SILK, 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. Among the Chinese the name of the silkworm is "si," Korean "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*.

History.—The silk industry originated in China; and according to native records it has existed there from a very remote period. The empress, known as the lady of Si-ling, wife of a famous emperor, Huang-ti (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 Korea a knowledge of the silkworm and its produce reached Japan, but not before the early part of the 3rd century. One of the most ancient books of Japanese history, the *Nihongi*, states that towards A.D. 300 some Koreans 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 Settsu. 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 head dress. The fact that sericulture was in India first estalished 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 *d'meseq* or *d'mesheq*, Amos iii. 12, a name of silk corresponding to the Arabic *dimaḳs*, 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 and supplied the Western world for more than twelve hundred years.

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 medieval 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 gave the 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 workers 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. Up to the year 1718 England depended on the thrown silks of Europe for manufacturing purposes. But in that year Lombe of Derby, disguised as a common workman, and obtaining entrance as such into one of the Italian throwing mills, made drawings of the machinery used for this process. On his return, subsidized by the government, he built and worked, on the banks of the Derwent, the first English throwing mill. 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 1865–1866, 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 *M. 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 *M. 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 *Bombycidae*, a family of *Lepidoptera* in which are embraced some of the largest and most handsome moths. *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 ½ in. 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 3½ in., 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 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 of this peculiarity to prepare from fully developed larvae silkworm gut used for casting lines in rod-fishing, and for numerous other purposes where lightness, tenacity, flexibility and strength are essential. The larvae 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 continuous and reelable thread of 800 to 1200 yds. in length, moving its head round in regular order continuously for three days or thereabouts. The thread so ejected forms the silk of commerce, which as wound in the cocoon consists of filaments seriposited from two separate glands (discovered by an Italian naturalist named Filippi) containing a glutinous or resinous secretion which serves a double purpose, viz. that of helping the thin viscous threads through their final outlets, and the adhesion of the two filaments when brought into contact with the atmosphere.

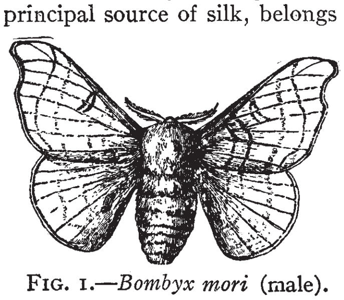

FIG. 1.—*Bombyx mori* (male).

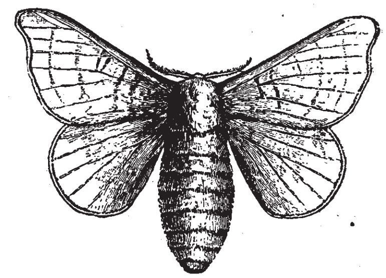

FIG. 2.—*Bombyx mori* (female).

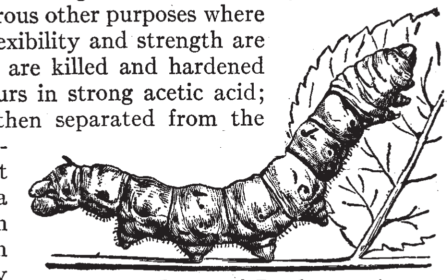

FIG. 3.—Larva of *Bombyx mori*.

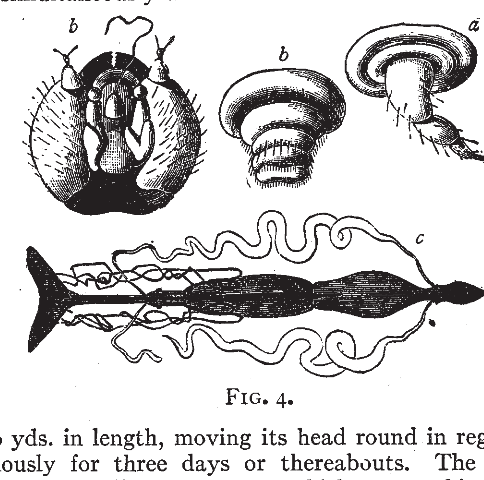

FIG. 4.

Under the microscope cocoon silk presents the appearance (fig. 5) of a somewhat flattened combination of two filaments placed side by side, being on an average $\frac{1}{1200}$ part of an inch in thickness (see also FIBRES, Plate I.). 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

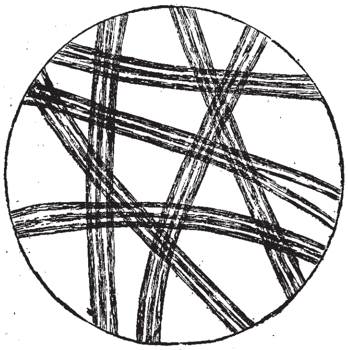

FIG. 5.—Microscopic appearance of Silk of *Bombyx mori*.

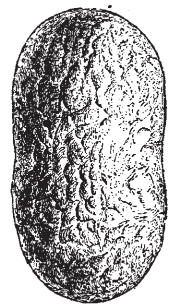

FIG. 6.—Cocoon of *Bombyx mori*.

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.

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 larvae. 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 the 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.

Laurent de l'Arbousset showed in 1905 that 1 oz. of seed of 30 grammes producing 30,000 to 35,000 silkworms (30,000 may be depended upon to reach the cocoon stage) will give a harvest of 130 to 140 ℔ fresh cocoons and an ultimate yield of about 12 ℔ raw silk properly reeled. The amount of nourishment required for this rearing is as follows:—hatching to first moult, about 9 ℔ of leaves of tender growth, equal to 40 to 45 ℔ ripe leaves; first to second moult, 24 ℔, representing 100 ℔ ripe leaves; second to third moult, 80 ℔, representing 240 ℔ ripe leaves; third to fourth moult, 236 ℔, representing 472 ℔ ripe leaves; fourth moult to mounting, 1430 ℔, representing 1540 ℔ ripe leaves, totalling to about one ton of ripe leaves for a complete rearing. 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
,, 2nd ,, ...	94 ,,	6
,, 3rd ,, ...	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 (*doupions*) by two worms spinning together and so interlacing their threads that they can only be reeled for a coarser and inferior thread. 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° F., 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 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 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 larvae; 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. So early as 1849 Guérin Méneville observed in the blood of diseased silkworms certain vibratory corpuscles, but neither did he nor the Italian Filippi, who studied them later, connect them distinctly with the disease. The corpuscles were first accurately described by Cornalia, whence they are spoken of as the corpuscles of Cornalia. The French Academy charged de Quatrefages, Decaisne and Péligot with the study of the disease, and they 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 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 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 Chavannes of Lausanne, and largely carried out in the canton of Vaud by 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. 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.

Grasserie is another form of disease incidental to the silkworm. It often appears before or after the first moult, but it is only after the fourth that it appears in a more developed form. The worm attacked presents the following symptoms: the skin is distended as if swollen, is rather thin and shiny, and the body of the worm seems to have increased, that is, it suffers from fatness, or is *engraissé*, hence its name. The disease is characterized by the decomposition of the blood; in fact it is really a form of dropsy. The blood loses its transparency and becomes milky, its volume increases so that the skin cannot hold it, and it escapes through the pores. This disease is more accidental than contagious and rarely takes very dangerous proportions. If the attack comes on a short time before maturity, the worms are able to spin a cocoon of a feeble character, but worms with this disease never change into chrysalides, but always die in the cocoon before transformation can take place. The causes which produce it are not well known, but it is generally attributable to currents of cold and damp air, to the use of wet leaves in feeding, and to sudden changes of temperature.

Another cause of serious loss to the rearers is occasioned by *Flacherie*, a disease well known from the earliest times. Pasteur showed that the origin of the disease proceeded from microscopic organisms called ferments and vitrios. One has only to ferment a certain quantity of mulberry leaves, chop them up and squeeze them, and so obtain a liquid, to find in it millions of ferments and vitrios. It invariably happens during the most active period of feeding, three or four days after the fourth moult up to the rising, and generally appears after a meal of coarse leaves, obtained from mulberries pruned the same year and growing in damp soil. *Flacherie* is an intestinal disease of the cholera species and therefore contagious. The definite course is not occasioned so much from the ferments which exist in the leaves themselves, but from an arrest of the digestive process which allows the rapid multiplication of the former in the intestines. Good ventilation is indispensable to allow the worm to give out by transpiration the great quantity of water that it absorbs with the leaf. If this exhalation is stopped or lessened the digestion in its turn is also stopped, the leaf remains longer than usual in the intestines, the microbes multiply, invading the whole body, and this brings about the sudden death which surprises the rearers. The true remedies consist in the avoidance of the fermentation of the leaves by careless gathering, transport or packing, in proper hygienic care in ventilation and in maintaining a proper degree of dryness in the atmosphere in rainy weather, and in the use of quicklime placed in different parts of the nursery to facilitate the transpiration of the silk-worms.

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. croesi*), the Dassee or Desi worm of Bengal (*B. fortunatus*) and *B. arracanensis*, the Burmese worm—all of which yield several

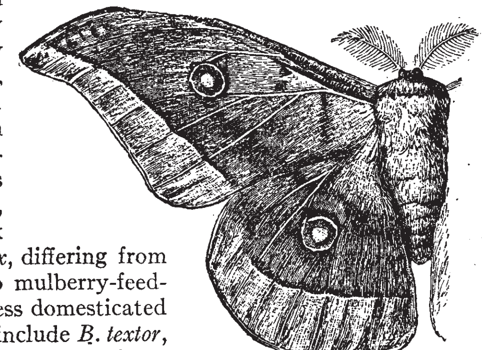

FIG. 7.—Chinese Tussur Moth, *Antheraea pernyi* (male).

generations in the year and form reelable cocoons. Besides these there are many other mulberry-feeding *Bombycidae* 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 *Saturnidae*. The most important of the species at the present time is the Chinese tussur or tasar worm, *Antheraea 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) *Antheraea mylitta*, found throughout the whole of India feeding on the bher tree, *Zizyphus jujuba*, and on many other plants. It yields a large compact cocoon (fig. 10) of a silvery grey colour, which Sir Thomas Wardle of Leek, who devoted a great amount of attention to the wild-silk question, succeeded in reeling. Next in promising qualities is the muga or moonga worm of Assam, *Antheraea assama*, a species to some extent domesticated in its native country. The yama-mai worm of Japan, *Antheraea* (*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 Duchêne du Bellecourt, French consul-general in Japan in 1861; but early in March following they hatched out, when no leaves on which the larvae 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 Guérin Méneville named and described the species. A further supply of eggs was secretly obtained by a Dutch physician 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. The mezankoorie moth of the Assamese, *Antheraea 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.

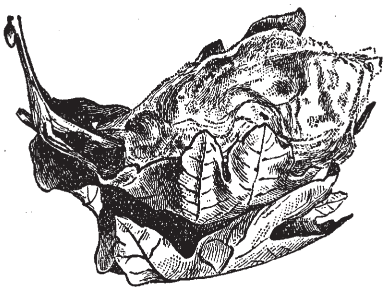

FIG. 8.—Cocoon of *Antheraea pernyi*.

FIG. 9.—*Antheraea mylitta* (female).

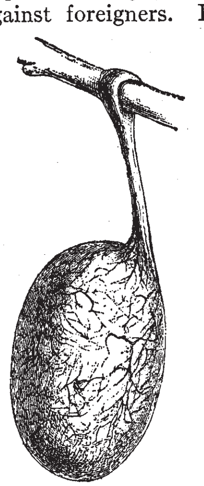

FIG. 10.—Cocoon of *Antheraea mylitta*.

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 lb. About one-sixth of this weight is pure cocoon, and of that one-half is obtainable as reeled silk, the remainder consisting of surface floss or blaze and of hard gummy husk. As the outer flossy threads and the inner vests are not reelable, it is difficult to estimate the total length of thread produced by the silkworm, but the portion reeled varies in length and thickness, according to the condition and robustness of the cocoon, in some breeds giving a result as low as 500 metres, and in others 900 to 1200 metres. Under favourable conditions it is estimated that 11 kilogrammes of fresh cocoons give 1 kilogramme of raw silk for commerce, and about the same quantity for waste spinning purposes. Sir Thomas Wardle of Leek, in his handbook on silk published in 1887, showed by a series of measurements that the diameter of a single cocoon thread or bave varied from $\frac{1}{1600}$th to $\frac{1}{2400}$th part of an inch in diameter in the various species of Bombycides, whilst those of the Saturnides or wild species varied from $\frac{1}{600}$th to $\frac{1}{1100}$th part of an inch. As this estimation presents some difficulties and divergences, the size of the thread is generally defined commercially by deniers or decigrammes, those of the Anthereas (wild silks) being said to range from 5 to 8 deniers or decigrammes, results confirmed by actual experience with the reeled thread. The silk of the various species of *Antheraea* 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 or tussore silk tend to split up into fine fibrillae 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.

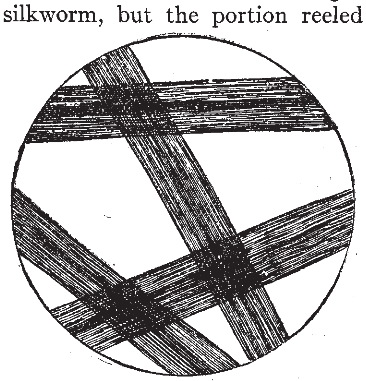

FIG. 11.—Microscopic appearance of Silk of Chinese Tussur.

Silk fibre (see FIBRES) 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 75 to 82 % 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. *grès*) 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 % 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 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. If desiccated at 250° F. it will be found to lose from 10 to 15 % of moisture according to the condition of the silk. 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 (see WEAVING). 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, 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 140° to 150° F., 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 is 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 140° to 150°. 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. Fig. 12 presents a sectional view of a reeling apparatus as used in Italy, and shows the passage of the thread from the basin to the reel, the threads being twisted around by the tavelette to give roundness to the thread, but though the principle remains much the same, great improvements have been made on this model.

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, called the swifts,

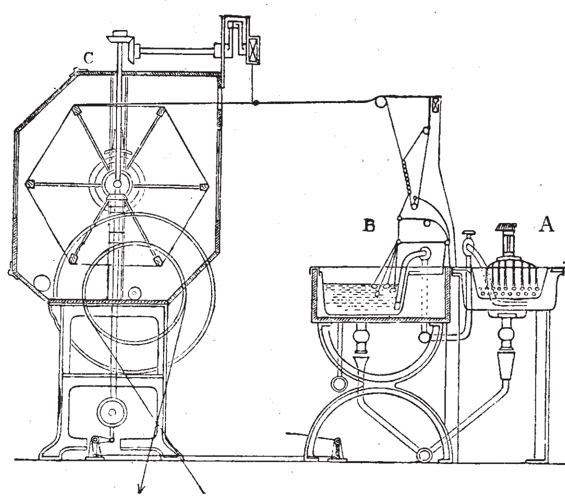

FIG. 12.

he winds it on bobbins with a rapid reciprocating motion, so as to lay the fibre in diagonal lines. These bobbins are then in general taken to the first spinning frame, and there the single strands receive their first twist, which rounds them, and prevents the compound fibre from splitting up and separating when, by the subsequent scouring operations, the gum is removed which presently binds them into one. Next follows the operation of cleaning, in which the silk is simply reeled from one bobbin to another, but on its way it passes through a slit which is sufficiently wide to pass the filament but stops the motion when a thick lump or nib is presented. In the doubling, which is the next process, two or more filaments are wound together side by side on the same reel, preparatory to their being twisted or thrown into one yarn. Bobbins to the number of strands which are to be twisted into one are mounted in a creel on the doubling frame, and the strands are passed over smooth rods of glass or metal through a reciprocating guide to the bobbin on which they are wound. Each separate strand passes through the eye of a faller, which, should the fibre break, falls down and instantly stops the machine, thus effectually calling attention to the fact that a thread has failed. The spinning or throwing which follows is done on a frame with upright spindles and flyers, the yarn as it is twisted being drawn forward through guides and wound on revolving bobbins with a reciprocating motion. From these bobbins the silk is reeled into hanks of definite length for the market. Numerous attempts have been made to simplify the silk-throwing by combining two or more operations on one machine, but not as yet with much success.

According to the qualities of raw silk used and the throwing operations undergone the principal classes of thrown silk are—(1) "singles," which consist of a single strand of twisted raw silk made up of the filaments of eight to ten cocoons; (2) tram or weft thread, consisting of two or three strands of raw silk not twisted before doubling and only lightly spun (this is soft, flossy and comparatively weak); (3) organzine, the thread used for warps, made from two and rarely three twisted strands spun in the direction contrary to that in which they are separately twisted. Silks for sewing and embroidery belong to a different class from those intended for weaving, and thread-makers throw their raw silks in a manner peculiar to themselves.

Numbering of Silk.—The metric system of weights and measures has been adopted so widely that it forms the most suitable basis for the *titrage* or counts of yarns. The permanent committee of the Paris International Congress of 1900, which was held for the purpose of unification of the numerotage of counts, unanimously decided—(*a*) With reference to cotton, silk and other textiles spun from fibres, that they should be based on a fixed weight and variable length, the unit being one metre to one gramme. Thus number 100 would be 100 metres per gramme calculated on the single strand. (*b*) With reference to raw and thrown silk, in order to enable the count to show the degrees of variation incidental to this class of material, it was decided for a basis of a fixed length and variable count weight. The length of skein adopted was 450 metres and the unit of length the half decigramme. Thus the count of silk is expressed by the number of half decigrammes which the length of 450 metres weighs. This obtains whether in the single, double or more threads joined together in the doubling.

This latter differs very little in actual practice from the previous method of determination by the number of deniers per 476 metres, the denier being calculated on the equivalent of 0·0531 gramme, the English equivalent showing $33\frac{1}{3}$ deniers per one dram avoirdupois.

As the old systems of counts have some technical conveniences they will no doubt be retained for some time. In some districts, especially in Yorkshire, the count is based on the number of yards per ounce, and in others the older method of drams avoirdupois per 1000 yard skein. The English cotton yarn and spun silk counts are reckoned upon the number of hanks of 840 yds. in 1 ℔ of silk, cotton being reckoned upon the single thread and spun silk on the doubled or finished thread. Thus $2/40^s$ cotton indicates single 40^s doubled to 20 hanks by 840 yds. to the ℔., while 40/2 fold spun silk means a single 80^s doubled to give 40 hanks of 840 yds. to the ℔. All continental conditioning establishments now formulate their tests for counts on the agreement arrived at by the International Congress of 1900.

Conditioning.—Silk in the raw and thrown state absorbs a large amount of moisture, and may contain a percentage of water without being manifestly damp. As it is largely sold by weight it becomes necessary to ascertain its condition in respect of absorbed water, and for that purpose official conditioning houses are established in all the considerable centres of silk trade. In these the silk is tested or conditioned, and a certificate of weight issued in accordance with the results. The silk is for four hours exposed to a dry heat of 230° F., and immediately thereafter weighed. To the weight 11 % is added as the normal proportion of water held by the fibre.

Scouring.—Up to this point the silk fibre continues to be comparatively lustreless, stiff and harsh, from the coating of albuminous matter (gum or *grès*) on its surface. As a preliminary to most subsequent processes the removal of the whole or some portion of this gum is necessary by boiling-off, scouring or *décreusage*. To boil off say 300 ℔ of thrown silk, about 60 ℔ of fine white soap is shred, and dissolved in about 200 gallons of pure water. This solution is maintained at a heat of 195°, and in it the hanks of raw silk are immersed, hung on a wooden rod, the hanks being continually turned round so as to expose all portions equally to the solvent influence of the hot solution. After being dried, the hanks are packed in linen bags and boiled for three hours in a weaker soapy solution, then washed out in pure warm water and dried in a centrifugal hydro-extractor. According to the amount of gum to be boiled off the soap solutions are made strong or weak; but care has to be exercised not to overdo the scouring, whereby loss of strength, substance and lustre would result. For some purposes—making of gauzes, crapes, flour-bolting cloth and for what is termed "souples"—the silk is not scoured, and for silks to be dyed certain dark colours half-scouring is practised. The perfect scouring of silks removes from 20 to 27 % of their weight, according to the character of the silk and the amount of soap or oil used in the working. Scouring renders all common silks, whether white or yellow in the raw, a brilliant pearly white, with a delicate soft flossy texture, from the fact that the fibres which were agglutinated in reeling, being now degummed, are separated from each other and show their individual tenuity in the yarn. Silks to be finished white are at this point bleached by exposure in a closed chamber to the fumes of sulphurous acid, and at the close of the process the hanks are washed in pure cold water to remove all traces of the acid.

Silk Weighting.—Into the dyeing of silk it is not here necessary to enter, except in so far as concerns a nefarious practice, carried on in dye-houses, which has exercised a most detrimental influence on the silk trade. Silk, we have seen, loses about one-fourth of its weight in scouring. To obviate that loss it has long been the practice to dye some dark silks "in the gum," the dye combining in these cases with the gum or gelatinous coating, and such silks are known as "souples." Both in the gum and in the boiled-off state silk has the peculiar property of imbibing certain metallic salts largely and combining very firmly with them, the fibre remaining to external appearance undiminished in strength and lustre, but much added to in size and weight. Silk in the gum, it is found, absorbs these salts more freely than boiled-off; so to use it for weighting there are these great inducements—a saving of the costly and tedious boiling-off, a saving of the 25 % weight which would have disappeared in boiling and a surface on which much greater sophistication can be practised than on scoured silk. In dyeing a silk black a certain amount of weight must be added; and the common practice in former times was to make up on the silk what was lost in the scouring. Up to 1857 the utmost the dyer could add was "weight for weight," but an accidental discovery that year put dyers into the way of using tin salts in weighting with the result that they were enabled to add 40 oz. to scoured silk, 120 oz. to souples and as much as 150 oz. to spun silks. This excessive adulteration quickly worked its own cure by a decreased consumption, and the weighting in practice in 1910 is confined to moderate and safer limits. The use of tin salts, especially stannic chloride, $SnCl_4$, enables dyers to weight all colours the same as black. In his "Report on English Silk Industry" to the Royal Commission on Technical Instruction (1885) Sir Thomas Wardle of Leek says:—

"Colours and white of all possible shades can very easily be imparted to this compound of silk and tin, and this method is becoming extensively used in Lyons. Thus weighting, which was until recently thought to apply only to black silks, and from which coloured silks were comparatively free, is now cheapening and deteriorating the latter in pretty much the same ratio as the former. Thus the proto- and per-salts of iron, as well as the proto- and per-salts of tin, including also a large variety of tannin, sumac, divi-divi, chestnut, valonia, the acacias (*Areca Catechu* and *Acacia Catechu* from India), from which are obtained cutch and gambier, &c., are no longer used solely as mordants or tinctorial matters, but mainly to serve the object of converting the silk into a greatly-expanded fibre, consisting of a conglomeration of more or less of these substances."

Sugar also is employed to weight silk. On this adulterant Sir Thomas Wardle remarks:—

"With a solution of sugar, silk can have its weight augmented from 1 oz. to 3 oz. per ℔. I am not quite sure that this method of weighting was not first used by the throwsters, as sugar is known to have been used for adulterating and loading gum silk for a very long time, and then the idea was afterwards applied to silk after the dyeing operations. It is much resorted to for weighting coloured silks by dyers on the continent, and, though a very clumsy method, no substitute has been found so cheap and easy of application. Bichloride of tin, having chemical affinity for silk fibre, bids fair to extinguish the use of sugar, which, from its hygrometric qualities, has a tendency to ruin the silk to which it is applied, if great care be not taken to regulate the quantity. There is not the slightest use or excuse for the application of sugar, except to cheapen the silk by about 15 to 20 %."

Wild Silk Dyeing.—Among the disadvantages under which the silks of the wild moths long laboured one of the most serious was the natural colour of the silks, and the extreme difficulty with which they took on dyes, specially the light and brilliant colours. For success in coping with this difficulty, as well as in dealing with the whole question of the cultivation and employment of wild silks, the unwearying patience and great skill of Sir Thomas Wardle of Leek deserve special mention here. The natural colour of tussur silk is a greyish fawn, and that shade it was found impossible to discharge by any of the ordinary bleaching agents, so as to obtain a basis for light and delicate dyes. Moreover, the chemical character of the tussur silk differs from that of the mulberry silk, and the fibre has much less affinity for tinctorial substances, which it takes up unevenly, requiring a large amount of dye-stuffs. After protracted experimenting Sir Thomas Wardle was able in 1873 to show a series of tussurs well dyed in all the darker shades of colour, but the lighter and bright blues, pinks, scarlets, &c., he could not produce. Subsequently Tessie du Motay found that the fawn colour of natural tussur could be discharged by solution of permanganate of potash, but the oxidizing action was so rapid and violent that it destroyed the fibre itself. Gentler means of oxidation have since been found for bleaching tussur to a fairly pale ground. The silk of the eria or castor-oil worm (*Attacus ricini*) presents the same difficulties in dyeing as the common tussur. A portion of the eria cocoons are white, while the others are of a lively brown colour, and for the dyeing of light colours the latter require to undergo a bleaching process. The silk takes up colour with difficulty from a strong vat, and is consequently costly to dye. Moonga silk from *Antheraea assama* has generally a rather dark-brown colour, but that appears to be much influenced by the leaves on which the worm feeds, the cocoons obtained on the champaca tree (*Michelia champaca*) giving a fine white fibre much valued in Assam. The dark colours are very difficult to bleach, but the silk itself takes dye-colours much more freely and evenly than either tussur or eria silk. (F. W.*)

Trade and Commerce.

About the beginning of the 19th century the chief silk-producing regions of the world were the Levant (including Broussa, Syria and Persia), India, Italy and France, the two first named sending the low-priced silk, the other two the fine qualities.

TABLE I.—*Raw Silk: Production and Importation.*

	Average for Five Years.			1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.
	1876 to 1880.	1881 to 1885.	1886 to 1890.																		
France	11,220	13,882	15,224	12,452	14,080	18,744	19,712	17,160	17,248	13,640	12,100	12,320	16,192	14,388	12,540	10,428	13,750	13,904	13,310	14,564	14,430
Italy	41,800	60,720	72,842	70,620	65,230	87,648	75,878	68,904	67,826	64,152	65,824	73,986	99,792	94,380	98,494	77,572	107,800	97,680	104,390	106,040	98,690
Spain	1,430	1,892	1,584	1,980	1,584	1,694	1,980	2,200	2,244	1,606	1,760	1,716	1,848	1,780	1,716	1,892	1,604	1,716	1,232	1,650	1,650
Austria-Hungary [1]	..	3,366	5,830	6,182	4,840	5,346	5,852	6,050	6,468	5,082	5,368	6,072	6,886	7,150	6,864	6,050	6,930	7,590	7,524	7,920	7,350
Brutia	1,870	3,080	4,092	2,970	4,532	7,216	7,816	6,600	9,130	6,952	9,064	10,692	8,360	9,196	11,066	11,572	10,934	14,212	12,188	14,630	13,530
Syria and Cyprus	3,456	5,170	6,688	6,380	7,700	11,440	10,252	8,250	9,240	10,780	10,230	10,032	9,900	9,350	11,880	11,220	10,340	10,780	10,340	11,770	10,780
Salonica and Adrianople	1,782	2,222	2,948	4,180	4,840	5,500	4,070	3,410	3,740	2,530	3,630	4,620	3,300	4,400	4,180	5,456	5,632	6,160	5,654	7,480	6,270
Bulgaria,[2] Servia and other provinces	..	..	..	..	..	..	550	792	990	814	748	924	1,672	2,112	2,860	2,992	3,366	4,180	4,070	4,730	7,750
Greece and Crete	572	418	462	660	770	990	836	924	880	946	880	748	1,100	1,320	1,430	1,320	1,430	1,540	1,650	1,672	14,30
Caucasus	..	..	..	4,180	3,960	4,400	3,850	4,070	5,500	5,280	5,060	6,820	7,700	9,680	10,230	8,800	7,920	6,380	10,010	10,780	7,920
	6,380	4,510	2,046																		
Exportations: Persia [3] and Turkey	..	..	..	..	..	..	..	660	1,056	2,310	2,926	5,412	6,820	5,610	12,100	14,300	9,372	10,120	13,816	13,420	11,570
Exportations: Shanghai [4]	72,336	53,856	60,676	84,348	89,452	92,730	83,314	93,412	85,470	86,350	102,300	120,010	101,772	111,408	79,200	93,368	92,730	88,220	93,764	96,360	124,040
Exportations: Canton	19,514	19,668	28,096	26,422	32,472	28,292	29,788	34,100	37,202	40,920	50,490	49,500	44,132	47,124	48,818	47,234	46,948	44,000	43,164	49,500	52,320
Exportations: Japan	22,726	29,920	45,232	65,868	62,876	59,070	67,848	75,020	65,978	77,154	68,684	77,924	90,750	99,000	104,940	101,376	128,194	101,618	131,825	139,700	166,540
Exportations: Calcutta and Bombay [5]	11,704	8,932	9,482	5,038	5,500	6,314	4,378	7,480	5,940	6,402	6,050	7,700	6,160	6,160	6,490	5,390	3,960	6,160	7,150	7,480	5,500
Total in Bales of 100 ℔	194,790	207,636	255,200	291,280	297,836	329,384	316,118	329,032	318,912	324,018	345,114	388,476	406,384	423,038	412,808	398,970	451,000	414,260	460,086	487,696	529,770
Price per ℔ of No. 4 Tsatlee, Maximum and Minimum [6]	28/- 15/-	17/- 13/9	15/- 11/6	14/- 11/9	13/3 12/-	14/9 11/3	11/3 9/6	10/9 9/6	10/9 10/3	10/6 9/6	11/- 10/-	14/3 11/-	14/3 11/3	11/6 9/6	10/9 9/6	14/- 12/6	13/- 11/6	13/3 12/9	16/- 13/-	17/- 14/-	11/6 9/6

[1] Austria-Hungary before 1881 was included with Italy.
[2] Before 1900 there is no account of silk from Bulgaria.
[3] Before 1897 there is no account of exportation from Persia.
[4] Before 1890 the exportation from Shanghai did not include Tussah.
[5] From 1905 the exports from India include Cashmere silks coming by Bombay.
[6] The prices are based upon the Blue Elephant Chap, although quality has deteriorated in the past few years.

Between 1840 and 1850, after the opening of trade with China, large quantities of silk were sent from the northern port of Shanghai, and afterwards also from the southern port of Canton. The export became important just at the time when disease in Europe had lessened the production on the continent. This increased production of medium silk, and the growing demand for fine sorts, induced many of the cocoon-growers in the Levant to sell their cocoons to Europeans, who reeled them in Italian fashion under the name of "Patent Brutia," thus producing a very fine valuable silk. In 1857 commenced the exportation of Japan silk, which became so fierce a competitor with Bengal silk as gradually to displace it in favour; and the native silk reeled in Bengal has almost ceased to be made, only the best European filatures, produced under the supervision of skilled Europeans, now coming forward.

China and Japan, both of which contribute so largely to the supplies that appear in European and American statistics, only export their excess growth, silk-weaving being carried on and native silk worn to an enormous extent in both countries. The other Asiatic exporting countries also maintain native silk manufactures which absorb no inconsiderable proportion of their raw material. Since about 1880 the silk production of the world (including only exports from the East) has more than doubled, the variations owing to partial failures from some countries being more than compensated by increase from others. The supplies available for European and American consumption have been carefully tabulated by the Lyons Chamber of Commerce, as shown by the table.

While the tables indicate the fluctuations of supply they show generally that Asiatic countries, in addition to supplying the necessities for their home trade, export to Europe and America about three-fifths of the whole of the silk consumed in Western manufactures.

Up to the year 1860 the bulk of the silks from the East was shipped to London, but subsequently, owing to the importance of continental demands, a large portion of the supplies has been unshipped at Genoa and Marseilles (especially the finer reeled silks from Japan and Canton), which are sold in the Milan and Lyons markets. Those for American consumption are sent direct by the Pacific route via San Francisco. Table II. shows the official annual returns of silk imports into Great Britain from 1880 to 1908.

TABLE II.—*Imports of Silk into Great Britain.*

Years.	Raw Silk.	Knubs or Husks of Silk and Waste.	Thrown Silk.	Silk (including Lace, &c.) Manufacture.
1880	3,673,949	55,002	203,567	13,329,935
1884	4,522,702	67,239	323,947	10,984,073
1888	3,065,771	83,466	559,289	10,466,537
1892	1,503,283	46,392	502,777	11,412,263
1896	1,697,668	62,923	572,599	16,923,176
1900	1,413,320	60,720	664,641	14,767,610
1901	1,332,480	48,162	624,859	13,708,645
1902	1,252,848	55,782	802,964	14,320,541
1903	1,109,930	66,782	662,677	13,493,961
1904	1,337,579	71,450	769,297	13,585,462
1905	1,160,265	72,055	878,850	13,010,766
1906	1,036,258	66,348	924,007	13,069,588
1907	1,195,366	66,299	938,112	12,862,834
1908	1,110,481	64,669	809,610	11,907,661

The power loom, owing to the improvement in its mechanism, has gained a distinct precedence and materially increased its producing power. In the development of silk manufacture the hand loom has taken a very secondary position. In order to form a relative idea of the importance of the various countries engaged in silk manufacture, a tabulation of the number of looms employed in each country would prove an inadequate guide, owing to the variations from time to time of the fabrics woven, as also to the difficulty in obtaining trustworthy statistics of the number in active operation. The production and consumption of raw material shown in Table III. was prepared by Messrs Chabrières, Morel & Co. of Lyons, Marseilles and Milan, and issued in 1905.

America takes a premier position in consumption of the raw material. The development and expansion of silk manufacture, owing to the importance and extent of the home market, coupled with high protective tariffs, has been enormous. In 1867 the import of raw material amounted to 491,983 ℔. In 1905 a record was reached of 17,812,133 ℔. During the decade of 1898 to 1908 the consumption has gone on steadily from about 10 million ℔ in the first five years to an average of 15 million ℔ in the second half of the decade. France comes a good second in importance with a consumption of 9 to 10 million ℔ annually. Lyons is the headquarters of the trade, principally in the production of dress fabrics, plain and figured, and other light and heavier fabrics. St Étienne and St Chamond are important centres for the ribbon trade. There

Table III.—*Production and Consumption of Raw Material.*

	Production. Average of Seasons 1903-1904, 1904-1905, 1905-1906.	Consumption. Same Average of Years 1902-1903, 1904.
Europe—		
France	1,276,000	9,519,400
Italy	9,233,400	2,125,200
Switzerland	99,000	3,509,000
Spain	176,000	402,600
Austria	360,800	1,707,200 (Austria and Hungary)
Hungary	323,400	
Russia and Caucasus	893,200	2,796,200
Bulgaria, Servia and Roumania	343,200	37,400
Greece and Crete	138,600	44,000
Salonica and Adrianople	574,200	66,000
Germany	Nil.	6,261,200
Great Britain	Nil.	1,559,800
America—		
United States	Nil.	13,481,600
Asia—		
Brutia	1,207,800	66,000
Syria	1,100,000	242,000
Persia (Exports)	556,600	(no estimates)
Turkestan "	600,600	"
China "	8,960,600	"
Canton, China "	4,661,800	"
Japan "	11,136,400	"
India "	563,200	770,000
Tonquin and Annam "	22,000	(no estimates)
Africa—		
Egypt	Nil.	440,000
Morocco	Nil.	154,000
Algeria, Tunis	Nil.	143,000
Various countries	Nil.	121,000
Total ℔	42,226,800	43,445,000

N.B.—The difference in the totals is owing to the figures being based on the production in seasons, and that of consumption upon calendar years.

are also important manufactures of silk at Calais, Paris, Nîmes, Tours, Avignon and Roubaix. Germany follows France with a consumption for the various fabrics of over six million ℔ annually. The principal seat of the trade in that country is at Crefeld, nearly one-half of the production of the empire being manufactured there. Velvet is the special feature of the industry, about one-half of the looms being devoted to this textile, the remainder being devoted to union satins, pure broad silk goods and ribbons. Other principal centres of the silk trade in Rhenish Prussia are Viersen, Barmen, Elberfeld and Mühlheim. The province of Saxony has also important manufactures of lace and glove fabrics. Third on the list of continental producers is Switzerland; Zürich takes the lead with broad goods (failles, armures, satins, serges, &c.), and Basel rivals St Étienne in the ribbon trade. Russia, by a prohibitive tariff on manufactured silks of other countries, has since 1890 developed and fostered a trade which consumes annually about 3 million ℔ of raw material for its home industry. This has also stimulated silk culture in the Caucasus, from which province it draws about one-third of its supplies. A special feature of its manufactures consists of gold and silver tissues and brocades for sacerdotal use. Moscow is one of the principal seats for the weaving of these fabrics. Italy, the early home of the silk trade in Europe, the land of the gorgeous velvets of Genoa and the damasks and brocades of medieval Sicily, Venice and Florence, now takes only a sixth place, the centre of greatest activity being at Como; but Genoa still makes velvets, and the brocades of Venice are not a thing of the past. Austria and England follow on the list of important silk manufactures. The former has found its principal development in Vienna and the immediate neighbourhood. By special grants from the Hungarian government silk-reeling has been fostered and encouraged. In 1885 the production of raw silk was about 300,000 ℔, while in 1905 it reached 750,000 ℔, an annual production which is still maintained.

In the United Kingdom all the silk industries (those depending on spun silk alone excepted) have been declining since the French Treaty of 1860 came into operation. This cannot be gauged by the decrease in imports of raw material from the fact before mentioned that formerly London was the centre of distribution for Eastern silk, which is now disembarked at other European ports for continental consumption. The shrinkage is the more noticeable in the throwing branch of the industry. Many of the mills formerly in operation in Derby, Nottingham, Congleton and Macclesfield have been closed owing to the importation of foreign thrown silks from Italy and France, where a lower rate of wages is paid to the operatives employed in this branch. In like manner the manufacture of silk fabrics in the districts of Manchester, Middleton, Macclesfield, London (Spitalfields) and Nottingham (for silk lace) has decreased proportionately. Against this we must set off a decided increase in the manufacture of mixed goods, carried on principally in Scotland, Yorkshire and Lancashire.

The remarkable development of the comparatively new trade in spun silk goes far to compensate for the loss of the older trade of net silk, and has enabled the exports of silk manufactures from Great Britain to be at least maintained and to show some signs of expansion. Silk spinning has chiefly developed in the Yorkshire, Lancashire, Cheshire and Staffordshire textiles centres. Its expansion and importance may be seen from the fact that the imports of waste, knubs, &c., which in 1860 was 1506 cwts., reached in 1905 a record of 72,055 cwts. But it is highly significant that while the exports of British silk manufactures have not decreased, the imports in the meantime have shown a marked expansion. Although the use of silk goods has unquestionably increased since the middle of the 19th century, the expansion of native productions has not kept pace with that growth. (R. Sn.)

The Spinning of "Silk Waste."

The term *silk waste* includes all kinds of raw silk which may be unwindable, and therefore unsuited to the throwing process. Before the introduction of machinery applicable to the spinning of silk waste, the refuse from cocoon reeling, and also from silk winding, which is now used in producing spun silk fabrics, hosiery, &c., was nearly all destroyed as being useless, with the exception of that which could be hand-combed and spun by means of the distaff and spinning wheel, a method which is still practised by some of the peasantry in India and other Eastern countries.

The supply of waste silk is drawn from the following sources: (1) The silkworm, when commencing to spin, emits a dull, lustreless and uneven thread with which it suspends itself to the twigs and leaves of the tree upon which it has been feeding, or to the straws provided for it by attendants in the worm-rearing establishments: this first thread is unreelable, and, moreover, is often mixed with straw, leaves and twigs. (2) The outside layers of the true cocoon are too coarse and uneven for reeling; and as the worm completes its task of spinning, the thread becomes finer and weaker, so both the extreme outside and inside layers are put aside as waste. (3) Pierced cocoons—*i.e.* those from which the moth of the silkworm has emerged—and damaged cocoons. (4) During the process of reeling from the cocoon the silk often breaks; and both in finding a true and

Table IV.—*Silk Goods exported from the United Kingdom.*

Year.	Raw Silk.	Knubs, Husks, Silk Waste and Noils.	Thrown and Spun Silk.		Silk Manufactures.	
			British.	Foreign and Colonial.	British.	Foreign and Colonial.
	℔.	cwts.	£	£	£	£
1860	3,153,993	1,506	826,107	426,866	1,587,303	224,366
1865	3,137,292	1,212	767,058	306,701	1,404,381	166,936
1870	2,644,402	4,167	1,154,364	39,771	1,450,397	166,297
1875	2,551,417	1,779	880,923	87,924	1,734,519	328,426
1880	947,165	9,241	683,591	7,553	2,030,659	259,023
1884	377,349	6,538	612,951	50,559	2,175,410	644,722
1888	167,086	7,438	388,828	63,192	2,664,244	727,673
1892	164,150	7,397	322,894	32,574	1,655,310	730,316
1896	142,034	5,053	265,142	74,140	1,423,174	725,123
1900	192,616	5,691	425,647	35,858	1,637,915	919,011
1901	244,566	5,370	294,311	48,666	1,429,381	1,021,637
1902	152,463	6,160	237,718	95,862	1,393,314	1,071,633
1903	178,458	9,740	256,341	81,707	1,436,734	1,038,634
1904	186,174	9,148	218,881	43,938	1,604,554	1,241,242
1905	188,246	13,524	298,299	53,825	1,693,314	1,142,217
1906	92,124	3,243	323,873	57,143	1,858,634	1,094,657
1907	80,645	5,007	401,336	47,404	2,009,613	1,490,066
1908	42,898	6,571	101,316	43,714	1,244,546	1,427,974

reelable thread, and in joining the ends, there is unavoidable waste. (5) Raw silk skeins are often re-reeled; and in this process part has to be discarded: this being known to the trade as gum-waste. The same term—gum-waste—is applied to "waste" made in the various processes of silk throwing; but manufacturers using threads known technically as organzines and trams call the surplus "manufacturer's waste." Finally we have the uncultivated varieties of silks known as "wild silks," the chief of which is tussur. The different qualities of "waste," of which there are many, vary in colour from a rich yellow to a creamy white; the chief producing countries being China, Japan, India, Italy, France and the countries in the Near East; and the best-known qualities are: steam wastes, from Canton; knubs, from China and from Italy and other Western countries; frisons, from various sources; wadding and blaze, Shanghai; china, Hangchow; and Nankin buttons; Indian and Szechuen wastes; punjum, the most lustrous of wastes; China curlies; Japan wastes, known by such terms as kikai, ostue, &c.; French, Swiss, Italian, China, Piedmont, Milan, &c. There are yellow wastes from Italy, and many more far too numerous to mention.

A silk "throwster" receives his silk in skein form, the thread of which consists of a number of silk fibres wound together to make a certain diameter or size, the separate fibre having actually been spun by the worm, and this fibre may measure anything from 500 to 1000 yds. in length. The silk-waste spinner receives his silk in quite a different form: merely the raw material, packed in bales of various sizes and weights, the contents being a much-tangled mass of all lengths of fibre mixed with much foreign matter, such as ends of straws, twigs, leaves, worms and chrysalis. It is the spinner's business to straighten out these fibres, with the aid of machinery, and then to so join them that they become a thread, which is known as spun silk.

There are two distinct kinds of spun silk—one called "schappe" and the other "spun silk" or "discharged spun silk." All silk produced by the worm is composed of two substances—fibroin, the true thread, and sericin, which is a hard, gummy coating of the "fibroin." Before the silk can be manipulated by machinery to any advantage, the gum coating must be removed, really dissolved and washed away—and according to the method used in achieving this operation the result is either a "schappe" or a "discharged yarn." The former, "schapping," is the French, Italian and Swiss method, from which the silk when finished is neither so bright nor so good in colour as the "discharged silk"; but it is very clean and level, and for some purposes absolutely essential, as, for instance, in velvet manufacture.

Schapping.—The method is as follows: If waste silk is piled in a heap in a damp, warm place, and kept moist and warm, the gum will in a few days' time begin to ferment and loosen, and can then be washed off, leaving the true thread soft and supple; but the smell caused by the fermentation is so offensive that it cannot be practised in or near towns. Therefore schappe spinners place their degumming plant in the hills, near or on a stream of pure water. The waste silk is put into large kilns and covered with hot water (temperature 170° F.). These are then hermetically closed, and left for a few hours for the gum to ferment and loosen. When thoroughly softened—the time occupied depending on the heat of the water and nature of the silk—the contents of the kiln are taken out and placed into vats of hot water, and allowed to soak there for some time. Thence the silk is taken to a washing machine, and the loosened gum thoroughly washed away. The silk is then partly dried in a hydro-extractor, and afterwards put in rooms heated by steam-pipes, where the drying is completed.

"Discharging" is the method generally used by the English, and results in a silk having brilliance and purity of colour. In this process the silk waste is put into strong, open-meshed cotton bags, made to hold (in accordance with the wish of individual spinners) from 1 ℔ to 5 ℔ in weight. When about 100 ℔ of silk has been bagged, the whole is placed in a large wooden tub and covered with boiling water in which 12 to 20 ℔ of white curd soap has previously been dissolved. In this the silk is boiled from one to two hours, than taken out and put through a hydro-extractor to remove the dirty gummy solution. Afterwards it is put into another tub of soapy liquor, and boiled from one to one and a half hours. It is then once more hydro-extracted, and finally taken to a stove and dried. "Discharged silk" must be *entirely free* from gum when finished, where "schappe" contains a percentage of gum—sometimes as much as 20%.

From this stage both classes of silk receive much the same treatment, differing widely in detail in different mills and districts.

Conditioning.—The "degummed silk," after it is dried, is allowed to absorb a certain amount of moisture, and thus it becomes soft and pliable to the touch, and properly conditioned for working by machinery.

Beating.—When the waste contains any large percentage of worm or chrysalis, it is taken to a "cocoon beater," a machine which has a large revolving disk on which the silk is put, and while revolving slowly is beaten by a leather whip or flail, which loosens the silk and knocks out the wormy matter. After the beating, the silk presents a more loose appearance, but is still tangled and mixed in length of fibre. The object of the spinner at this point is to straighten out the tangles and lumps, and to lay the fibres parallel: the first machine to assist in this process being known as an opening machine, and the second as a filling engine.

Opening and Filling.—The silk to be opened is placed on a latticed sheet or feeder, and thus slowly conveyed to a series of rollers or porcupines (rollers set with rows of projecting steel pins), which hold the silk firmly while presenting it to the action of a large receiving drum, covered with a sheet of vulcanized rubber, set all over with fine steel teeth. As the drum revolves at a good speed, the silk is drawn by the steel teeth through the porcupines into the drum in more or less straight and parallel fibres. When the teeth are full the machine is stopped, and the silk stripped off the drum, then presenting a sheet-like appearance technically known as a "lap." The lap is taken to the filling engine, which is similar in construction and appearance to the opener as far as the feeding arrangements are concerned, but the drum, in place of being entirely covered with fine steel teeth, is spaced at intervals of from 5 to 10 in. with rows of coarser straight teeth, each row set parallel with the axle of the machine. The silk drawn by the rows of teeth on the drum through the porcupine rollers (or porcupine sheets in some cases) covers the whole of the drum, hooked at certain intervals round the teeth; and when a sufficient weight is on the machine, it is stopped, and an attendant cuts, with a knife, the silk along the back of each row of teeth, thus leaving a fringe of silk hooked on the pins or teeth. This fringe of silk is placed by the attendant between two hinged boards, and whilst held firmly in these boards (called book-boards) is pulled off the machine, and is called a "strip"; the part which has been hooked round the teeth is called the "face," and the other portion the "tail." By these means the silk has been opened, straightened and then cut into a certain length, the fibres now being fairly laid parallel and ready for the next operation, known as silk dressing.

Silk Dressing.—This is the process equivalent to combing in the wool industry. Its purpose is to sort out the different lengths of fibre, and to clear such fibres of their nibs and noils. There are two well-known principles of dressing: one known as "flat frame," giving good result with discharged silk, and the other known as "circular frame" dressing, suitable for schappes.

The flat dressing frame is a box or frame holding a certain number of book-boards from the filling engine, which boards when full of silk are screwed tightly together in the frame. The frame is capable of being raised into contact with travelling combs, affixed to an endless belt placed round two metal rollers about 6 ft. apart. The attendant allows the silk to enter gradually into close contact with the combs, which comb through the silk in exactly the same manner as a lady combs her tresses. In a circular frame the silk is clamped between boards, and these are fixed on a large drum. This drum revolves slowly, and in its revolution conveys the fringes of silk past two quickly running smaller combing drums. These combing drums being covered with fine steel teeth penetrate their combs through the fringes of silk depending from the large drum, thus combing through the silk. In each machine the object is the same. First the filled silk is placed into a holding receptacle, clamped fast, and presented to combing teeth. These teeth retain a certain proportion of shorter fibre and rough places and tangled portions of silk, which are taken off the combs in a book-board or wrapped round a stick and again presented to the combs. This fibre again yields combings which will also be combed, and so on for five or six times until the combings are too short, and are taken from the machine and known as noils. The productions from these several combings are known as "drafts" and are of different lengths: the product of the filled silk first placed in the dressing frame being the longest fibre and of course the most valuable.

The flat frame is the most gentle in its usage of the silk, but is most costly in labour; whilst the circular frame, being more severe in its action, is not suitable for the thoroughly degummed silks, but on the other hand is best for silks containing much wormy matter, because the silk hanging down into the combing teeth is thoroughly cleansed of such foreign matter, which is deposited under the machine. This method also has the advantage of being cheaper in cost of labour. Recently a new machine has been invented giving the same results as circular frame: the silk depends from boxes into combs, and at the same time has the gentle action of the flat frame. The cost of the operations is as cheap as the circular frame, therefore the machine combines the advantages of each of its predecessors.

Noils.—The noils resulting from the dressing operations are sometimes combed, the comb used being similar to those used in the cotton trade. The resulting sliver is used by silk spinners who make a speciality of spinning short fibres, and the exhaust noils are bought by those who spin them up into " noil yarns " on the same principle as wool. The yarns are chiefly used by manufacturers of powder bags. The noils are also in great demand for mixing with wool to make fancy effects in wool cloths for the dress goods trade.

Drafts.—The drafts from the dressing frame are valued in accordance with their length of fibre, the longest being known as A or 1st drafts and so on:—

	1st Drafts.	2nd Drafts.	3rd Drafts.	4th Drafts.	5th Drafts.	6th Drafts.
or as quality	A	B	C	D	Shorts.	

Each draft may be worked into a quality of its own, and by such means the most level yarns are obtained. But occasionally one or more drafts are mixed together, when price is the determining factor.

Processes peculiar to Silk Spinning Industry.—The foregoing processes are all peculiar to the silk waste trade, no other fibre having to go through such processes, nor needing such machinery. In the first stages of the spun-silk industry, the silk was dressed before boiling the gum out; the resulting drafts were cut into lengths of one or two inches. The silk was then boiled and afterwards beaten, scutched, carded, drawn, spun, folded, &c., in exactly the same way as fine cotton. Short fibre silks are still put through cards and treated like cotton; but the value of silk is in its lustre, elasticity and strength, which characteristics are obtained by keeping fibres as long as possible. Therefore, when gill drawing machinery was invented, the cutting of silk into short fibres ceased, and long silks are now prepared for spinning on what is known as " long spinning process." Following the process of dressing, the drafts have to go through a series of machines known as preparing machines: the object being to piece up the lengths of fibre, and to prepare the silk for spinning.

Preparing or Drawing Machinery.—A faller or gill drawing machine consists of a long feeding sheet which conveys silk to a pair of rollers (back rollers). These rollers present the silk to a set of fallers (steel bars into which are fixed fine steel pins), which carry forward the silk to another pair of rollers, which draw the silk through the pins of the fallers and present it to the rollers in a continuous way, thus forming a ribbon of silk called a " sliver." The fallers are travelled forwards by means of screws, and when at the end of the screw are dropped automatically into the thread of a receiving screw fixed below, which carries the fallers back to their starting point to be risen by cams into the top pair of screws thus to repeat their journey.

Silk Spreader.—This is the first of the series of drawing machines. The drafts from the dressing frame are made into little parcels of a few ounces in weight, and given to the spreader, who opens out the silk and spreads it thinly and evenly on to the feeding sheet, placing a small portion of the silk only on the sheet. Another portion is opened out and placed tail end to the first portion; and these operations are repeated until the requisite weight is spread. During this time the silk has been conveyed through the fallers and into a large receiving drum about 3 ft. in diameter, the silk being wrapped thinly and evenly all round the circumference of the drum. When the agreed-on weight is on the drum, the silk is drawn across the face of the drum parallel with its axle, and pulled off in form of a sheet, and is called a lap. This lap is thin, but presents the fibres of silk now joined and overlapped in a continuous form, the length measured by the circumference of the drum. This lap is sometimes re-spread to make it more even, and at other times taken to a drawing machine which delivers in a sliver form. This sliver is taken through a series of four other drawing machines called " four head drawing box." Eight or more slivers are put behind the first drawing head, conveyed through the fallers and made into one sliver in front of the machine. This sliver is put up behind the second drawing; eight or more ends together run through the second head again into one sliver; and so on through the third and fourth heads of drawing. All these doublings of the sliver and re-drawing are for the purpose of getting each fibre to lie parallel and to make the sliver of an equal weight over every yard of its length. From the last head of drawing the sliver is taken to a machine known as a gill rover. This is a drawing machine fitted with fallers through which the sliver is drawn, but the end from the front roller is wound on to a bobbin. The machine is fitted with 20 to 40 of these bobbins placed side by side, and its product is known as " slubbing roving," it being now a soft, thick thread of silk, measuring usually either 840 or 1260 yds. to 1 lb weight. Hitherto all the drawing has been by rollers and fallers, but in the next machine the drawing is done by rollers only.

Dandy Roving Frame.—This is a frame built with forty or more spindles. Two or three slubbing rovings are put up behind the machine opposite each spindle; each end is guided separately into back rollers and thence between smaller rollers, known as carrier rollers, to the front rollers. The back rollers revolve slowly, the front rollers quickly, thus drawing the rovings out into a thinner size or count. The product is wound on to the bobbin by means of flyer and spindle, and is known as dandied or fine roving, and is then ready for the spinning frame.

Spinning.—The spinning is done by exactly the same methods as cotton or worsted, viz. either mules, ring frames, cap or flyer frames, the choice of machine being determined by the size or count of yarn intended to be produced.

Twisting and Doubling.—If a 2-fold or 3-fold yarn is needed, then two or more ends of the spun thread are wound together and afterwards conveyed to the twisting frame for the purpose of putting the needed twist in the yarn necessary for weaving or other requirements. This process is exactly the same as in the cotton or worsted industry, ring or flyer frames being used as desired.

Weft Yarns.—These are taken straight from the spinning frame, wound on to a long paper tube and so delivered to the manufacturer ready to place in the loom shuttle.

Folded Yarns are hairy after being spun and folded, and in addition sometimes contain nibs and rough places. The fibre and nibs have to be cleaned off by means of a gassing machine so constructed that the end of silk (silk yarn) is frictioned to throw off the nibs, and at the same time is run very rapidly through a gas flame a sufficient number of times to burn off the hairy and fibrous matter without injuring the main thread. The yarn is now ready for reeling into skeins or for warping, both of which operations are common to all the textile yarns. It may be washed or dyed just as required, either in hank or in warp.

Growth of Industry and Uses of Spun Silk.—As will have been gathered, spun silk is pure silk just as much as that used by the throwster. The spinning industry has not decreased in England. The number of mills has decreased, but machinery now runs so much more quickly than formerly that more yarn is being spun on fewer spindles. The American spinning industry shows little signs of expansion in spite of a protective tariff of some 35%. The continental spinners have largely increased, but are developing into huge syndicates, all working on the schappe principle. The three chief syndicates, one each in Italy, France and Switzerland, work very much together, practically ruling the prices for yarns and raw materials.

Spun silks are used largely for silk linings, hosieries, sewing threads, elastic webbing, lace, plush and many other purposes, such as mufflers, dress goods and blouse silks; also for mixing with other fibres in form of stripes in the weaving of various fabrics, or to be used in what are known as mixed goods, *i.e.* a warp of silk and weft of some other fibre or weft of silk and a warp of cotton or other fibre. The article known as tussur spun is prepared in exactly the same manner as other spun silks, but its chief use is to make an imitation of sealskin known commercially as silk seal. (A. Mel.)