external floss, and preserved at a temperature of from 66° to 72° Fahr., and after a lapse of from eleven to fifteen days the moths begin to make their appearance. The coupling which immediately takes place demands careful attention; the males are afterwards thrown away, and the impregnated females placed in a darkened apartment till they deposit their eggs.

Diseases.—That the silkworm is subject to many and serious diseases is only to be expected of a creature which for upwards of 4000 years has been propagated under purely artificial conditions, and these most frequently of a very insanitary nature, and where, not the healthy life of the insect, but the amount of silk it could be made to yield was the object of the cultivator. Among the most fatal and disastrous of these diseases with which the cultivator had long to grapple was "muscardine," a malady due to the development of a fungus, *Botrytis bassiana*, in the body of the caterpillar. The disease is peculiarly contagious and infectious, owing to the development of the fungus through the skin, whence spores are freed, which, coming in contact with healthy caterpillars, fasten on them and germinate inwards, giving off corpuscles within the body of the insect. Muscardine, however, has not been epidemic for many years. But about the year 1853 anxious attention began to be given in France to the ravages of a disease among silkworms, which from its alarming progress threatened to issue in national disaster. This disease, which at a later period became known as "pebrine," —a name given to it by M. de Quatrefages, one of its many investigators,—had first been noticed in France at Cavaillon in the valley of the Durance near Avignon. Pebrine manifests itself by dark spots in the skin of the larvæ; the eggs do not hatch out, or hatch imperfectly; the worms are weak, stunted, and unequal in growth, languid in movement, fastidious in feeding; many perish before coming to maturity; if they spin a cocoon it is soft and loose, and moths when developed are feeble and inactive. When sufficient vitality remains to produce a second generation it shows in increased intensity the feebleness of the preceding. The disease is thus hereditary, but in addition it is virulently infectious and contagious. From 1850 onwards French cultivators were compelled, in order to keep up their silk supply, to import graine from uninfected districts. The area of infection increased rapidly, and with that the demand for healthy graine correspondingly expanded, while the supply had to be drawn from increasingly remote and contracted regions. Partly supported by imported eggs, the production of silk in France was maintained, and in 1853 reached its maximum of 26,000,000 kilos of cocoons, valued at 117,000,000 francs. From that period, notwithstanding the importation at great cost of foreign graine, reaching in some years to 60,000 kilos, the production of silk fell off with startling rapidity: in 1856 it was not more than 7,500,000 kilos of cocoons, in 1861 and 1862 it fell as low as 5,800,000 kilos; and in 1865 it touched its lowest weight of about 4,000,000 kilos. In 1867 De Quatrefages estimated the loss suffered by France in the 13 years following 1853, from decreased production of silk and price paid to foreign cultivators for graine, to be not less than one milliard of francs. In the case of Italy, where the disease showed itself later but even more disastrously, affecting a much more extended industry, the loss in 10 years De Quatrefages stated at two milliards. A loss of £120,000,000 sterling within 13 years, falling on a limited area, and on one class within these two countries, constituted indeed a calamity on a national scale, calling for national effort to contend with its devastating action. The malady, moreover, spread eastward with alarming rapidity, and, although it was found to be less disastrous and fatal in Oriental countries than in Europe, the sources of healthy graine became fewer and fewer, till only Japan was left as an uninfected source of European graine supply.

A scourge which so seriously menaced the very existence of the silkworm in the world necessarily attracted a great amount of attention. The disease was studied by the most eminent men of science; reports and suggestions innumerable were made, and a whole pharmacopœia of remedies proposed. So early as 1849 M. Guérin Méneville observed in the blood of diseased silkworms certain vibratory corpuscles, but neither did he nor the Italian Signor Filippi, who studied them later, connect them distinctly with the disease. The corpuscles were first accurately described by Signor Cornalia, whence they are spoken of as the corpuscles of Cornalia. The French Academy charged MM. de Quatrefages, Decaisne, and Peligot with the study of the disease, and these learned men issued two elaborate reports—*Études sur les Maladies Actuelles des Vers à Soie*, 1859, and *Nouvelles Recherches sur les Maladies Actuelles des Vers à Soie*, 1860; but the suggestions they were able to offer had not the effect of stopping the march of the disease. In 1865 M. Pasteur undertook a Government commission for the investigation of the malady. Attention had been previously directed to the corpuscles of Cornalia, and it had been found, not only that they occurred in the blood, but that they gorged the whole tissues of the insect, and their presence in the eggs themselves could be microscopically demonstrated. Pasteur set himself to elucidate the life-history of these corpuscles, and he soon established (1) that the corpuscles are the special characteristic of the disease, and that these invariably manifest themselves, if not in earlier stages, then in the mature moths; (2) that the corpuscles are parasites, and not only the sign but the cause of the disease; and (3) that the disease manifests itself by heredity, by contagion with diseased worms, and by the eating of leaves on which corpuscles are spread. In this connexion he established the very important practical conclusion that worms which contract the disease during their own life-cycle retain sufficient vitality to feed, develop, and spin their cocoon, although the next generation is invariably infected and shows the disease in its most virulent and fatal form. But this fact enabled the cultivator to know with assurance whether the worms on which he bestowed his labour would yield him a harvest of silk. He had only to examine the bodies of the moths yielding his graine: if they were free from disease then a crop was sure; if they were infected the education would assuredly fail. Pasteur brought out the fact that the malady had existed from remote periods and in many unsuspected localities. He found corpuscles in Japanese cocoons and in many specimens which had been preserved for lengthened periods in public collections. Thus he came to the conclusion that the malady had been inherent in many successive generations of the silkworm, and that the epidemic condition was only an exaggeration of a normal state brought about by the method of cultivation and production of graine pursued. The cure proposed by Pasteur was simply to take care that the stock whence graine was obtained should be healthy, and the offspring would then be healthy also. Small educations reared apart from the ordinary magnanerie, for the production of graine alone, were recommended. At intervals of five days after spinning their cocoons specimens were to be opened and the chrysalides examined microscopically for corpuscles. Should none have appeared till towards the period of transformation and escape of the moths, the eggs subsequently hatched out might be depended on to yield a fair crop of silk: should the moths prove perfectly free from corpuscles after depositing their eggs the next generation would certainly live well through the larval stage. For special treatment towards the regeneration of an infected race, the most robust worms were to be selected, and the moths issuing from the cocoons were to be coupled in numbered cells, where the female was to be confined till she deposited her eggs. The bodies of both male and female were to be examined for corpuscles, and the eggs of those found absolutely free from taint were preserved for similar "cellular" treatment in the following year. By this laborious and painstaking method it has been found possible to re-establish a healthy stock of valuable races from previously highly-infected breeds. The rearing of worms in small educations under special supervision has been found to be a most effective means of combating pebrine. In the same way the rearing of worms for graine in the open air, and under as far as possible natural conditions, has proved equally valuable towards the development of a hardy, vigorous, and untainted stock. The open-air education was originally proposed by Dr Chavannes of Lausanne, and largely carried out in the canton of Vaud by M. Roland, who reared his worms on mulberry trees enclosed within "manchons" or cages of wire gauze and canvas. The insects appeared quickly to revert to natural conditions; the moths brought out in open air were strongly marked, lively, and active, and eggs left on the trees stood the severity of the winter well, and hatched out successfully in the following season. M. Roland's experience demonstrated that not cold but heat is the agent which saps the constitution of the silkworm and makes it a ready prey to disease.

Wild Silks.—The ravages of pebrine and other diseases had the effect of attracting prominent attention to the numerous other insects, allies of the mulberry silkworm, which spin serviceable cocoons. It had been previously pointed out by Captain Hutton, who devoted great attention to the silk question as it affects the East Indies, that at least six species of *Bombyx*, differing from *B. mori*, but also mulberry-feeding, are more or less domesticated in India. These include *B. textor*, the boropooloo of Bengal, a large species having one generation yearly and producing a soft flossy cocoon; the Chinese monthly worm, *B. sinensis*, having several generations, and making a small cocoon; and the Madrasi worm of Bengal (*B. crœsi*), the Dassee or Desi worm of Bengal (*B. fortunatus*), and *B. arracanensis*, the Burmese worm,—all of which yield several generations in the year and form reelable cocoons.

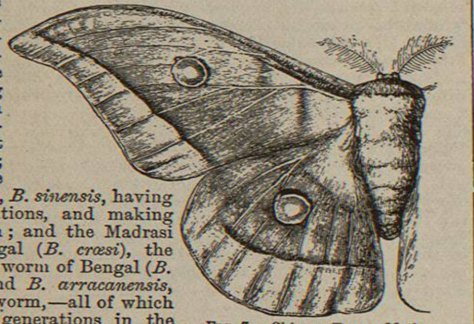

Fig. 7.—Chinese Tussur Moth, *Antheræa pernyi* (male).

Besides these there are many other mulberry-feeding *Bombycidæ* in the East, principally belonging to the genera *Theophila* and *Ocinara*, the cocoons of which have not attracted cultivators. The moths yielding wild silks which have obtained most attention belong to the extensive and handsome family *Saturnidæ*. The most important of the species at the present time is the Chinese tussur or tasar worm, *Antheræa pernyi* (figs. 7, 8), an oak-feeding species, native of Mongolia, from which is derived the greater part of the so-called tussur silk now imported into Europe. Closely allied to this is the Indian tussur moth (fig. 9) *Antheræa mylitta*, found throughout the whole of India feeding on the bher tree, *Zizyphus jujuba*, and on many other plants.

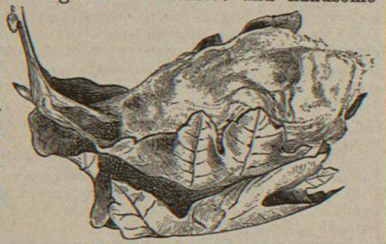

Fig. 8.—Cocoon of *Antheræa pernyi*.

It yields a large compact cocoon (fig. 10) of a silvery grey colour, which Mr Thomas Wardle of Leek, who has devoted a great amount of attention to the wild-silk question, has succeeded in reeling. Next in promising qualities is the muga or moonga worm of Assam, *Antheræa assama*, a species to some extent domesticated in its native country. The yama-mai worm of Japan, *Antheræa* (*Samia*) *yama-mai*, an oak-feeder, is a race of considerable importance in Japan, where it was said to be jealously guarded against foreigners. Its eggs were first sent to Europe by M. Duchêne du Bellecourt, French consul-general in Japan in 1861; but early in March following they hatched out, when no leaves on which the larvæ would feed were to be found. In April a single worm got oak-buds, on which it throve, and ultimately spun a cocoon whence a female moth issued, from which M. Guérin Méneville named and described the species. A further supply of eggs was secretly obtained by a Dutch physician M. Pompe van Meedervoort in 1863, and, as it was now known that the worm was an oak-feeder, and would thrive on the leaves of European oaks, great results were anticipated from the cultivation of the yama-mai. These expectations, however, for various reasons, have been disappointed. The moths hatch out at a period when oak leaves are not ready for their feeding, and the silk is by no means of a quality to compare with that of the common mulberry worm.

Fig. 9.—*Antheræa mylitta* (female).

The mezankoorie moth of the Assamese, *Antheræa mezankooria*, yields a valuable cocoon, as does also the Atlas moth, *Attacus atlas*, which has an omnivorous larva found throughout India, Ceylon, Burmah, China, and Java. The Cynthia moth, *Attacus cynthia*, is domesticated as a source of silk in certain provinces of China, where it feeds on the *Ailanthus glandulosa*. The eria or arrindi moth of Bengal and Assam, *Attacus ricini*, which feeds on the castor-oil plant, yields seven generations yearly, forming loose flossy orange-red and sometimes white cocoons. The ailanthus silkworm of Europe is a hybrid between *A. cynthia* and *A. ricini*, first obtained by Guérin Méneville, and now spread through many silk-growing regions. These are only a few of the moths from which silks of various usefulness can be produced; but none of these presents qualities, saving perhaps cheapness alone, which can put them in competition with common silk.

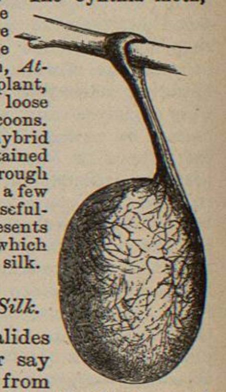

Fig. 10.—Cocoon of *Antheræa mylitta*.

Physical and Chemical Relations of Silk.

Common cocoons enclosing chrysalides weigh each from 16 to 50 grains, or say from 300 to 600 of small breeds and from 270 to 300 of large breeds to the ℔. One-seventh of this weight is pure cocoon, and of that not more than one-half is obtainable as reeled silk, the remainder consisting of surface floss and of hard gummy husk or "knub." The total length of double thread or "bave" which the silk-worm winds into its cocoon may amount to 4000 yards; the quantity reelable therefrom rarely exceeds 900 yards, and may range from 330 to 650 yards. It is found that the reelable fibre is as a rule thickest and strongest at the middle portion, tapering down very notably towards each extremity. In 1885 Mr T. Wardle of Leek showed by an elaborate series of measurements that the transverse section of common silk double thread or bave measures on the average $\frac{1}{900}$ to $\frac{1}{1000}$ in. at the thinnest and from $\frac{1}{700}$ to $\frac{1}{800}$ in. at the thickest part, and in some instances the middle was one-third thicker, stronger, and more elastic than the ends. As a great deal of silk remains on the husk after reeling, it is obvious that the thread last emitted by the silkworms on the inner wall of the cocoons must be of extreme tenuity. The silk of the various species of *Antheræa* and *Attacus* is also thicker and stronger at the centre of the reeled portion than towards its extremities; but the diameter is much greater than that of common silk, and the filaments under the microscope (fig. 11) present the appearance of flat bands, the exudation from the two spinnerets being joined at their flat edges. On this account the fibres of tussur silk tend to split up into fine fibrillæ under the various preparatory processes in manufacturing, and its riband structure is the cause of the glassy lustre peculiar to the woven and finished fibres.

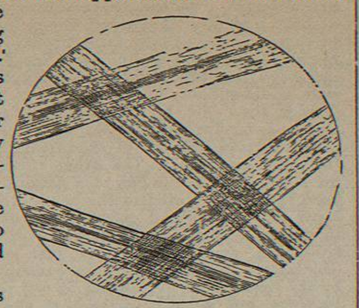

Fig. 11.—Microscopic appearance of Silk of Chinese Tussur.

Silk fibre consists essentially of a centre or core of fibroin, with a covering of sericin or silk albumen, and a little waxy and colouring matter. Fibroin, which is analogous to horn, hair, and like dermal products, constitutes about 66 per cent. of the entire mass, and has a composition represented by the formula $C_{15}H_{23}N_5O_6$. It has the characteristic appearance of pure silk,—a brilliant soft white body with a pearly lustre,—insoluble in water, alcohol, and ether, but it dissolves freely in concentrated alkaline solutions, mineral acids, strong acetic acid, and in ammoniacal solution of oxide of copper. Sericin, which constitutes the gummy covering (Fr. *gres*) of the fibre, is a gelatinous body which dissolves readily in warm soapy solutions, and in hot water, in which on cooling it forms a jelly with even as little as 1 per cent. of the substance. It is precipitated from hot solutions by alcohol, falling as a white powder. Its formula is $C_{15}H_{25}N_5O_8$. According to the researches of P. Bolley, the glands of the silkworm contain semi-liquid fibroin alone, and it is on exposure to the air that the surface is acted on by oxygen, transforming the external pellicle into the more soluble form of sericin. Silk is highly hygroscopic, taking up as much as 30 per cent. of water without feeling perceptibly damp. It is a most perfect non-conductor of electricity, and in its dry state the fibres frequently get so electrically excited as to seriously interfere with their working, so that it becomes necessary to moisten them with glycerin or soapy solutions. Silk is readily distinguished from wool and other animal fibres by the action of an alkaline solution of oxide of lead, which darkens wool, &c., owing to the sulphur they contain, but does not affect silk, which is free from that body. Again, silk dissolves freely in common nitric acid, which is not the case with wool. From vegetable fibres silk is readily distinguished by the bright yellow colour it takes from a solution of picric acid, which does not adhere to vegetable substances. The rod-like appearance of silk and its absence of markings under the microscope are also easily recognizable features of the fibre.

Silk Manufacture.

Here we must distinguish between the reeled silk and the spun or waste silk manufactures. The former embraces a range of operations peculiar to silk, dealing as they do with continuous fibres of great length, whereas in the spun silk industry the raw materials are treated by methods analogous to those followed in the treatment of other fibres. It is only floss, injured and unreelable cocoons, the husks of reeled cocoons, and other waste from reeling, with certain wild silks, which are treated by the spun silk process, and the silk thereby produced loses much of the beauty, strength, and brilliance which are characteristic of the manufactures from reeled silk.

Filature or Reeling.—When the cocoons have been gathered the chrysalides they contain are killed either by dry heat or by exposure to steam. All cocoons stained by the premature death of the chrysalides (*chiques*), pierced cocoons, double cocoons, and any from other causes rendered unreelable, are put aside for the spun-silk manufacture. Then the uninjured cocoons are by themselves sorted into classes having similar shades of colour, size, and quality of fibre. This assortment is of great consequence for the success of the reeling operations, as uniformity of quality and evenness and regularity of fibre are the most valuable features in raw silk. The object of reeling is to bring together the filaments (*bave*) from two or more (generally four or five, but sometimes up to twenty) cocoons, and to form them into one continuous, uniform, and regular strand, which constitutes the "raw silk" of commerce. To do this, the natural gum of the cocoons which holds the filaments together must be softened, the ends of the filaments of the required number of cocoons must be caught, and means must be taken to unwind and lay these filaments together, so as to form a single uniform rounded strand of raw silk. As the reeling proceeds the reeler has to give the most careful attention to the thickness of the strand being produced, and to introduce new cocoons in place of any from which the reelable silk has become exhausted. In this way a continuous uniform fibre or strand of raw silk of indefinite length is produced. The apparatus used for these purposes in some localities is of a very primitive kind, and the reeling being uneven and lumpy the silk is of inferior quality and low value. With comparatively simple appliances, on the other hand, a skilled reeler, with trained eye and delicate touch, can produce raw silk of remarkably smooth and even quality. According to the method commonly adopted in North Italy and France the cocoons are for a few minutes immersed in water a little under the boiling point, to which a small quantity of alkali has been added. A girl with a small hand brush of twigs keeps stirring them in the water till the silk softens, and the outer loose fibres (floss) get entangled with the twigs and come off till the end of the main filament (*maître brin*) is found. These ends being secured, the cocoons are transferred to a basin or tray containing water heated to from 75° to 85° Fahr., in which they float while the silk is being reeled off. If the water is too cold the gum does not soften enough and the cocoons rise out of the basin in reeling; if it is too hot the cocoons collapse and fall to the bottom. The ends of the requisite number of filaments being brought together, they are passed through an eyelet or guide, and similarly another equal set are passed through a corresponding guide. The two sets of filaments are then crossed or twisted around each other several turns as if to make one thread, after which they are separated and passed through separate guides to the reel round which they are separately wound. When a large number of cocoons are to be combined into one strand they may be reeled from the tray in four sets, which are first crossed in pairs, then combined into two, and those two then crossed and afterwards combined into a single strand. The object of crossing (*croissage*) is to round, smooth, and condense the separate filaments of each set into one strand, and as the surface of the filaments are gummy and adhesive it is found on drying that they have agglutinated into a compact single fibre of raw silk. In the most approved modern filatures there is a separate cocoon boiler (*cuiseuse*), an oblong tank containing water boiled by steam heat. In these the cocoons are immersed in rectangular perforated boxes for about three minutes, when they are transferred to the beating machine (*batteuse*), an earthenware trough having a perforated false bottom through which steam keeps the water at a temperature of from 140° to 160°. In this water the cocoons are kept stirring by small brushes rotated by mechanical means, and as the silk softens the brushes gradually rise out of the water, bringing entangled with them the loose floss, and thereby revealing the main filament of each cocoon. The cocoons are next, in sufficient number, transferred to the reeler's tray (*bacinella*), where the water is heated to about 120°. From the tray the filaments are carried through a series of porcelain and glass eyelets, so arranged that the strand returns on itself, two portions of the same strand being crossed or intertwisted for rounding and consolidation, instead of the croissage of two separate strands as in the old method. The reel to which the raw silk is led consists of a light six-armed frame, enclosed within a wooden casing having a glass frame in front, the enclosure being heated with steam-pipes. To keep the strands from directly overlaying each other and so adhering, the last guide through which the silk passes has a reciprocating motion whereby the fibre is distributed within certain limits over the reel. A sectional view of the reeling apparatus and arrangements—now in common use in Italy—is shown in fig. 12.

Throwing.—Raw silk, being still too fine and delicate for ordinary use, next undergoes a series of operations called throwing, the object of which is to twist and double it into more substantial yarn. The first operation of the silk throwster is winding. He receives the raw silk in hanks as it is taken from the reel of the filature, and putting it on a light reel of a similar construction,