

all the evidence which has been collected it would appear that the natives of Cos (mentioned in Aristotle) received it indirectly through the Phœnicians and Persians from China. The silken webs of Cos found their way to Rome, but it was long before it was obtainable except by the wealthy. The cultivation in Europe of the worm itself did not take place until 530 A.D., when, according to Procopius, the eggs were brought from India (China) to the Emperor Justinian by some monks. In China the cultivation of silk is of the highest antiquity, and, according to Chinese authorities, it was first begun by Si-ling, the wife of the Emperor Hoang-ti (2609 B.C.), and the mulberry was cultivated for feeding silkworms only 40 years later.

Since its introduction into Europe silk culture has always formed a great branch of industry in Italy, Turkey, and Greece, and it has been carried on to some extent in France, Spain, and Portugal.

In early times the American colonists devoted much labor to the growth of the mulberry and culture of silkworms. In 1732 the Colonial government of Georgia allotted a piece of ground for a nursery plantation for white mulberry trees. Lands were granted to settlers on condition that they planted 100 of these trees on every 10 acres when cleared, 10 years being allowed for their cultivation. In 1749 the British Parliament passed an Act exempting from duty all raw silk certified to be the product of Georgia or Carolina. In the same year an Italian expert was sent to Georgia to conduct a filature—for reeling, etc.—and in 1759 receipts of cocoons at the filature exceeded 10,000 pounds, the quality of the raw silk being so good that it sold in London at three shillings a pound more than that from any other part of the world. After 1759, however, the production of silk in Georgia fell off greatly. Mansfield, Conn., became, in the latter part of the eighteenth century, an important silk-raising section, and this continued to be a fixed industry in that locality. Pennsylvania engaged in the culture about 1767, and a filature was established in Philadelphia in 1769 or 1770, and, in 1771, 2300 pounds of cocoons were brought there to reel. This State maintained the industry up to Revolutionary times. From the close of the Revolution to about 1825 silk manufacture in the United States was domestic, families making small quantities—hardly ever reaching 100 pounds per annum in a single family. Importation of silk goods in the meantime had increased, so that in 1821 it amounted to \$4,486,924. It was felt that this costly importation should be stayed, and congressional committees investigated the subject, and voluminous reports were made. This brought about the enthusiastic culture of the *Morus multicaulis*, which grew into a mania, during which a great many speculators and private buyers were ruined.

The result of this speculative incident, the financial depression of 1837, and the fact that in 1844 a blight affected all the mulberry trees in the country were disastrous to silk culture in the United States. In California, in 1860-75, the business was largely prosecuted, but did not succeed. In 1884 Congress began making appropriations for the encouragement of silk culture in the United States, and these, expended under the Department of Agriculture, were continued until 1890, when they lapsed until 1901. In the meantime considerable silk

SILK (AS. *seole*, *sioloc*, *sioluc*, OHG. *silecho*, silken robe, probably from OChurch Slav. *šelkú*, silk, from Lat. *sericum*, silk, neut. sing. of *Sericus*, from *Seres*, Gk. Σήρες, Chinese). The fibre derived from the cocoon of the silkworm (*Bombyx mori*), or from some other form of caterpillar or spider, and woven into many useful and ornamental fabrics.

Historical Sketch. Silk appears not to have been well known to the ancients; though mentioned in the translations of the Bible, authorities deny that it is in the original or was known to the Hebrews. Among the Greeks, Aristotle is the first who speaks of it. From

was grown in Utah under State bounties, and private individuals have raised cocoons and reeled the silk on hand reels for home weaving in many other States. The climate and soil of many parts of the United States seem admirably adapted to silk culture, but as yet there are no commercial reeling establishments. The first silk mill on the Western Continent was set up at Mansfield, Conn., in 1810. The manufacture was introduced into Philadelphia about 1815, and as early as 1824 the Jacquard loom began to be used there. Power looms were next introduced, and power-loom weaving begun about 1838. From 1831 to 1839 many factories were started at Windsor Locks (Conn.), Poughkeepsie (N. Y.), Philadelphia, and elsewhere, most of which failed. Burlington, N. J., became an important silk-producing locality about 1838. The industry included the culture of the mulberry tree and the raising of silkworms, as well as the manufacture of silk. Hartford, South Manchester (Conn.), Holyoke, Northampton, and Haydenville (Mass.) are among the New England towns in which silk has been manufactured extensively. But the most important centre of this industry in America is Paterson, N. J. (q.v.), where the water power of the Passaic River, facilities for transportation, etc., offer good conditions for its prosecution. The first silk mill in Paterson was set up about 1838 in the fourth floor of Samuel Colt's pistol factory and was followed by other factories, until in the years succeeding the Civil War Paterson became, and has since remained, the chief seat of silk manufacture in the United States.

Processes of Manufacture. Although raw silk, unlike other textile fibres, is a continuous thread and requires no spinning, yet its preparation for the loom includes many distinct operations. After the cocoons reserved for breeding purposes are set aside, those to be used for silk are submitted to treatment that will kill the chrysalis without injury to the cocoon, just at the time when the insect has finished spinning and is ready to force its way through its covering. Several methods have been adopted for this. The chrysalis may be destroyed in an oven heated to 60° C. or 70° C. (140°-160° F.), or by placing it in the hot sun for several days under glass, or by a steam bath. The last method was invented by Professor Castrogiovanni of Turin. The cocoons are placed under an iron receiver, where steam is applied at a uniform temperature of 212° F. One objection to this process is that the pupa sometimes bursts, soiling the silk. It is said the Chinese reel off the silks from the cocoon while the silkworm is still alive.

Reeling. In order to be able to remove the silk from the cocoon the latter is soaked in warm water, which loosens the gummy substance binding the filaments. As a single fibre has not sufficient tenacity, from 4 to 18 filaments, according to the size of the thread desired, are taken, and two threads formed by passing them through perforated metal or porcelain guides. The threads are crossed or twisted together at a given point, and again separated and passed through a second pair of guides, the temporary twisting or crossing causing the agglutination of the individual fibres of each thread. The thread is then passed through a pair of distributing guides on to the reel. Great care and skill are required in reeling silk from

cocoons to keep the thread of uniform thickness. The threads of different cocoons are not the same length, and that from the inner part of the cocoon is finer than the outside, so the filament from another cocoon must now and then be added to keep the thread even. The common reeling machine is a simple device consisting of a reel 60 to 90 inches in diameter, adjusted in a frame which contains the guides, the water basin, and means for keeping the water warm. Steam flatures are in general use, in which the heat of the water can be regulated. Reeled silk is the raw material of the silk manufacturer, called raw silk. It is shipped by silk growers in hanks of various sizes, packed in bundles or bales.

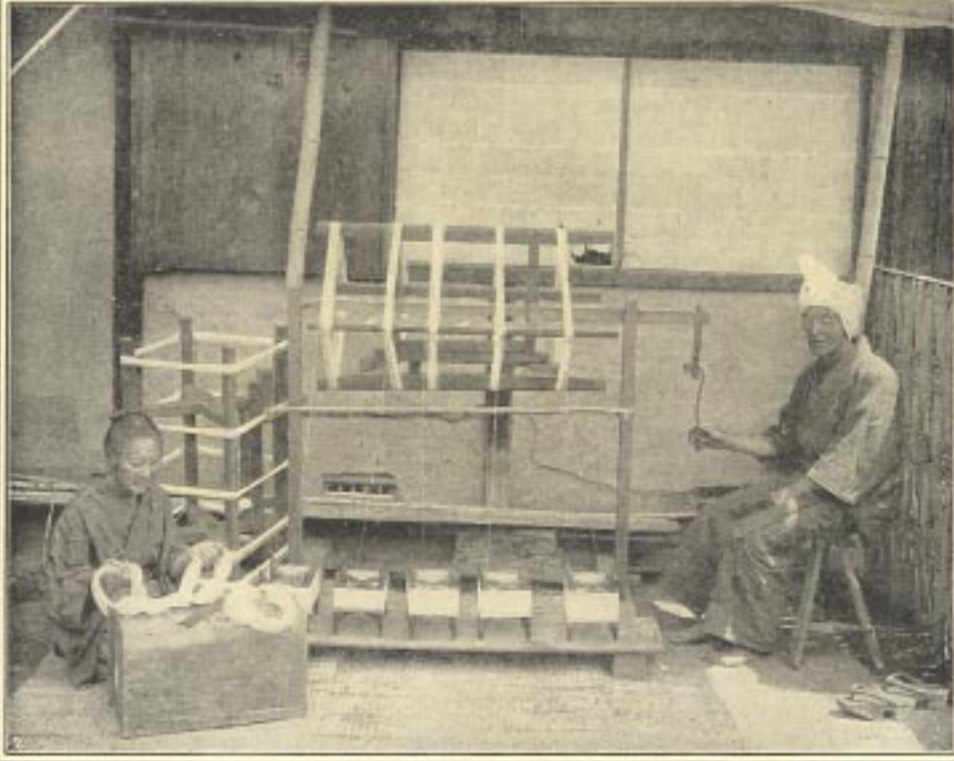
Silk Conditioning. One of the most striking physical characteristics of raw silk is its avidity for moisture; it will readily absorb 30 per cent of its weight in moisture without the fact being perceptible. In order, therefore, to determine the amount of normal silk in a given bulk, the raw silk is tested in an apparatus called a desiccator. This is done by first weighing a sample, then drying it to constant weight at 105°-110° C. (220° F.), and noting the loss of weight. To the thoroughly dried silk an allowance of 11 per cent is added and the result taken as normal weight. In the great centres of silk manufacture the testing is required by buyers and is done by special houses called silk-conditioning establishments.

Throwing. The process of preparing the reeled silk for the loom is technically called throwing. The first step is to transfer the silk from the skeins to bobbins. The skeins, inclosed in a light cotton bag, are soaked for several hours in soapy water at 110° F. They are then dried in a hydro-extractor and stretched upon swifts—skeleton reels so adjusted that they will hold the skeins tightly. Thence they are wound on bobbins. The silk is next cleaned by passing it from one bobbin to another through the cleaner, which consists of two parallel plates so adjusted that there is just room for the thread to pass through. Adhering dirt or an imperfection in the thread at once holds the thread and arrests the motion of the spindle until the operator removes the cause. The best Italian silk does not require this process, but for Chinese silk it is always necessary.

Doubling and Twisting is the next process performed, and the manner in which it is done gives the name to the three different silk threads. 1. Single silk is doubled or twisted little if at all, being usually woven direct from the cleaning process. Cloth produced in this way possesses a softness and brilliancy not obtainable in that made from twisted silk. Pongee is a familiar fabric made from singles. 2. Tram silk is made by twisting two or more single threads, which are then doubled and slightly twisted. It is used for the woof thread in weaving. 3. Organzine silk is made by the union of two or more single threads, twisted separately in the same direction, which are doubled and then retwisted in the opposite direction. It is used chiefly for warp threads.

Boiling-off is the process applied to thrown silk to remove more or less of the glue adhering to the silk thread, so it will have a greater lustre and may be able to take a better color in dyeing. According to the amount of gum removed in scouring, silk is known as boiled, in which from 24 to 30 per cent is removed; souple,

SILK



1. UNWINDING THE COCOONS

2. REELING

in which only from 5 to 12 per cent is removed; éru, in which not more than 5 per cent is removed. The boiling-off is performed in soap-suds. The silk is now ready to be dyed, although for white or pale shades it must first be bleached in sulphur fumes.

Shaking, Glossing, and Lustring are supplementary processes for which special machinery has been devised, designed to develop the lustre of the silk.

Loading or Weighting of Silk was, in the beginning, an attempt on the part of silk dyers to make up for the loss of weight, often amounting to one-fourth, incurred during the process of boiling-off, by the use of certain chemicals which, combining with the silk, took up the dye. For a time weavers were satisfied if the dyeing process was so conducted that there was no loss of weight. But the art of imparting factitious weight to silk was soon developed to a ruinous extent. Sugar and glucose were at first the favorite agents of sophistication, but were soon abandoned for more effective materials. In black silks the extreme weighting was first practiced, a pound of silk being treated so as to weigh 100 ounces. The discovery of the use of salts of tin, however, has made it possible to weight the white and colored silks as heavily as black. By this process the durability of the silken fabric, once its most prominent characteristic, is entirely lost.

Spun Silk. Before winding the cocoons a flossy portion has to be removed. (See FLOSS SILK.) After the filament has been wound off another remains like a compact bag. These, together with the silk from perforated and double cocoons and the fragments of broken thread which accumulate during the process of throwing, are sold under the name of waste silk. This waste is thoroughly cleaned by washing, boiling, and drying and is then carded and spun like cotton, the yarn thus produced being known as spun silk or fleuret silk. This greatly economizes the use of silk, as the quantity of silk waste always greatly exceeds the amount of good silk reeled off. The processes employed in the production of silk yarn or floss silk, from the waste, differ little from those for spinning other materials. Four million pounds of floss silk are annually consumed in France alone. The United States imports about 6,000,000 pounds of silk waste annually.

Wild Silk. Many silk-producing moths exist besides the *Bombyx mori*, or cultivated moth, from which the ordinary commercial silk is derived. The one at present attracting the most attention is that from which Tussah silk is manufactured, much used in connection with ordinary silk and in the manufacture of plush. Tussah silk is the product of the moth *Antheraea mylitta*, found in India. Other wild silks are the eria silk of India, the fagara silk of China, and the yamamai silk of Japan. See SILKWORM.

Other Silk. A certain amount of silk is spun by many insects. The bombycid and Saturnian moths spin the largest quantity. There is a butterfly (*Eucheira socialis*), however, whose caterpillars live in an enormous silken nest. Insects of other orders, also, have smaller silk glands and secrete some silk. In the Arachnida a number of groups produce silk, the greatest amount being spun by the spiders, and many experiments have been made to place the production of spider silk upon a commercial basis.

Silk Fabrics. The process of weaving silk

does not differ from that of weaving other fabrics, except that in Europe for the finer grades

RAW SILK PRODUCTION OF THE WORLD
FROM UNITED STATES CONSULAR REPORTS, JUNE 9, 1915

	Production in pounds	
	1913	1914
Western Europe:		
France.....	771,618	892,872
Italy.....	7,804,363	8,994,859
Spain.....	180,779	154,324
Austria-Hungary.....	601,862	272,410
Total.....	9,358,622	10,714,465
Levant and Central Asia:		
Asiatic Turkey:		
Anatolia.....	1,025,149	793,664
Syria and Cyprus.....	1,080,265	925,941
Other provinces.....	297,624	242,509
European Turkey:		
Adrianople.....	187,393	132,277
Balkans: Bulgaria, Servia, and Rumania.....	297,624	231,485
Greece, Saloniki, and Crete.....	407,885	330,693
Caucasus.....	848,780	771,618
Turkestan and Central Asia (exports).....	496,040
Persia (exports).....	462,971
Total.....	5,103,701	3,428,187
Extreme Orient:		
China:		
Exports from Shanghai.....	12,709,648	8,201,195
Exports from Canton.....	6,062,711	4,287,990
Japan:		
Exports from Yokohama.....	26,720,022	21,495,068
East Indies:		
Exports from Bengal and Kashmir.....	249,122	66,139
Indo-China (exports).....	26,456	22,046
Total.....	45,767,959	34,072,438
Grand total.....	60,230,282	48,215,090

The apparent falling off in 1914 as contrasted with 1913 was due to the state of war, which almost completely suppressed the arrivals of raw silk from Turkestan, Persia, and the extreme Orient.

the hand loom is still largely employed. (See WEAVING.) The four principal silk-woven textures are sarcenet, taffeta, satin, and velvet.

SILK AND MANUFACTURES OF SILK IMPORTED INTO THE UNITED STATES

For the fiscal year ending June 30, 1915

UNMANUFACTURED		
Cocoons.....	free	pounds... 51,495 dollars... 35,114
Raw, or as reeled from the cocoons.....	free	pounds... 26,030,925 dollars... 80,531,785
Waste.....	free	pounds... 4,970,254 dollars... 2,563,658
Total unmanufactured.....		dollars... 83,130,557
MANUFACTURES OF		
Clothing, ready-made, and other wearing apparel.....	dut.	dollars... 2,629,550
Dress and piece goods.....	dut.	dollars... 9,135,804
Laces and embroideries.....	dut.	dollars... 3,034,804
Ribbons not over 12 inches wide.....	dut.	dollars... 1,862,078
Spun silk, or schappe silk yarn.....	dut.	pounds... 2,147,975 dollars... 4,038,773
Velvets, plushes, and other pile fabrics.....	dut.	pounds... 596,509 dollars... 2,231,923
Bandings, beltings, bindings, etc. not over 12 inches wide.....	dut.	dollars... 304,326
Bolting cloths.....	free	dollars... 256,941
All other.....	dut.	dollars... 1,549,366
Total manufactures.....		dollars... 25,042,670

Statistics. According to the United States Census of 1910 there were in the country at the close of 1909 852 silk factories, with a combined

capital of \$152,158,002 and a product valued at \$133,288,072. The rapid growth of the industry during the last half of the nineteenth century and the first decade of the twentieth is shown by the fact that in 1850 there were only 67 silk factories, having a capital of \$678,300 and a product of \$1,809,476.

In 1909 there was a total of 75,406 silk looms in the United States, of which 28,915 were in New Jersey, 26,249 in Pennsylvania, 7575 in New York, 5006 in Connecticut, and 2717 in Massachusetts. During the year 1914, 51 silk mills were built, and nearly one-half of the silk product of the world was consumed in the United States. Returns for the year 1909 for the State of New Jersey gave the total number of silk establishments in that State as 348; average number of men and women employed therein, 30,285; gross value of product, \$65,429,550.

Consult: E. A. Posselt, *Structure of Fibres, Yarns, and Fabrics* (Philadelphia, 1890); Coles, *Ornament in European Silks* (London, 1899); S. P. Sadtler, *Handbook of Industrial Organic Chemistry* (Philadelphia, 1912); J. M. Matthews, *Textile Fibres: Their Physical, Microscopical, and Chemical Properties* (3d ed., New York, 1913). See also SILKWORM; SPINNING; TEXTILE MANUFACTURING; WEAVING; and bibliographies there given.