called the swifts, 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

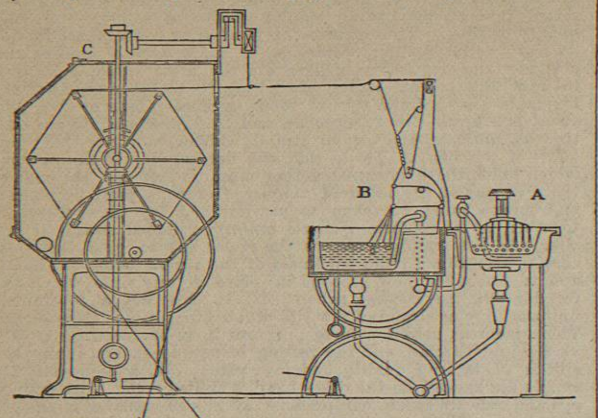

Fig. 12.

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 numbering (*titrage*) of raw and thrown silks, by which the size or fineness of the yarn is stated, is determined by constant length with variable weight, whereas other yarns are indicated by constant weight with variable length. The original standard length was 9600 Paris ells = 11,400 metres, the number being the weight in deniers of 24 grains = 1·275 grammes. This still remains the most common standard, and in practice the number is ascertained by the weight in grains, $\frac{1}{24}$ of a denier of a hank containing 476 metres (properly 475$\frac{3}{8}$ metres = 400 Paris ells). According to this standard a single cocoon filament weighs 2 to 3·5 deniers, a 3 to 4 cocoon strand ranges from 7 to 10 deniers, and a 16 or 17 cocoon strand is numbered from 48 to 52. Spun silk is numbered on a different principle. In the United Kingdom it is determined by the cotton standard, the number of skeins of 840 yards per lb. In Continental manufacturing centres generally the standard is the number of écheveaux of 500 metres contained in a half kilogramme, or, more simply, the number of kilometres per kilogramme. According to the resolution of the international congress for promoting uniformity in the numbering of yarns, held at Vienna in 1873 and at Brussels in 1874, the grade of silk ought now to be expressed by ten times the number of grammes given by a hank of 1000 metres.

These methods of indicating grades of silk give, however, only the most imperfect idea as to the quality of the thread; and specially they convey no information as to uniformity of diameter and strength. To test the raw material in respect of uniformity a most ingenious American invention, the serigraph, has been introduced, and is now largely used. The serigraph has two reels mounted on one spindle, or at least so arranged that they make precisely the same number of revolutions. The reels are covered with india-rubber, and No. 2 is 3 per cent. greater in circumference than No. 1. The silk to be tested is placed on No. 1 reel and from that wound on No. 2, which, being of greater diameter, puts a certain amount of strain on the elastic fibre. In passing from the one reel to the other the silk is carried over an agate hook attached to the bob of a pendulum, so that the strain on the yarn is communicated to the pendulum. The strain caused by the 3 per cent. tension of course varies with the strength of the yarn to which it is applied, being greater with increased strength and thickness, and falling away just as the strength of the yarn decreases. Thus the yarn in passing over the agate hook keeps by its tension the pendulum at one particular position while it is uniform, but when it increases in strength it raises the pendulum higher, and when it becomes weaker the pendulum falls. To the extremity of the pendulum is attached a pencil or marker, which traces on a web of paper, travelling at a rate in fixed proportion to the winding, the changes in the pendulum, and thus is obtained a graphic record in a most distinct manner of every variation in the strength of the silk. The precise spot where any imperfection occurs is shown on the tracing, which thus not only absolutely certifies the quality of the yarn, but also automatically measures the quantity reeled.

Conditioning.—Silk in the raw and thrown state, as has already been pointed out, absorbs a large amount of moisture, and may contain from 20 to 30 per cent. 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° Fahr., and immediately thereafter weighed. To the weight 11 per cent. 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 *gres*) 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 *decreusage.* To boil off say 300 lb of thrown silk, about 60 lb 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 French silks removes from 25 to 27 per cent. of their weight, and Chinese silks lose from 30 to 31 per cent. 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.

Spun Silk Manufacture.—The materials of the spun silk trade are—(1) the floss or loose outer fibres which surround ordinary cocoons; (2) the remains of cocoons after the reelable silk has been removed; (3) waste from throwing processes and from all the stages through which reeled silk passes in manufacturing; (4) unreelable cocoons, *i.e.*, those which are pierced, torn, or cut, stained by dead chrysalides, &c., and double cocoons; (5) cocoons of various wild silks, which are either unreelable or most profitably worked by carding. The waste spinners' first duty is to bring these diverse materials into uniform fibrous condition for spinning. In dealing with cocoons and cocoon husks, the fibres, which are gummed together into a dense compact mass, must be so washed, softened, and freed from each other that they can be readily teased and torn into a tow-like mass. For this purpose they are washed with a strong hot soap solution in a revolving washing machine, in which they are continuously subjected for three or four hours to

the action of falling stampers. From this treatment they are taken to the cold-water washing machine, where they are treated with a continuous spray of pure water whilst revolving in the tub under the action of falling stampers, as in the hot-water machine. Next the cocoons are rinsed in a spray of pure water, then the moisture is expelled in a hydro-extractor, and so, thoroughly degummed and softened, they are allowed to dry. For further treatment they are damped with a sprinkling of weak solution of Marseilles soap, then beaten either with the hand or by means of a machine. This machine has a series of leather straps attached to an endless band, which by its rapid revolution causes the straps to hit with a quick whipping stroke against the surface of a revolving tray on which are placed the washed cocoons. The beating serves to free the fibres fully from each other, and expels in the form of a fine dust the remains of chrysalides from the interior of the cocoons. It now remains only by the operation of the cocoon opener to tease out and separate the fibres into a kind of lap. The cocoon-opener is a modified carding machine, the drum or cylinder of which is covered with strong card teeth. On this drum the fibres collect as they are opened and teased out, and when the teeth are full the lap so formed is stripped off by the attendant. The silken fibres are now ready for the operations preparatory to spinning.

To bring raw waste other than cocoons to this point a different series of operations are necessary. The removal of the gum is first usually effected by a process of fermentation or maceration instead of washing with soap, whereby a great saving of soap is secured. Into a large tank a quantity of waste is packed, and soaked with a weak soapy solution which is maintained by steam at about 170°. The tank is closed over, and in the course of a few days fermentation begins, and according to circumstances is allowed to go on from two to three weeks. From time to time proof samples are withdrawn to observe the progress of the rotting, as over-fermentation would result in the same injury which arises from over-scouring,—weakness of fibre, loss of lustre, and waste of substance. By maceration the silk loses from 20 to 30 per cent. of its weight. From the maceration vat the silk is conveyed to the hot-water washing machine, where with a weak soapy solution it is washed under the influence of stampers for about five minutes. Great care is necessary to prevent the silk from cooling before this washing, as thereby the macerated slime would form an almost insoluble deposit on the silk fibre. From the hot soap solution the silk is taken to the cold-water machine, where, with the aid of stampers, it undergoes a thorough and prolonged washing. After being hung over hurdles to dry it is sprinkled with a weak solution of Marseilles soap, and then dried by means of the hydro-extractor and subsequent exposure in a heated well-ventilated chamber. At this point both cocoon waste, as already described, and floss waste are in the same condition.

The spinner has now to deal with a mass of entangled fibres of all lengths, which he must render even, parallel, and comparatively uniform in length before it can be spun. The fibres are slightly damped with a weak soapy solution and taken to a filling drum, which consists of a large cylinder having set into it, parallel with its axis, from twelve to twenty rows of strong steel spikes. A feeding apron of cloth covered with card-teeth is provided to the machine, and, as the fibre is carried forward towards the drum, a similar card-teeth-covered band travels close over the surface of the apron, so that the fibre is presented to the drum from between two sets of card-teeth. The rows of spikes catch the fibre as presented to them, draw it through the card-teeth, and carrying it with them lap it around the drum in regular combed-out order. When the spikes are sufficiently filled, the lap is cut at each set of spikes, and so stripped from the drum it forms a definite number of "stricks," of the breadth of the drum itself and the length of the space between the sets of spikes. These stricks are caught in wooden clamps or "books," which are fastened in the bed of the flat dressing frame. Over them an endless band travels, having on it at short intervals belts of heckle-teeth, called combs, which comb out doubled and short fibres, and, acting first on one end of the strick and next on the other, leave the silk in the condition of beautifully parallel and comparatively uniform flakes. The product of the first combing, called the first draft, is the longest and purest fibre. The material combed out as it fills the comb teeth is caught in books, and when itself combed out forms second drafts, shorter and less valuable than the first; and again the combings of second drafts, when combed, form third drafts still shorter. In this way five or six separate drafts or combings from the original lap are obtained, all increasingly short and impure. The final combed waste is treated by a different process for making noil or bourette yarn.

A new form of dressing-frame is now coming into favour, in which the stricks of silk have their ends rolled round wooden rods, and so secured between wooden clamps on the surface of a huge cylinder which revolves so slowly that the attendant can change and fill the clamps as the drum goes round. In its revolution the exposed portion of the silk is first combed on one side by a rapidly revolving card-toothed cylinder, from which it passes onwards to meet a second similar cylinder revolving in a contrary direction, which combs the opposite side. In the second revolution of the cylinder the portion of the strick which was previously wound on the rod is similarly combed on both sides, and thus the entire strick is rendered smooth and parallel.

The above is an outline of the ordinary process of preparing silk waste as practised in Switzerland and in the United Kingdom, &c., the range of machines being that of Messrs Greenwood and Batley of Leeds. In the great Manningham silk mills at Bradford, Mr S. C. Lister, the well-known inventor of wool-combing machinery, while using machinery of the class described, treats by patented methods peculiar to himself a great proportion of his material. According to his original process, scoured, teased, and opened waste is first drawn into a lap on a screw gill box. These laps, containing all the fibres both long and short, are taken to the circular nip combing machine, where the "top" of long fibre is drawn out as a continuous sliver and separated from the "noil" or short fibre, which according to its length is delivered at separate points. In his most recent mode of working, Mr Lister forms his waste into a broad lap on the large drum of a kind of carding engine, the drum being stripped when its teeth are filled with the prepared fibre. These laps are laid on the feeding table of a machine which has an oscillating or rocking filling head. At each oscillation the end of the lap in front of the table is "filled" on to a row of heckle-teeth parallel with it, and just as the feeding-table recedes a knife comes down between the heckles and the table with a sudden stroke and separates from the lap such fibres as have been placed or filled on to the heckle-teeth. These heckle-teeth in the meantime, being fixed on an endless band, are continuously moving forward in a horizontal direction parallel with the front of the feeding machine, and a set of three such machines place a portion of their laps on to the heckle-teeth in their progress, thus filling the teeth with a fair "bite" of silk. Immediately the heckles have passed the machines, the silk is caught and cleaned off the endless comb by pairs of endless revolving nips rising from under and descending from above, and between these nips the stricks are carried forward in the same horizontal line in which they travelled on the heckle-teeth, which here begin their return journey to be again filled. The stricks in their progress are now submitted to the combing action of revolving card-covered cylinders and card-covered cloth. Half way on in its horizontal path a second set of endless nips seize the combed portion of the silk, the uncombed portion held between the first set is released, and it in its turn is submitted to the combing action of cylinders and endless card-bands. In the end the fully dressed stricks of silk fall on a narrow feeding cloth, which has a combined reciprocating and forward motion, so that the material is spread with the utmost regularity and evenness. It passes through a set of screw gills, and is delivered into cans in the form of a most uniform and equal continuous sliver. The great advantage of these machines is the small amount of tending they require and the large quantity of dressed silk they deliver with unerring regularity.

The spinning proper of dressed waste is done precisely as in the spinning of flax yarn. The flakes are formed into a broad sliver on the spreading frame, and further attenuated and equalized on the set frame and the drawing frame, from which last the silk passes to the roving frame, where it receives its first preliminary twist and is sufficiently condensed to wind on a bobbin. The rovings are finally elongated and spun on the ordinary spinning frame, and for twisting into thread the yarns in two, three, or more strands are wound together on the doubling frame, and finally twisted as in dealing with raw silk spinning.

Spun silk, as it comes from the spinning frame, shows a good many nibs and irregularities and some roughness of surface. To remove these it is wound from one bobbin to another over an improving or cleaning and gassing machine, which consists of a frame having attached to it a number of small cone rollers, around which the yarn passes in a way which makes the entering portion of the thread rub against the portion running off. In this way, with considerable rubbing, the yarn cleans itself; and in its course over the rollers it rapidly passes through a gas flame, which singes off the fine projecting fibres, leaving the yarn clean, round, and compact. It is submitted to a further examination by eye and hand after being wound into hanks; and some yarns are finally dressed with albumen and gum solutions.

In the combing of waste silk as much as from 25 to 30 per cent. of waste in a second degree arises, much of which is very short, full of nibs and dust. From this a lower quality of yarn is spun, called noil yarn, and on the Continent "bourette" silk, to distinguish it from the "floret" silk made from first waste. On account of the shortness of staple it is worked up by machinery different from that used in the floret manufacture, being prepared by carding, and combed out with a modification of Heilmann's or Lister's combing machines. The finished noil yarn is very lumpy, and requires severe improving and singeing.

Spun silk lacks the smoothness, brilliance, and strength of raw silk yarn, but still it is an extremely valuable and useful material, and its comparative cheapness gives it an important place among the products of textile industry. It is used very largely in mixed fabrics, as well as for the cheaper ribbons, velvets, hat plush, and for many other silk woven fabrics, as also in the hosiery and glove trades and for sewing, knitting, and embroidering yarns.

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 per cent. 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 can now add 40 oz. per lb to scoured silks, 120 oz. to souples, and as much as 150 oz. to spun silks, and yet call these compounds "silk." Not only so, but 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) Mr 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 Mr Wardle remarks:—

"With a solution of sugar, silk can have its weight augmented from 1 oz. to 3 oz. per lb. 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 per cent."

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 Mr 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 Mr 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 the late M. 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, but the dyeing of light colours cannot yet be said to be a commercial success. 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 *Antheræa 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.

Trade and Commerce.

About the commencement of this 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. 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 importation of Japan silk, which became so fierce a competitor with Bengal silk as gradually to displace it in favour; and recently 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. The silk production of the world, including only the amount exported from these Oriental countries, amounts on an average to from 20,000,000 lb to 25,000,000 lb yearly; but the crop is subject to great variations.

The supply available for European consumption during recent years was thus stated, in bales of 100 lb, by the *Moniteur des Soies* of Lyons, 25th July 1885:—

	1854–55.	1875–76.	1876–77.	1877–78.	1878–79.	1879–80.	1880–81.	1881–82.	1882–83.	1883–84.	1884–85.	1885–86 (estimates). Maximum.	Minimum.
Italy	92,400	57,000	25,000	40,500	62,500	32,000	68,500	70,000	52,000	73,000	65,000	45,000	40,000
France	44,000	16,000	2,000	19,000	13,500	8,500	9,500	9,500	17,500	14,500	10,000	10,000	8,000
Spain	3,300	2,500	1,500	750	1,100	800	1,500	1,500	2,300	1,750	1,500	500	500
Greece and Asia Minor	6,600	16,000	10,000	6,000	6,000	5,000	5,000	5,000	6,000	12,000	12,000	10,000	8,000
Total bales	146,300	91,500	38,500	66,250	83,100	46,300	84,500	86,000	77,800	101,250	88,500	65,500	56,500
China	55,000	68,000	65,000	46,000	53,000	55,000	67,000	44,000	47,000	50,000	50,000	45,000	42,000
Canton	19,800	14,000	10,000	12,500	9,000	12,500	5,000	14,500	11,500	16,000	7,000	12,000	12,000
Bengal	11,000	8,492	6,000	5,000	6,000	5,000	4,000	3,000	3,000	3,000	3,000	2,000	2,000
Japan	...	14,000	13,000	22,000	22,000	14,000	15,000	15,500	25,000	25,000	20,000	15,000	12,000
Total bales	85,800	104,492	94,000	85,500	90,000	86,500	91,000	77,000	86,500	94,000	80,000	74,000	68,000
Grand total of bales	232,100	195,992	132,500	151,750	173,100	132,800	175,500	163,000	164,300	195,250	168,500	139,500	124,500
Price of Tsatlee No. 4	15s.	15s.	28s.	17s. 6d.	15s.	15s. 3d.	13s. 9d.	17s.	14s. 6d.	16s.	13s.	12s. 6d.	12s. 6d.

While these tables indicate remarkable fluctuation of supply they show generally that Asiatic countries, besides supplying their own considerable demands, send to Europe fully one half of the whole silk consumed in Western manufactures. China stands first as a silk-producing country, yielding about 35 per cent. of the entire supply; the whole produce of Italy amounts to nearly the same proportion; the exports of Japan account for about 12 per cent. of the annual supply; while in recent years France and the Levant are credited with about equal proportions.

In the United Kingdom the trade in raw silks has been in a condition of decline for a considerable number of years, much of the Chinese and Eastern produce which formerly came to London now being unshipped at Marseilles, and sold in the Lyons market, which has become the leading silk mart. But there is a very steady and continuous expansion in the demand for waste silks and cocoons for the spun silk trade. The following figures show the official annual returns of silk imports since 1860, the date of the French commercial treaty, which exposed many branches of the trade to severe and fatal competition:—

Years.	Raw Silk.	Knubs or Husks of Silk and Waste.	Thrown Silk.	Silk Manufactures.
	lb	Cwts.	lb	£
1860–65	43,137,997	132,020	543,679	30,127,878
1865–70	31,645,505	141,628	850,251	49,885,971
1870–75	34,220,037	171,166	747,505	55,116,815
1875–80	23,003,683	158,887	545,247	62,539,166
1880	3,673,949	55,002	203,567	13,324,935
1881	2,904,580	54,119	131,836	11,727,397
1882	3,377,119	44,277	294,207	11,174,573
1883	3,178,593	62,064	292,433	10,523,920
1884	4,522,702	67,239	323,947	10,984,073

The sources whence the English imports of raw silk, the commercial names under which they pass, and their relative importance and values, are exemplified in the following table, extracted from the annual circulars issued by Messrs H. W. Eaton & Sons of London:—

Description.	Imports, 1884.	Imports, 1885.	Extreme Prices during 1885.	Consumption, including Export, 1885.	Prices 1st January 1886.
China—	lb	lb	*s. d. s. d.*	lb	*s. d. s. d.*
Tsatlee [1], Haineen, &c.	2,803,572	1,001,436	9 0 to 14 6	1,225,938	9 6 to 14 6
Taysaam [2]	416,466	271,116	7 6 „ 15 0	293,964	8 0 „ 14 6
Canton	339,976	159,328	8 6 „ 12 6	469,456	9 9 „ 13 0
Szechuen	23,154	6,936	7 0 „ 11 3	17,544	7 0 „ 11 3
Japan	388,304	70,560	10 6 „ 15 6	372,176	12 0 „ 15 6
Bengal	126,450	114,000	8 0 „ 14 6	154,800	9 6 „ 15 0
Patent Brutia	8,750	7,875	19 0 „ 23 0	7,700	19 0 „ 21 0
Persian	225	...	...	...	...
Italian—					
Raw, Novi	205,610	211,700	17 0 to 21 0 20 0 „ 24 0	208,220	17 0 to 21 0 20 0 „ 24 0
Thrown	273,760	310,300	20 0 „ 25 0	307,400	20 0 „ 25 0
Total	4,586,267	2,153,251	...	3,057,198	...

In the manufacture of silken fabrics France occupies the most important position among the nations. Not only is the whole of the raw silk produced in France worked up within the country, but a very considerable proportion of that imported from the Levant and from Asia passes into the hands of the French manufacturers. In all, between 8,000,000 and 9,000,000 lb of raw silk are on an average manufactured into various textures in France. Lyons is the headquarters of the trade, and, if the surrounding regions be included, employment is given to about 120,000 looms,—20,000 of which are driven by power,—principally in the production of dress silks, plain and figured, and in other heavy silken fabrics, and at St Étienne and St Chamond in the ribbon trade. There are also important manufactures of silk at Calais, St Pierre les Calais (tulles and passementerie), Paris, Nîmes, Tours, Avignon, and Roubaix. Next to France in the extent and value of manufactures comes Germany, where the principal seat of the silk trade is at Crefeld, nearly one half of the whole production of the empire being manufactured there. The looms of Crefeld and the district it controls numbered in 1881 about 33,000, and the trade was flourishing and expansive. The manufacture of union velvets is the special feature of the industry, about one half of the looms being devoted to that textile; but Crefeld controls also a large trade in union satins, and pure silk broad goods and ribbons of all kinds. The whole value of its trade amounted in 1881 to almost £4,000,000, one-fourth of which found a market in England, and about a quarter of a million went to France. The other principal centres of the silk trade, all in Rhenish Prussia, are Viersen, Barmen, Elberfeld, and Mühlheim. Third on the list of Continental producers is Switzerland where Zurich takes the lead with broad goods (failles armures, satins, serges, &c.), and Basel rivals St Étienne in the ribbon trade. The number of looms throughout the country is estimated at 40,000, of which 4000 are power-looms. Italy—the early home of the silk trade, the land of the gorgeous velvets of Genoa and the damasks and brocades of mediæval Sicily, Venice, and Florence—has fallen from its high estate, and now employs not more than 30,000 looms, 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. In Austria the silk trade has found its principal development in Vienna and its immediate neighbourhood, the number of looms throughout the entire empire being estimated at from 15,000 to 20,000, of which 2000 are power-looms. In Russia there is, with a growing cultivation of raw silk, a considerable and increasing manufacture, the special feature of which is the weaving at Moscow of gold and silver tissues and brocades for sacerdotal use, and for traffic with Central Asia.

In the United Kingdom all the silk industries—these depending on spun silk alone excepted—have been in a depressed and declining condition ever since 1860. The principal silk manufacturing towns of England have been Coventry, Macclesfield, Congleton, Leek, Derby, London (Spitalfields), Manchester, Middleton, and Nottingham, and it is estimated that at the best period not fewer than 150,000 looms found employment in the trade. In 1872 that number was reduced to 65,000, of which 12,500 were power-looms. Spitalfields in her best days (about 1825) kept 24,000 hand-looms occupied; now there are not more than 1200. Manchester once had about 20,000 looms weaving silk; now there are not 6000 so employed. When the French treaty of 1860 came into operation Coventry had about 9000 looms, principally employed in ribbon weaving; now not more than one-fourth of that number are in operation. The cause of several of these severe changes is to be found in the introduction of the factory system of working and the extension of power-loom weaving, which crushed out domestic weaving, the original form of the silk industry; but undoubtedly also the English manufacturers were beaten in the battle of free competition brought on by the French treaty. On the other hand, the remarkable development of the

Silk and Silk Goods exported from the United Kingdom during the years 1860 to 1884 inclusive.

Year.	Raw Silk.	Knubs or Husks of Silk and Waste.	Thrown Silk. British.	Thrown Silk. Foreign and Colonial.	Silk Manufactures. British.	Silk Manufactures. Foreign and Colonial.
	lb	Cwts.	£	lb	£	£
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
1876	3,064,725	4,210	1,080,678	50,202	1,794,565	303,054
1877	1,652,935	7,450	570,999	17,910	1,705,153	229,130
1878	1,841,505	8,012	565,266	40,470	1,922,953	222,133
1879	1,375,608	5,029	694,735	24,461	1,697,209	248,495
1880	947,165	9,241	683,591	7,553	2,030,659	259,023
1881	903,997	4,528	1,008,272	5,561	2,564,730	263,826
1882	915,773	6,941	825,572	6,281	2,69[illegible],275	341,107
1883	524,182	5,216	705,825	5,596	[illegible]26,299	340,805
1884	377,349	6,538	612,951	50,559	[illegible],410	644,722

[1] The figures relating to Tsatlee comprise Re-reel, Hangchow, and Yuun-fa.
[2] The figures relating to Taysaam comprise Tussah.

comparatively new trade in spun silk goes far to compensate for the loss of the older trade, and has enabled the exports of silk manufactures from the country to be at least maintained and to show some signs of expansion. The spun-silk industry has chiefly developed in the Yorkshire and Lancashire textile centres,—Bradford, Halifax, Rochdale, &c. 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; and unquestionably, although the use of silken goods has increased very greatly within twenty-five years, the expansion of native silk manufactures has not kept pace with that growth.

Favoured by the operation of protective duties ranging from 50 to 60 per cent. *ad valorem*, the native manufacture of silk in the United States has been nursed into considerable activity and expansion, till now well-nigh one-half of the silken fabrics used in the country are of home manufacture. In 1860 the proportion of native manufacture was 13 per cent., in 1880 it reached 38 per cent., and in 1882 it was 40 per cent. of the entire consumption. Reeled silks are principally manufactured at Paterson and Hoboken, N. J., and Brooklyn and New York City, N. Y., and the spun silk industry flourishes at South Manchester and Hartford, Conn.

The following estimate of the relative importance of the silk manufacture of various countries was made in 1883 by Mr Peixotto, the United States consul at Lyons:—

France	$85,000,000	Russia	16,000,000
Germany	45,000,000	Austria	12,000,000
United States	35,000,000	Italy	12,000,000
Great Britain	25,000,000	Spain	5,000,000
Switzerland	18,000,000	Other countries	17,000,000

giving a total of $270,000,000. (J. PA.)

SILLIMAN, BENJAMIN (1779–1864), American chemist and geologist, was born in 1779 at Trumbull (then called North Stratford), Connecticut. His father, Gold Selleck Silliman, was brigadier-general in the war of the revolution, and had also held important civil positions. The history of the family points to an Italian origin, but Daniel Silliman, the first to settle in the United States, came from Holland. Silliman received his early education at Fairfield, Connecticut, at that time the residence of his father's family, and in 1792 he entered Yale College, where he graduated in 1796. He then studied law, and was admitted to the bar in 1802, while a tutor in Yale College, to which position he had been appointed in 1799. In 1802 a professorship of chemistry and natural history was established in the college, and he was at once elected to fill it. He spent portions of 1801 and 1802 in Philadelphia in preparation for his work, and the year 1804 he spent in Europe, chiefly in England and Scotland, where he attended the lectures of Hope and Gregory, and also formed the acquaintance of Davy, Wollaston, Brewster, Leslie, and other eminent men of science. As a result of this visit he published *A Journal of Travels in England, Holland, and Scotland, and of Two Passages over the Atlantic in the years 1805 and 1806* (2 vols., 1810), which had a marked success. In 1813 he began service with the medical department of Yale College as professor of chemistry and pharmacy, and continued to give instruction there for many years. In 1818 he founded the *American Journal of Science and Arts*, a periodical devoted to the physical sciences, which has been, and is, the most important American scientific serial. In 1851 he made a second journey to Europe, of which he likewise published an account in two volumes, edited by his son, who had accompanied him. In 1853 he became professor *emeritus*, but he continued to lecture for a year or two longer. His closing years were quietly spent in unabated mental activity at New Haven until his death in 1864. Though devoted to scientific pursuits, he interested himself in the public movements of the time.

One of Silliman's earliest scientific publications was an account of the famous meteorite which fell in Weston, Conn., December 14, 1807. This account, which excited great public interest in the country, was reproduced abroad, and was read before the Royal Society of London, and also before the French Academy. Among his other scientific labours may be mentioned his experiments upon the fusibility of various substances in the flame of the compound blowpipe of Hare, then a novelty in science, and upon the vaporization and transference of the carbon in the voltaic arc from the positive to the negative pole, which he was the first to observe. He also repeated the experiment by which Gay-Lussac had separated potassium from its hydrate, and obtained the element in its metallic form, doubtless for the first time in the United States. Other professional labours were an exploration of the coal formations of Pennsylvania in 1830, and an examination of the gold mines of Virginia in 1836. In 1832 and 1833, by appointment of the United States Government, he made a scientific investigation of the culture and manufacture of sugar, embodying his results in a voluminous report published by the Government. Though Silliman published a large number of scientific papers upon chemical and geological subjects, his reputation was more especially due to the courses of public lectures which he delivered in the college and in various cities and towns of the United States. The happy combination of a graceful and interesting style with unwonted splendour of experimental illustration gave these lectures an unprecedented popularity, and they exerted a powerful influence in awakening and developing a taste for scientific matters throughout the country.

Besides the works already mentioned, Silliman published in 1808 an American edition of Henry's *Chemistry*, with notes, in 1827 an edition of Bakewell's *Geology*, and in 1830 *Elements of Chemistry*, in two volumes. An account of his life, by Prof. George P. Fisher, of Yale College, was published in two volumes in 1866.

SILLIMAN, BENJAMIN (1816–1885), American chemist and physicist, son of the preceding, was born in 1816 at New Haven, Connecticut, and educated at Yale College, where he graduated in 1837. He then became assistant to his father in chemistry, mineralogy, and geology, working in his laboratory at the college, and pursuing original investigations. He began teaching in the laboratory soon afterwards. The school thus informally established was shortly afterwards recognized by a formal act of the corporation of the college, and ultimately developed into the Sheffield Scientific School of Yale College. In 1838 he became associate editor with his father of the *American Journal of Science and Arts*, and he continued in the editorship of the journal until the close of his life, Prof. J. D. Dana (his brother-in-law) having joined him in 1846. In the winter of 1845–46 he gave a course of lectures on agricultural chemistry in New Orleans, which is believed to have been the first course of lectures upon that subject ever given in the United States. In 1849 he was appointed professor of medical chemistry and toxicology in the medical department of Louisville university, Louisville, Kentucky, which position he held for five years. In 1854 he succeeded his father as professor of chemistry, and continued to give instruction in this science, first in the academical and afterwards in the medical department of Yale College, until his death in 1885. In 1853 he was connected with the exhibition at the Crystal Palace in New York, having charge of the departments of chemistry, geology, and mineralogy. As a result of this work he edited a large quarto volume, *The World of Science, Art, and Industry* (1853), followed in 1854 by *The Progress of Science and Mechanism*. He also published in 1846 *First Principles of Chemistry*, a text-book which had a wide sale and passed through three editions. In 1858 he published a manual of physics entitled *First Principles of Physics or Natural Philosophy* (2d ed. 1861). In 1864 and again in 1867 and 1872 Silliman visited California, being engaged in professional work connected with various mines and in mineralogical and geological explorations. Still later he made several visits to the mining regions of the western States and Territories, and the results of his observations formed the subjects of numerous scientific papers. In 1874, the centennial anniversary of Priestley's discovery of oxygen, he delivered at Northumberland, Pa., where Priestley had resided during the later years of his life, an historical address on "American Contributions to Chemistry," which he afterwards expanded into a considerable volume.

SILO. A modern silo is a pit or erection in which green crops are preserved in an undried condition for fodder. The term is derived from the Greek σιρός (Lat. *sirus*), a pit for holding grain. It is only of recent years that *ensilage*, *i.e.*, the preservation of green food for cattle by partial fermentation in silos, has become an important feature in agricultural economy. In various parts of Germany a method of preserving green fodder precisely similar to that used in the case of sauerkraut (see vol. iv. p. 618) has prevailed for upwards of a century. Special attention was first directed to the practice of ensilage by a French agriculturist, M. Auguste Goffart of Sologne near Orleans, who in 1877 published a work (*Manuel de la Culture et de l'Ensilage des Mais et autres Fourrages Verts*) detailing the experiences of many years in preserving green crops in silos. An English translation of M. Goffart's book by Mr J. B. Brown was published in New York in 1879, and, as various experiments had been previously made in the United States in the way of preserving green crops in pits, M. Goffart's experience attracted considerable attention. The conditions of American dairy farming proved eminently suitable for the ensiling of green maize fodder; and the success of the method was soon indisputably demonstrated among the New England farmers. The favourable results obtained in America led to much discussion and to the extensive introduction of the system in the United Kingdom, where, with different conditions, success has been more qualified, but still highly encouraging.

It has been abundantly proved that ensilage forms a wholesome and nutritious food for cattle. It can be substituted for root crops with advantage, because it is succulent and digestible; milk resulting from it is good in quality and taste; it can be secured largely irrespective of weather; it carries over grass from the period of great abundance and waste to times when none would otherwise be available; and a larger number of cattle can be supported on a given area by the use of ensilage than is possible by the use of green crops.

A silo should have a depth of at least 15 feet, and may either be a pit or a building above ground, provided it is water-tight and, as far as possible, air-tight. The crops suitable for ensilage are the ordinary grasses, clovers, lucerne, vetches, oats, rye, and maize; but various weeds may also be stored in silos with good results, notably spurrey (*Spergula arvensis*), a most troublesome plant in poor light soils. As a rule the crop should be mown when in full flower, and deposited in the silo on the day of its cutting. Fair dry weather is not essential; but it is found that when moisture, natural and extraneous, exceeds 75 per cent. of the whole, good results are not obtained. The material is spread in uniform layers over the floor of the silo, and closely packed and trodden down. If possible, not more than a foot or thereby should be added daily, so as to allow the mass to settle down closely, and to heat uniformly throughout. When the silo is quite filled a layer of straw or some other dry porous substance is spread over the surface, then it is covered with boards, and a pressure of not less than 100 ℔ per square foot is applied by weighting or other mechanical means.

A silo thus contains, to begin with, a mass of living vegetable cells surrounded with a minimum of oxygen. The activity of the cells continuing, oxygen is absorbed and carbonic acid evolved, and part of the starch of the plants is converted into sugar. In the atmosphere of carbonic acid thus created the acid ferments manifest their vitality, and acetic, lactic, and butyric acids are developed at the expense of the starch and sugar. These chemical changes are accompanied with an evolution of heat, and the temperature of the mass rises, till, when it attains 122° Fahr., the action of the ferments is arrested. Should the heat rise to 150° the vitality of the vegetable cells themselves is destroyed; and also when the available oxygen is exhausted chemical change ceases and sweet silage is produced. When from excess of moisture or other cause the temperature of the silo does not reach 122° Fahr., the acid ferments are not killed, and they go on evolving chiefly acetic and lactic acids, the results being sour silage. These ferments, requiring nitrogen for their existence, act on the nitrogenous constituents of the plants, rendering the albuminoids partly soluble, evolving peptones, and by further splitting up producing amides, urea, and ammonia. The production of sour silage is accompanied by much greater transformation and loss than is incident to sweet silage; and in extreme action the material acquires a most disagreeable odour. There is, however, no sharp line of distinction between the two, and both varieties are eaten freely by stock. Frequently a considerable loss occurs around the edges, and at other points where air gets access to the mass, by mildewing. See *Report* of Select Committee.

SILURIDÆ, a large family of freshwater Fishes, flourishing in the present epoch, and represented by a great variety of forms in all the tropical and temperate regions, many of them reaching back into the Tertiary age. The principal characters of this family (termed a "suborder" by some), its position in the system, its geographical distribution, and some of the most remarkable points in the structure and life-history of its members have been already sufficiently noticed under ICHTHYOLOGY, but we have here to notice more fully the sections into which it has been divided, and certain remarkable forms which were referred to nominally only in that article.

The modifications of the vertical fins, or rather the specialization of certain portions at the expense of others, and the greater or less extent of the branchial aperture form excellent characters for subdividing the Siluroids.

I. In the *Siluridæ Homalopteræ* the vertical fins are exceedingly long, occupying nearly the whole extent of the embryonal fin, and in one genus (*Heterobranchus*) a great part of the dorsal portion retains its embryonic character, being a rayless adipose fin. All the Siluroids of this section belong to the fauna of the Old World and Australia. The rivers and lakes of tropical Africa harbour many species of the genera *Clarias* and *Heterobranchus*,—those of the Nile being known under the name of "Carmoot." One of the Nilotic species, *Clarias macracanthus*, occurs abundantly in the Lake of Galilee, and, being a long, scaleless, eel-like fish of black colour, with eight long barbels round its broad mouth, was certainly included among those which the Jews were forbidden to eat by the Mosaic law. These fish grow to a length of from 4 to 6 feet, and are eaten by the natives of tropical Africa.

II. In the *Siluridæ Heteropteræ* the dorsal fin has almost or entirely disappeared; only its foremost portion and a small adipose remnant may be preserved; on the other hand the anal portion is retained in its whole extent. The gill-membranes remain separate and overlap the isthmus. This section likewise belongs to the fauna of the Old World, and includes, among many others, the species which has given the name to the whole family *Silurus glanis*, the "Wels"

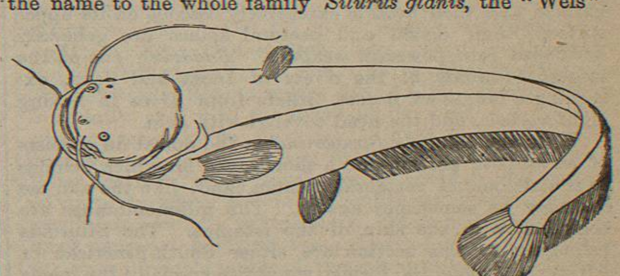

FIG. 1.—The "Wels" (*Silurus glanis*).

of the Germans. It is the only representative of the family in Europe, and with the exception of the sturgeon, is the largest freshwater fish of the Continent. It was known to Aristotle, who described it under the name of *Glanis*. It inhabits more the central and eastern portions of Europe than the western, being absent in Italy, Greece, southern Switzerland, France, and those parts of Germany which are drained by the Rhine and its affluents. In general appearance it somewhat resembles the burbot. Its head is large