SPONS' ENCYCLOPÆDIA

OF THE

INDUSTRIAL ARTS, MANUFACTURES,

AND

COMMERCIAL PRODUCTS.

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INDUSTRIAL ARTS, MANUFACTURES,

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DIVISION III.

EDITED BY

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CONTENTS:

COTTON MANUFACTURES (*continued*), DISINFECTANTS, DRUGS, DYEING AND CALICO-PRINTING, DYESTUFFS, ELECTRO-METALLURGY, EXPLOSIVES, FEATHERS, FIBROUS SUBSTANCES, FLOOR-CLOTH, FOOD PRESERVATION, FRUIT, FUR, GAS [COAL], GEMS, GLASS, GRAPHITE, HAIR, HAIR MANUFACTURES, HATS, HONEY, HOPS, HORN, ICE, INDIA-RUBBER MANUFACTURES.

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1882.

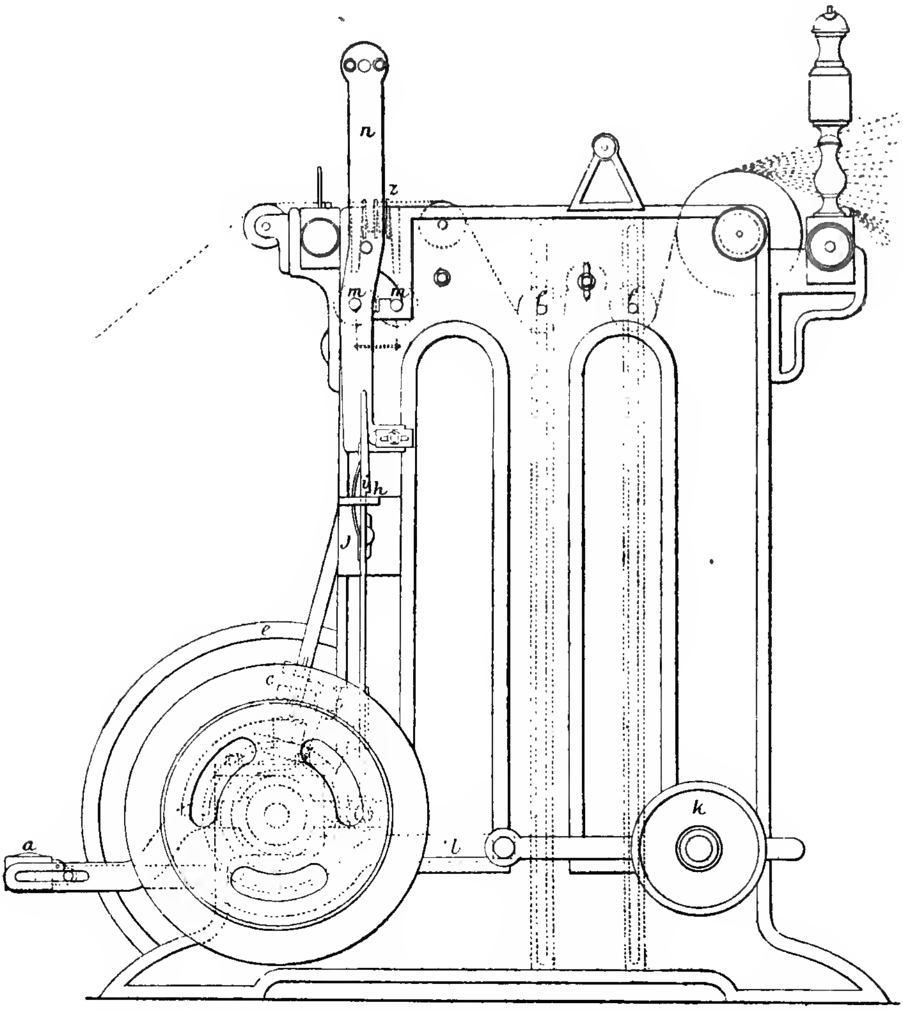
and the tin cylinder *g*, extending throughout the length of the frame, by means of a cotton driving-band. A fast and a loose pulley are fitted at one end of the frame upon the shaft that carries the tin cylinder. The traverse motion of the guide-rail is obtained from suitable gearing, and the chains *h*.

The process is as follows: The winder successively fills her skewers with cops of yarn, places them in the skewer-rail *a*, draws the threads between the guide-wires in the knee-board, and, taking a bobbin in hand, attaches the thread thereto by tying it to the yarn already upon it, or upon the empty barrel; then places the bobbin upon the revolving spindle, when the thread is drawn into and through the cleansing-brushes, and the lump-detector behind the brush, which stops anything the brushes have been unable to arrest, by breaking the thread. From here it passes upon the bobbin. The yarn is placed in layers upon the bobbin, by means of the traverse-rail. The filled bobbins are placed in receptacles, whence they are carried to the warpers.

When the winding is done from yarn in the hank, which is generally the case in using bleached, dyed, or printed yarns, the skewer rail of the above machine is replaced by reels.

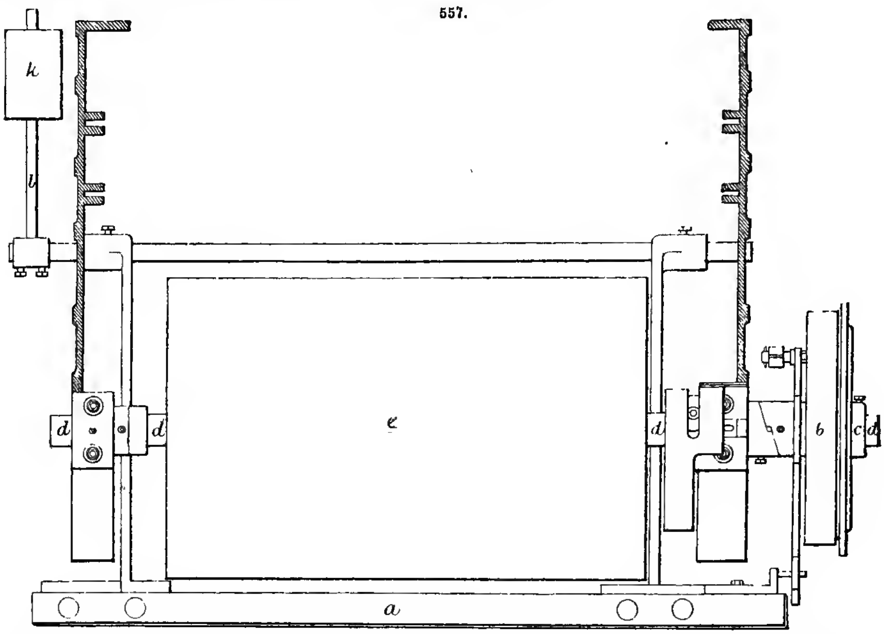
Warping.—In simplicity, this process almost equals the preceding one. But carelessness here has worse results than in the winding process. Threads dropped in warping are missed in the

556.



weaver's beam, and are often difficult to replace. When replacement is impossible, the cloth is considerably damaged. A few years ago, good warping depended entirely upon the carefulness and quickness of eye of the attendant, and, owing to the frequent lack of these qualities, much inferior work was the result. In order to obviate this, endeavours were made to supply the warping-frame with an automatic stopping apparatus, to operate whenever a thread broke. The first machine in which this was effectually accomplished was the invention of Singleton, of Darwen; it has become known as the self-stopping warping-frame. Figs. 556 and 557 show elevation and plan of this machine, which is made by Howard and Bullough, of Accrington.

557.



The following brief description will enable its operation to be easily understood. It contains the following parts: *a*, treadle; *b*, friction, or driving-pulley; *c*, friction-plate; *d*, drum-shaft; *e*, drum; *f*, drop-rollers; *h*, ledge on slide-bar; *i*, slide-bar; *j*, bracket; *k*, weight; *l*, treadle-lever; *m*, nip-rollers; *z*, drop-wires. The creel having been filled with bobbins, the threads are drawn through the reed, passed over the large roller, under the rollers *f*, over the intermediate one, and are next carried over the two succeeding rollers, whence they descend to the beam, which, however, to admit of the more easy explanation of the working parts of the machine, has been omitted from the illustration. Over the point of contact of the two last rollers, the drop-wires *z* are hung upon the threads. These wires are in shape like the following figure ∩.

The arrangements for work being complete, the treadle *a* is pressed down, which brings the friction-pulley *b* into contact with the friction-plate *c*, which sets the drum *e* slowly in motion, and brings the drop-rollers *f* into their working position. Further pressure upon the treadle, raises the ledge *h* upon the slide-bar, until it reaches the point where it is pressed upon the bracket by a spring. By these means the friction-pulley and plate are brought into such close contact as to drive the machine at its required speed. As long as the threads are unbroken, it continues in operation. Immediately a fracture occurs, the drop-wire *z* falls between the nip-rollers *m*, causing the front one to be pressed outwards, carrying with it the lower arm of the lever *n*, which pushes the slide-bar *i* out of its position in the bracket; this, falling, separates the driving-pulley and friction-plate, and thus stops the machine. The response to the drop of a wire is extremely quick. The drop-wires are suspended in position on the threads, over the nip-rollers, and are arranged in three slots, extending across the machine. Sinking into these grooves to almost the extent of their depth, the wires bring the threads into contact with the top of the frame, causing them to act as "self-flukers," or automatic scavengers, which prevents stoppages, or defective work, from an accumulation of loose fibres. The nip-rollers being placed at about 3–5 in. below the drop-wires, the machine is not stopped by a bobbin temporarily overrunning the beam, and causing slackness of the thread. The length of yarn run upon the beam is accurately measured, and shown upon an index plate. This is necessary to avoid waste, which would arise from working together beams of different lengths.

Sizing.—The beams from the warping-mill are conveyed to the sizing-machine,* in which 3–5 or 6, according to requirement, are combined to form a warp for the loom.

The sizing-frame is the most important machine in the series necessary for manufacturing. Two or three suffice for a large weaving establishment, and upon their efficiency and skilful superintendence, to a large extent depends the success of the firm. Perfect and uniform sizing is necessary to produce even results in the cloth. A few years ago, sizing, especially as conducted in the mills, was a rude process. The compounding of the size was left to the skill and discretion of some superannuated man in connection with the establishment, who probably was appointed to this duty through having, in his early days, been a hand-loom weaver, when the sizing of his own warps would fall to his lot. The utensils deemed necessary were a few tubs, a bucket, and a stout stick. The flour was put into the tubs, water was poured upon it from the bucket, and the mixture was thoroughly incorporated by means of the stick. It was usually then considered ready for use. Subsequently, it was discovered, from mixtures being left until fermentation had set in, and perhaps subsided, that size subjected to this action, had its particles of flour more minutely subdivided, and in consequence made a smoother cloth than when used fresh. This led to the extensive adoption of the use of fermented size, though new size was never without advocates. At this time, sizing was not thought of as a means of adulteration, in which capacity it was subsequently for some time used. The system of adulteration arose during the period known as the Cotton Famine, the result of the American Civil War. Eastern communities being in the habit of purchasing their textiles according to prescribed widths, lengths, and weights, were difficult to wean from this habit; and the impossibility of obtaining cotton, so as to comply with this requirement, at a reasonable price, or such price as natives of the East could pay, caused manufacturers to resort to the introduction of a substitute, which to a great extent was found in Kaolin or China clay. Cloth sized with a composition, of which this mineral formed a considerable proportion, proved very acceptable in the Eastern markets, and this enabling manufacturers to comply with requirement as to weight, the system was generally adopted. It has been still further developed, and, by the introduction of various chemical salts, cloth is now made to possess an appearance, and feel to the hand, which prove so acceptable to consumers that without these properties, especially the latter, it is practically unsaleable. So much is this the case, that cotton textiles containing no yarns finer than 30's—from which a cheap and substantial cloth can be made—admitted duty free by a recent regulation of the Indian Government, have been generally refused, unless sized to produce this peculiar sensation. What may be the cause of this it is difficult to divine. It may be that as the bulk of the cotton textiles exported to Eastern countries are consumed in clothing which is simply meant to cover, and not to warm the wearer, the presence of these minerals in a fabric may give it an advantage over one of pure fibre, in rendering it cooler.

The moral question involved has been discussed at times with a great amount of asperity, and still continues to be talked of amongst ignorant people. As a matter of fact, however, all questions of fraud or deception have long since disappeared, the consumer knowing as well as the manufacturer the character of the article he is buying, and knowingly giving it the preference. It has been thought fit to introduce these remarks, in explanation of a matter which is greatly misunderstood.

The practice of heavy sizing has, however, not been without important drawbacks. For a long time, cloth so treated proved exceedingly liable to mildew; and the damage resulting from the development of fungoid growths upon it caused great losses in numerous cases. Out of these occurrences, several important lawsuits have arisen with a view to testing the liability of the manufacturer. The two most notable instances are those of Mody *v.* Gregson, the trial of which took place some 10-12 years ago; and that of Provand *v.* Langton and Riley, which terminated in 1879. In both of these, the verdict went against the manufacturer. A different issue was tried in each case, the first being upon the manufacturer's responsibility for the damage, the fact of mildew being indisputable. The decision of this case against the defendant settled the question of liability; and in the law courts it has since formed a precedent in like cases. In the second instance the dispute hinged upon a question of fact: as to whether certain stains that the plaintiff alleged were mildew, were such or not. In this case also, the verdict was cast against the defendant. The results of these trials have laid the manufacturer under heavy responsibilities, with the nature of which he should make himself acquainted. Reports of the cases, *in extenso*, have been published, and to these the reader is referred.

Under the stimulus of necessity and risk, combined with the hope of advantage, a great deal of skill and attention have been of late years bestowed upon the question of sizing, and especially upon the composition of the size. The latter of course depends upon its purpose: whether the end to be accomplished is light, medium, or heavy sizing. These terms may be defined to mean:—1. "light sizing": that which is requisite to lay down the loose fibres of the threads, and to enable the yarn to withstand the friction and strain incident to the operation of weaving; 2. "medium sizing": in which a larger quantity is put upon the warp than is requisite for the above purpose, and in order to procure to some extent the peculiar feel remarked upon above; 3. "heavy sizing": in which the yarn is loaded to the extent of its capacity to carry the burden, consistently with retaining its adaptability for weaving. In the first case, the weight of the warp will be increased from 5–10 per cent., according to the strength of the cloth into which it has to be woven; in the second, 25–30 per cent. may be added; and in the last, this proportion will probably be doubled.

The materials that enter into the composition of size vary according to the requirement and opinion of the manufacturer. In all cases, however, they may be classified under the following heads:—Starchy matters, to lay the fibres of the yarn, and to induce close coherence; fatty substances, to reduce the harshness resulting from the former; mineral matters, generally used to procure "feel" and weight; and chemicals, chiefly introduced for antiseptic purposes. The starchy matters generally in use are wheat-flour; farina, or potato-flour; rice-flour; sago; and maize, or Indian corn-flour. The two first are in most extensive use. The fatty substances introduced for softening purposes are chiefly soap, tallow, coconut-, palm-, olive-, and castor-oils. Sometimes, a small proportion of white wax is introduced. Of mineral substances used for weight-giving purposes, China-clay is the most common: that of a white hue is the best (see Clays—China-clay). Soap stone, or French chalk, has also been introduced for sizing purposes in this capacity, but has not met with much favour. The "chemicals" or salts used in sizing are primarily for the purpose of keeping the yarn moist and pliable, whilst passing through the process of weaving. This they do, owing to their power of absorbing moisture from the atmosphere. The principal ones hitherto used have been chloride of magnesium and chloride of calcium. In some cases, they are used in excess of the above requirement, for obtaining weight, but this is exceedingly dangerous, unless a powerful antiseptic, such as chloride of zinc, is used in combination therewith. Without this, if other necessary conditions are favourable, mildew or other fungoid growth is liable to be developed.

For light sizing, whereby a pure cloth results, the following recipes give the prescribed quantities of ingredients used by numerous manufacturers: (1) Flour, 280 lb., or 1 sack (fermented); soft soap, 5 lb.; tallow, 8 lb.; used at 14° Tw. (2) Flour, 280 lb., or 1 sack (fermented); curd soap, 10 lb.; tallow, 12 lb.; used at 16° Tw. (3) Sago, 180 lb.; water, 360 gal.; coconut-oil, 22 lb. These, especially the two first, will serve for medium sizing by the addition of China-clay to one-third the weight of flour, and proportionate quantities of the chlorides of magnesium and zinc. For heavy sizing, the composition is materially altered in its proportions. (4) Flour, 5 sacks, or 1400 lb.; China-clay, 10 bags, or 1240 lb.; tallow, 200 lb.; chloride of magnesium, 24 gal. at 56° Tw.; chloride of zinc, 10 gal. at 92° Tw.; blue, 1 oz.; used at 42° Tw. (5) Flour, 1 sack, or 280 lb.; China-clay, 2½ bags, or 560 lb.; tallow, 100 lb.; chloride of magnesium, 20 gal. at 56° Tw.; chloride of zinc, 2 gal. at 92° Tw.; blue, 5 dwt. (6) Farina, 180 lb.; China-clay, 580 lb.; tallow 25 lb.; dulcine, 8 gal.; chloride of magnesium, 14 gal. at 56° Tw.; chloride of zinc, 6 gal. at 92° Tw.; blue, 2 dwt. Dulcine is a mixture of glycerine, gum, and Chinese wax, in various proportions. The above mixtures, for heavy sizing, are used at a high degree of specific gravity, generally 38° to 44° Tw. If light sizing be required, it can be attained by simply reducing the strength of the above mixtures 20°–25° Tw.

The following is a recipe used with advantage in making "shirtings," a description of cloth largely exported from this country to India, China, and adjacent markets:—Flour, 840 lb. containing 12 per cent. of gluten, fermented at 21°–27° (70°–80° F.), aged for 6 weeks, and made to 34° Tw., is mixed cold with 225 lb. solution of chloride of zinc at 90° Tw., and 112 lb. solution of chloride of magnesia at 56° Tw., the whole kept at 27° (80° F.); 896 lb. China-clay, mixed with water, and boiled for one day; 193 lb. tallow; 24 lb. wax; 10 lb. cheap fat is melted and run into the clay, and the mixture is boiled for another day. The flour at 27° (80° F.) is run into the clay at boiling heat, and allowed to cool; 200 lb. farina is mixed with water, and heated to 65° (150° F.) for 6 hours, then run into the other mixture, the whole being heated to 65° (150° F.). It is then ready for use.

The above mixtures fairly represent some of the best sizing compositions, but there is no positive formula in the matter. Every man modifies these according to the dictates of his experience, and this is never uniform.

The manner in which these compounds have to be put together is also of importance. The water ought to be quite pure, as the presence of organic matter greatly increases the risk of mildew. But every sizing-room in which the cylinder sizing-machines are used can furnish a supply of pure water from the condensed steam, which is the result of the operation.

Modern sizing-rooms are supplied according to their magnitude, and the system of sizing pursued, with a series of tanks called "becks." These are furnished with "agitators"—vertical dashers with centre shafts, on the top of which are fitted bevel wheels, gearing into similar ones on a horizontal driving-shaft, extending the length of the becks. These becks communicate with each other, so as to allow the size to flow from one end to the other, as required.

In mixing, it is usual to allow 20 gal. water to each sack (280 lb.) flour. This is thoroughly agitated, and subsequently allowed to stand and ferment for about a week. The fermentation is promoted and hastened by keeping the mixture at a temperature of 21°–27° (70°–80° F.), but the latter degree should not be exceeded, as it would have a tendency to destroy the fungoid germs to which fermentation is due. After fermentation has ceased, the size is pumped into the succeeding becks, where it is agitated for a period varying from a few days to 5–6 weeks, and in some instances for a greater length of time. The longer it is kept, the more finely disintegrated the flour becomes, fitting it the better for its purpose, which is to penetrate to the core of the yarn in the sizing process. The granules of all starches, when heated with water, swell, and the pellicle bursts, and discharges its contents of granulose. This is requisite to accomplish the sizer's end. The size is passed through the series of becks at such a rate as to reach the machines at a uniform age.

The sizing-machine in most general use in this country is that known as the cylinder drying-machine. Its origin is clearly traceable to the inventions of Radcliffe of Stockport, and his assistant Johnson, to whom the cotton trade owe the dressing-frame. The defects of the latter machine led to many efforts to improve upon it, the first which achieved any considerable success being the tape-frame of Hornby and Kenworthy, of Blackburn, which was invented in 1839. This constituted a great advance, but about 14 years subsequent to that date it was superseded by the "slasher" sizing-machine, the invention of Bullough and Whittaker, the production from which was much greater. It is the perfected form of this machine which is now in general use, and which is known as the "cylinder sizing-machine" to distinguish it from the more recently introduced hot or cold air drying-machines.

The cylinder-frame is made by numerous machinists with their own improvements, which are claimed as special excellencies. Figs. 558 and 559 show elevation and plan of a very effective frame made by Howard and Bullough, of Accrington. The creel *a* is constructed for the reception of 6 warpers' beams, or any less number required for a weaver's warp. The size-box *b* contains the immersion-roller *n*, the size-roller J, and the finishing-roller I, with their pressure-rollers. The first-named, by means of a rack, can be submerged in the size. The sizing-roller J may be of wood or copper, but it is usually of the latter, when the slow-motion doffing arrangement is adopted, and the pressure-roller is of iron. The bottom roller of the second pair I is always of copper, and the top one of iron. The pressure-rollers are covered with flannel. The acid of the size quickly corrodes these rollers, producing irregular sizing at the inequalities, and it would be an improvement if they were covered with brass. Their function as pressure-rollers necessitates their being solid, their weight usually being 2–4 cwt., according to the counts of yarn in use. Size-boxes are now made with a second compartment, into which the size is fed at the bottom, and boiled before overflowing into the principal compartment, where it comes into contact with the size. By this means is prevented the use of raw size, which would make the warp hard and rough. In this machine, this plan is improved upon. As will be seen from the drawing, the size-box is divided into two parts, the partition being shown by the dotted lines between N and M. The small division M contains a float, regulating the admission of size, and a single pipe, for boiling purposes, at the bottom. The size enters at one side, towards the top, as seen at K, and only reaches the principal compartment after traversing the width of the machine, and sinking to the bottom, where it passes through an opening in the partition, shown at L. The boiling-pipe, at the bottom of the small compartment, being constantly supplied with steam, and the top being covered with a lid, the heat is retained, and the contents are kept boiling violently, so that the newly introduced size, slowly and regularly admitted by the float, has to cross the width of the machine, and descend through the boiling mass, before it can come to the opening L at the bottom of the partition. It can only enter the next division as the size is carried away by the yarn. Experiments show that, if the size in the small compartment be coloured, it will require 20–30 minutes to reach the second division, which shows the length of time it undergoes boiling before admixture with the bulk, where it is further subjected to the same process before it is taken up by the yarn.

The main cylinder c is placed in reverse order as compared with the small one *d*, being so arranged that the greatest portion of its surface may be utilized for drying, the same end also being secured from the small one *d*. The construction of these cylinders should be such as to withstand all danger of explosion from the pressure of the steam, which is 4–15 lb. an in. Provision is made to secure a complete discharge of the water resulting from the condensation of the steam by which they are heated. If this be neglected, their efficiency for drying purposes is greatly impaired. The cylinder-shafts, or centres, revolve upon loose-pulleys, which is a great improvement upon the old plan of stuffing-boxes, and diminishes the strain upon the yarn. The condition of the cylinders should be frequently examined, the best means being to turn them with the hand when the yarn is slack: if they revolve easily, and seem to be properly balanced, the test may be regarded as satisfactory. The periphery of the cylinder is usually composed of strong tin plates; and the ends, of steel; the interior is well stayed. In some cases, however, the tin soon wears off, and exposes the iron surface to the corrosive action of the acids of the size, which soon results in iron stains upon the warp. To obviate this risk, copper cylinders are sometimes used, and, though more costly in the first instance, they make better work, and will be found more economical in the end. An equilibrium-valve, and deadweight safety-valves for each cylinder, should be attached to every machine. The cylinders should contain manholes at one end, so that interior repairs can be effected without taking them out of the frame. A steam-trap should also be attached to each, for carrying off the condensed water. In the event of only one being used, the pressure of the steam, which is usually greater in the large cylinder, interferes with the delivery of water from the small one.

Steam is admitted into the cylinders *c* and *d* through the chests *e e'*; these are provided with safety-valves, set to allow the steam to escape within a pressure to which the cylinders can

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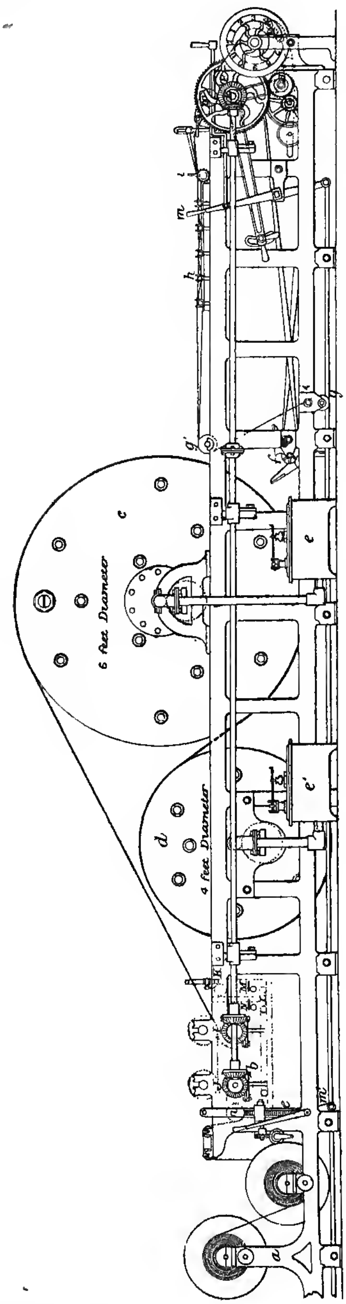

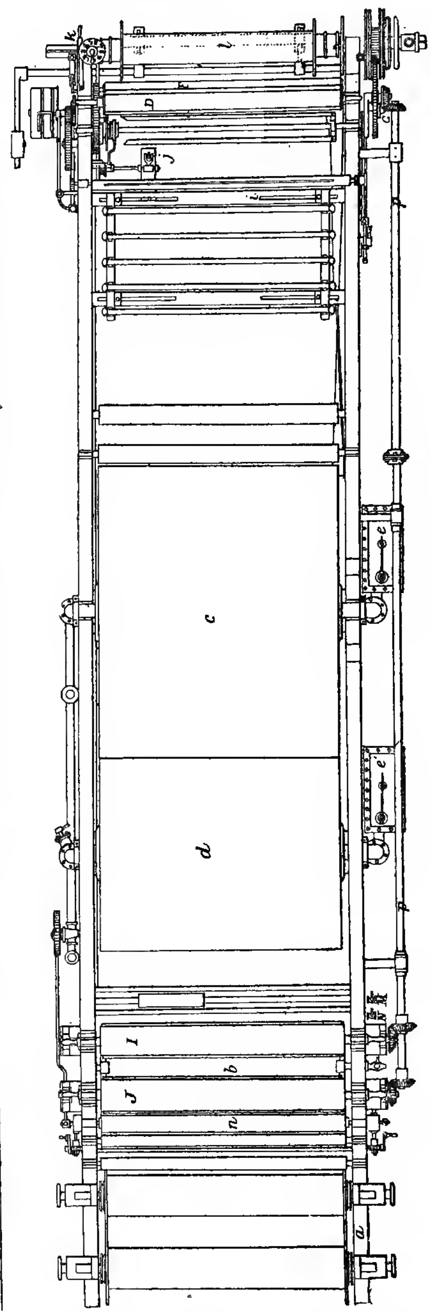

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safely be subjected. The fan *f* completes the drying, and cools the yarn as it passes from the cylinders, over the carrier-rollers *g g'*, to the series of rods *h*, whose function is to separate the threads of the warp from each other after they have passed through the size, which has a tendency to make them adhere. An expanding wraithe or reed extends across the frame between *i* and the marker *j*, by means of which the sheet of yarn is evenly spread over the space between the flanges of the beam *l*. The marker *j* is a small bowl, which dips into a trough containing colouring matter, and marks the warp in prescribed lengths for the guidance of the weaver. The figured plate *k*, with the pointer seen in the plan, is the register, shewing the length of warp which has passed upon the beam *l* at any moment. The machine is stopped by the levers *m*, of which there are several, conveniently placed for the sizer, at different parts of the machine.

Until 1874, the beam *l* was, and, in many existing machines, is now, driven by a pair of cone-drums, by which the steam can be accommodated to the increasing diameter of the beam *l*, caused by the winding on of the warp. This necessitated constant vigilance on the part of the sizer, whilst the result of the best attention was unsatisfactory, owing to the variation of speed causing the yarn to be immersed in the size for longer or shorter intervals as the speed was slow or quick. In the year named, Howard and Bullough introduced the triple roller arrangement, which has done for the sizing-machine what the positive taking up motion has for the loom. This improvement has been widely adopted, and found to obviate most of the practical difficulties previously experienced.

The triple roller arrangement greatly simplifies the machine, dispensing with cone-drums, strap-fork, worm, and guide-shaft, existing in the old frame; and yields, without the attention of the sizer, that which could not be obtained before, namely a perfectly uniform speed in winding the warp upon the beam. Uniform sizing and drying is the consequence—a great improvement upon the preceding condition. The letters D E F will shew the arrangement of the rollers. The bottom or draw-roller E is driven at a positive uniform speed from the first driver, and, as it drives the delivery-rollers I in the size-box by means of the side-shaft *p*, it determines the speed at which the yarn passes through the machine. The proper speed, having been decided upon, remains unaltered until circumstances require it to be changed, which can be accomplished in a moment by putting a larger or smaller pinion on the boss G geared into the carrier-wheel H, and so increasing or diminishing the speed of the drawer-roller E. Stopping a sizing-machine in the midst of work is objectionable, from the fact that a great strain is often put upon the yarn to overcome the inertia of the beams, rollers, and cylinders, whilst, during the stoppage, the squeezing-roller—should it be of metal—and the yarn are baking together, and damagiug the warp; if the roller be of wood, it gets so often out of repair, and, by rapid wear, varies so unequally in its diameter, that it is undesirable to apply positive driving to it, on account of its liability to deliver more or less yarn than required by the copper roller in front of it; hence results the great evil of the sizing-rollers having to be turned by the drag of the wet yarn, which is strained and broken, and its elasticity almost destroyed. The slow-motion apparatus of the inventors dispenses with the necessity of having the sizing-roller of wood, to avoid baked places upon the yarn, because, with the reduced speed, broken threads, called "lappers," can be cut off, and doffing, and all necessary operations, can be performed without stopping, and therefore without risk of the size baking. The roller may then be of metal, and be turned to the exact diameter required, which, to allow of the yarn being in the best condition for absorbing size, requires that it should be a little larger than the finisher-roller I in front of it. With this arrangement, it can be driven positively from the side shaft, in which case the quality of the yarn undergoes no deterioration from excessive strain.

The rollers D E F take such firm hold of the yarn that it cannot slip, and they would continue to deliver the yarn on the floor, were there no beam to take it up. At this point, also, the yarn is protected against all risk of straining, the beam being driven by the friction-disc at such a rate only as is required to take up the yarn delivered by the rollers. A firm, hard beam being desirable, it is obtained by the employment of a revolving presser-roller, in sizes to fit the various widths of beams.

The roller D is made to serve the purpose of the measuring-roller, and is made of iron. Formerly it was a hollow tin cylinder, placed near the roller *g'*, and was liable to be easily damaged; brought to the position shown in this frame, it adds to the facility of doffing, and, combined with the improved self-adjusting marker, prevents a considerable amount of waste being made at the commencement of the beam, and enables the sizer to concentrate his attention upon the front of the head-stock, during the important operation of doffing.

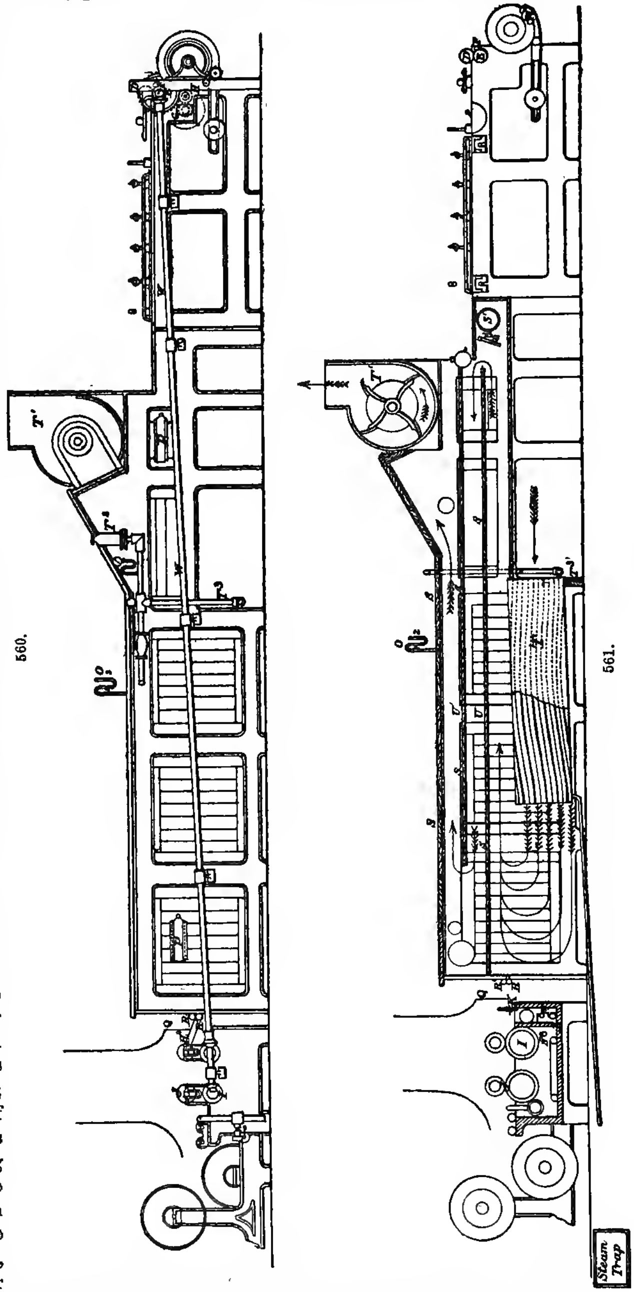
The cylinder sizing-machine is, comparatively speaking, universal in the cotton trade, in those branches where the yarns are used in their grey state. There are a few exceptions, where, in the case of very fine yarns, it is thought prudent to retain the old system of dressing; but these cases are so rare that they do not call for remark.

The disadvantages that have been experienced in connection with the cylinder-machine have led to the invention of air drying-machines, in which a current of either hot or cold air is employed to extract the moisture. At their first introduction, these machines excited great anticipations, owing to the softness and pliability of the warps sized upon them. But a little experience soon demonstrated the existence of various weak points, especially a want of uniformity in drying, which revealed itself by the development of mildew in the warps. This arose chiefly in warps that had been sized during a very humid state of the atmosphere, it being found that in such a condition the drying power was greatly reduced. However strong the current may be, little more than mechanical impact could be obtained. This difficulty proved insuperable in connection with cold-air machines, and they are now rarely found in the market. In hot-air machines, however, the case is different; they have been so far improved that, for some classes of work, they now obtain a preference over the cylinder drying-frame.

The accompanying illustrations, Figs. 560, 561, and 562, show elevation, plan, and cross section of the Bullough and Whitehead hot-air drying-machine. The only points requiring notice are those wherein it differs from the cylinder-machine, the creel, size-box, and head-stock being the same.

In air drying-machines, it is obvious that provision must be made for a much longer exposure of the yarn to the heated atmosphere than is necessary in the cylinder-frame, where the yarn comes into immediate contact with the heated surfaces of the cylinder. It is also requisite that the heated atmosphere, when it has become surcharged with moisture, should be speedily and effectually withdrawn, because, when its power to absorb moisture has been exhausted, it is useless. This will necessarily require a supply of hot air which shall be constant and steady, to replace the saturated atmosphere withdrawn.

In the above machine, these conditions have been met by the following arrangements: — In the large chest forming the central part of the frame, four steam-cylinders T are laid parallel and near the bottom, as will be seen in the cross section; each of these contains a series of small air-pipes, into which air is drawn by the fan T′, revolving at 1300 rev. a minute. The cylinders T being filled with steam, the air, in its passage through the pipes, gets heated, and, entering the hot-air chambers, follows the direction of the arrows, until it is carried out by the fan at the vent. The yarn, after its passage through the size-box, enters the drying chambers between the rollers RR′ and passes through the hot air, over the cylinders, around the roller s′, through the middle chamber u, then around the large roller at its extremity, through the chamber u′, over and under the roller in proximity to the fan, and, reversing its track, passes from the upper side, around the small roller at the



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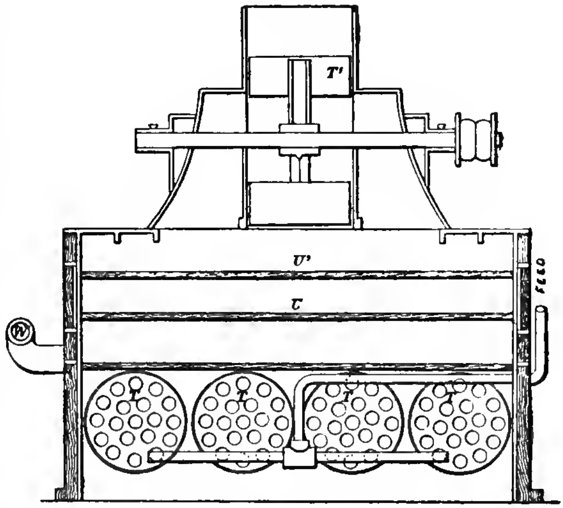
561.

opposite extremity, and thence back along the chamber, making its exit between the large and small rollers in the line of the framing. The warp is opened by half of it passing over, and half under, the small rollers near the rods which further separate the threads, after which it passes upon the beam.

The arrangement of this machine, as will be apparent from the description, is well calculated to accomplish its purpose. The air from the heaters, in its hottest state, first comes into contact with the yarn just as it leaves the sizing-rollers; and, as the yarn passes through the chamber in a line almost in contact with the heater, the current of air is forced to penetrate the sheet of yarn, thus drying it perfectly on every side. In the other chambers, the current must similarly pass through the warp. The current induced by the fan T' ensures a constant supply of dry air; whilst the heater-cylinders, being capable of bearing a steam pressure of 20 lb. an in., afford a wide margin of heating power, capable of drying either lightly or heavily sized yarn. Several leading firms have adopted this system, and find it very satisfactory.

562.



Another very useful machine on the same principle, but differing considerably in details, has been designed by Baerlein and Co., of Manchester, and is made by Atherton Bros., of Preston.

Ball-warp sizing is older than the above systems of sizing, and is mostly carried on as a separate and independent business, manufacturers sending out their warps to the sizing establishment, where they are sized at a specified charge, and returned in the ball form.

Where this system is retained, it necessitates the employment, by the manufacturer, of the ball-warping machine and the beaming-frame. The former is a large reel, revolving on a vertical axis. It is furnished with a bobbin-creel, containing a given number of bobbins, a certain multiple of which will constitute the quantity required for the warp. The length is obtained by several layers of yarn being wound upon the reel by means of a guide-rail. When the length and breadth for a loom warp is completed, the warper doffs his creel, by winding the warp in a ball upon his arm—hence its name—after which it is ready for the sizer. When sized it is returned in the same form to the manufacturer, and is passed to the beamer. The beaming-frame is a very simple machine, in which the warp is wound upon the loom-beam, being spread over its width by a hand wraithe, held and guided by the beamer. As this plan is gradually declining, and will probably become extinct at an early date, it requires no further description.

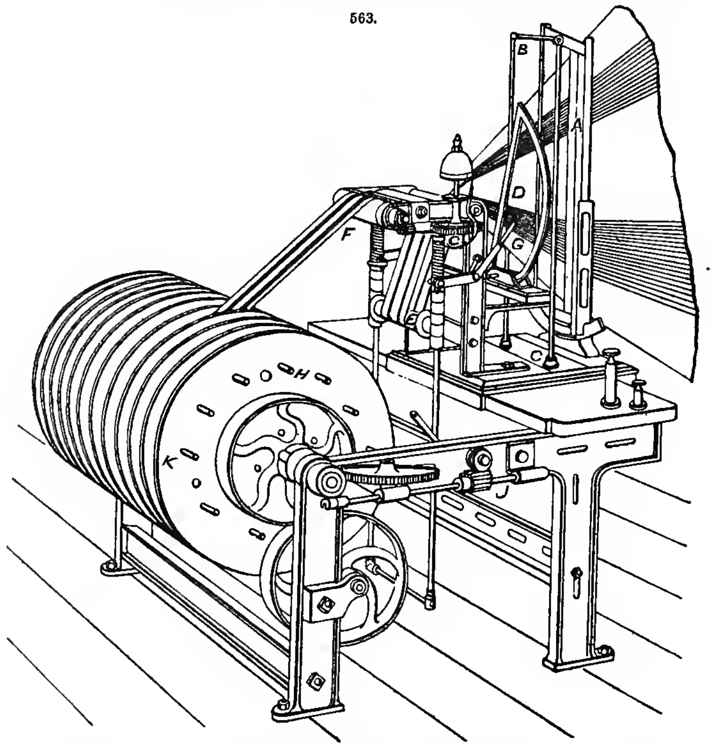
Hank-sizing is chiefly resorted to when the yarn has been bleached, dyed, or printed, these processes rendering it necessary that the yarn throughout its length should be subjected to treatment. Hence, dealing with it in the hank greatly facilitates the handling. Hank-sizing is undoubtedly a crude form of working, and might be considerably improved, but it is still very general for the classes indicated above. The method of operation is to take a "knot" of hanks—the number reeled at one time—and dip them into the size, as often as may be necessary to thoroughly saturate them. The hanks are then wrung out, either by hand or machinery, and then thoroughly dried. Cold size is mostly used for coloured yarn, particularly when the colours would suffer from heat. To preserve the colours, it is advisable that the yarn should be air-dried, and not allowed to come into contact with hot surfaces. Another reason why hank-sizing is used is that the various coloured yarns which are sometimes united in one warp cannot advantageously be sized together, as should any one colour "bleed" in the process, the remainder would be injured. In some newly-constructed sizing-machines, separate size-boxes can be used for the different colours.

The hank winding-frame is similar to the cop-frame, already described, except that reels are introduced for the hanks in place of the skewer-rail for cops.

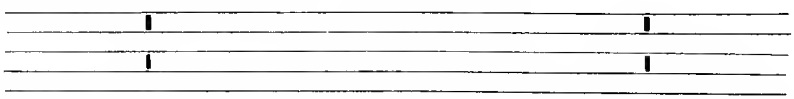
A great improvement in the warping of coloured warps was introduced about three years ago by the invention of the section warping-frame of J. J. Ashworth and Bros., of Pendleton. This is one of the most important improvements that have been introduced in the preparatory department of the coloured goods trade for a long time past.

Fig. 563 will enable the reader to follow the description. The creel in this machine is slightly altered from its form in the ordinary warping-frame, being oblique, and constructed to hold about 400 bobbins. To that end of the creel—not shown in the drawing—which is nearest the machine, is attached an eyelet-rod, the eyelets being composed of strips of white earthenware, about 2 in. broad by 5–6 in. long. These are perforated by two lines of circular holes, and are fitted in a frame in

563.



the manner of reed-dents. This rod extends from the top to the bottom of the creel, and receives the threads of the bobbins, carrying them in a horizontal position until they pass the eyelets. The threads then converge to the lease-reed *a*, a small reed, every alternate dent of which is soldered up about 2 in. from its extremity thus:—



the others being open throughout their length. By means of this reed, the threads, though undergoing condensation, are still kept apart, and the "lease" is easily obtained. This "lease" is a separation of the threads, to prevent their entanglement in weaving. Near the reed, are two vertical rods *b b′*, joined at the top by a cross-rod, and fitted at the bottom into a sliding-board. The yarn, after leaving the reed, passes through this frame. By sliding it a sufficient distance in one direction, and then in the other, the leases are correctly and instantly obtained, in a manner much superior to the old plan. By means of the bow *d*, the threads are contracted to suit the width of the section of the beam. This bow has also a further use. When coloured warps of a large pattern are being made, it is usual to warp only half the pattern at once, putting it upon every alternate section of the beam. When the first half is thus completed the bow is used to reverse the pattern, which is then filled upon the empty sections, and completes the design. The yarn, after passing the bow, goes over a roller, and descends thence to and around the roller *e*. This is a faller-roller, automatically taking up the slack on the stoppage of the frame. The warp next passes upwards, and under and over several tension-rods, which compensate for the diminishing weight of the bobbins, owing to the loss of their contents; then over the roller *f*, and upon the beam. The lever *g* is for the purpose of raising the tension-rods, in order to pull back. The roller *f* is an indicating-roller, and, by means of a worm upon its axle, it measures the length of yarn wound upon the first section of the beam. The beam is an important part of the machine, the sections being adjustable, according to requirement. The pinion *i*, at the base of the bell-pillar, is the regulator, measuring the length of yarn delivered upon the beam. Each tooth delivers 2 yds., so that the length can be accurately measured for marking purposes. At every revolution of the marking-pinion, the bell is rung, and the piece-mark is put in. The pinion *j*, which is driven by a worm upon the beam shaft, is an indicator, showing the number of revolutions of the beam during the filling of each section, by which a uniform length can be obtained, and waste prevented. Gauges are used for setting the section-flanges accurately.

The operation is as follows: the first process, creeling, is commenced at the top of the creel, and carried across, each succeeding line being creeled in the same direction. This completed, the threads of each row are drawn through the eyelets in the rod, then through the reed, commencing with an open dent, and following with a closed one, thus proceeding until all are drawn in. The warp is then passed through the brass lease-rods, next across the cord of the bow, and through the rollers, to the beam. The wire-rods *k*, projecting through the flange of the beam, pass through all the sections. The axle is an iron shaft, upon which the sections are movable, being fixed with set-screws. Between the rods and the axle, is a cavity, into which the warp end is passed, and secured to the heads of the set-screws. The tension-rods are screwed down, the measuring-roller is set with proper pinion, the revolution-indicator is adjusted, and the section-warp is laid in. "Taking the lease" is performed by drawing to one side the vertical rods *b b'*, the result being that half the threads—alternate ones—are drawn to one side of the reed, the second half being arrested at the points where the dents are closed. A shed or opening is thus formed between the two sets of threads, through which a cord is passed. The rods are next pushed to the opposite side, a second opening is made, another cord is passed through and secured to the previous one, which completes the leasing; this requires to be done at the commencement of each section. The two indicators are set, and the beam is turned round to discover if the section-warp is wide enough to fill the beam section; if this be not the case, a slight inclination of the bow secures it in a moment. The frame is then set to work, the warp running upon the beam like a ribbon, every thread perfectly parallel with the other, showing no confusion or admixture of colours. The divisions of the beam are thus successively filled, when it is ready for transfer to the loom-beam, upon which it is directly run, without the aid of a wraithe, in a perfectly even sheet, in which no two threads are crossed. In this respect it is even superior to the sizing-frame, showing the pattern of the warp as perfectly as the cloth itself. In the process of weaving, the warp comes from the beam with the same evenness, and freedom from entanglement or twisted parts, as it went on. A better cloth is produced, the quantity is increased, the weaver has less labour and earns more money, and the employer, from being enabled to engage the cheaper labour of females, economizes wages, secures a greater production from his looms, obtains more profit, and is subject to less loss owing to the improved quality of the goods produced.

In the coloured goods trade, it is customary to make pattern-warps, in order to test designs; for this purpose, the above machine offers unequalled facilities for producing warps of very short lengths, in great variety, yet perfect in every detail. Where the importance of securing these at little expense is considered, this feature will be appreciated.

The weft yarns for coloured goods, unlike those used for grey goods, often have to go through two or three processes, such as reeling, bleaching, printing, or dyeing, before they are ready for the loom. From the hank form the yarn has to be wound upon pirns for the loom-shuttle. There are numerous pirn winding-frames made by different machinists, which vary chiefly in points of detail.

Fig. 564 shows a well-designed pirn winding-frame, made by Hacking and Co., Bury. The reel-creel is shown at *a*; the series of friction-discs *b* are fixed upon the shaft *c*, and are bevelled at the edges to form the cone of the pirn. A spindle is fixed in the vertical socket *d*, having its free end downwards, and inserted in a hole in the rail, through which it extends a short distance. Upon this spindle, the pirn *e*—often called a bobbin—is placed. Its shape is seen in the section, Fig. 565, and in the three spindles of the frame on the right.

When ready for work, the threads are conducted from the hanks on the reels to the bobbins, and as the latter fill with yarn, the bevelled edge of the disc pushes the bobbin upward, as shown at the left of the drawing; the socket moves up the rod as the bobbin fills, until the bottom of the spindle is lifted out of the hole, as shown at *f* in the frame, when the point is pushed aside into a groove prepared for the purpose; contact then ceases, and the bobbin, being full, is removed by the attendant.

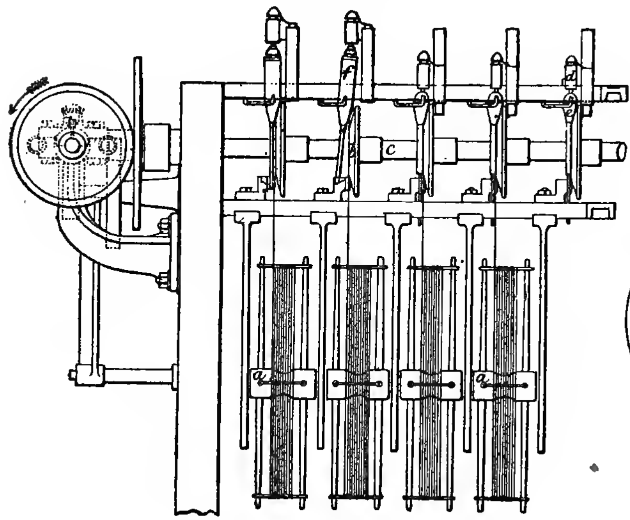
This machine is, in its leading features, thoroughly novel. A firm, hard, and well-constructed pirn is formed by it, without friction upon the yarn, which thus preserves the bloom of the dye, an important matter in coloured goods.

Drawing- or twisting-in.—When the warp has been put upon the loom-beam, there is one more process before it is ready for the loom: it has to be furnished with healds or heddles.

The "heald" is composed of two flat staves of wood, of a length proportionate to the width of the loom, placed about 10 in. apart, and connected by a series of cords extending across and uniting the staves throughout the length. The yarn which enters into the manufacture of healds for the cotton trade, is composed of cotton of two or three strands, each strand containing several threads. Heald manufacturing is a separate business. The yarn forming the heald is always varnished when composed of cotton, but this is often omitted when it is of worsted. Sometimes, though rarely in the cotton trade, metallic healds are employed.

For plain weaving, four "leaves" constitute a set; these are arranged in two pairs, thus, 1–2 3–4. The warp threads are drawn through the rings in the middle by means of a specially

564.



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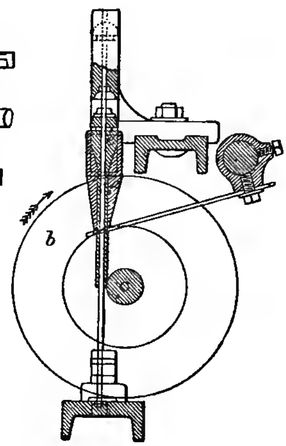


constructed wire hook. The order of the draught, commencing on the left hand, is 1 3 2 4; this is repeated throughout. Whilst this is being done, the threads are also passed through the reed, between the dents, in pairs, in the last-mentioned order of the heald-draught, 1–3 and 2–4 going together. The reed is composed of a series of short strips of flattened wire, set vertically, and bound at each extremity between two strips of wood, laid horizontally, with the wires between them. The spaces between the wires are perfectly uniform, and are obtained by means of a pitch-covered band being wrapped around the horizontal strips of wood, with a wire dent between each round. The parts are, by this means, held firmly together, and in their whole, constitute a reed. When all the threads of the warp are thus "drawn in," they are tied together by several knots in front of the reed, to secure them. Drawing-in is the process followed when the healds are new, and attached to a warp for the first time. As, however, they last for several warps, in successive attachments, "twisting-in" is substituted for the above, as being more economical. This consists simply in leaving a small portion of the warp in the reed and healds, with which the threads of the new warp are deftly twirled by the operative's fingers.

The warp, having received its "gears," as the healds and reed are called, when attached, is ready for the loom to which it is carried by the overlooker, or "tackler," or "tuner," as he is called in different parts of the country.

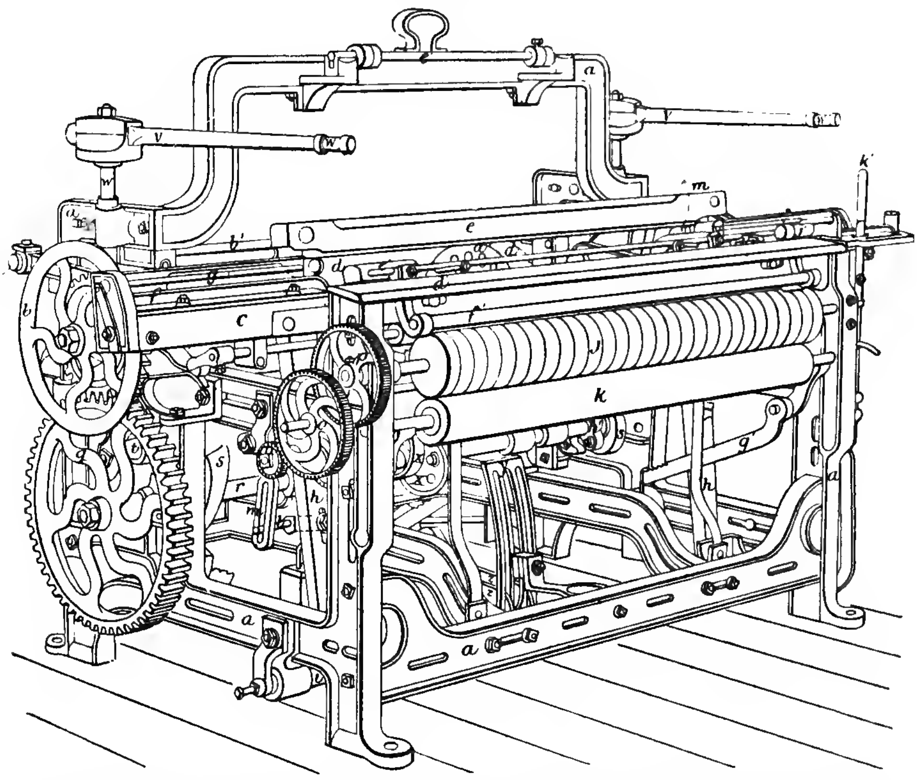
Weaving.—The loom is a machine which is as characteristic of manufacturing as the mule is of spinning, and claims an equal if not greater antiquity. It is not, however, necessary to trace the descent of the present comparatively perfect loom from remote times. The present epoch of mechanical invention was inaugurated by the invention of the picking-stick, or peg, of the elder Kay, of Bury, in 1738. Until his time, the shuttle was passed from hand to hand, through the open warp, by the weaver, which system, when the cloth was wide, required two weavers to each loom. Kay ingeniously added a box to each end of the slay or lathe, for the reception of the shuttle, furnishing each with a horizontal spindle, and placing a piece of wood cut into a convenient form, and pierced with a hole, upon the spindle, to "pick" or push the shuttle across the warp: hence its name "picker." A cord was attached to each of these pickers, and to a stick or peg placed equidistant from the pickers. By the horizontal movement of this lever, the weaver was enabled to jerk the shuttle across the warp, which he opened by means of treadles—levers worked by the feet—placed under the loom, whilst, with his left hand, he moved the slay backwards and forwards, to bring home the thread of weft left by the passage of the shuttle. The effect of this invention was to enable the weaver to quadruple his production. Kay's son subsequently invented the "drop-box" for the loom, which was to place, at one or both ends of the slay, more than one shuttle-box, lying horizontally upon each other. This enabled the weaver to use wefts of several colours, the boxes being raised or lowered by means of a finger-lever, so as to deliver the colour of yarn required to make the pattern. By this appliance, checked goods could be woven with almost the same facility as plain cloth.

These inventions gave a great impulse to the cotton and other textile industries. Weft-yarns, scarce before, now became fourfold more so, and the scarcity was not obviated until the inventions of Hargreaves, Arkwright, and Crompton, had been brought into general use, half a century later.

As before observed, anxiety about the ability to consume the product of these improvements in spinning, suggested the power-loom, which, during the lapse of another half century, was brought to a considerable degree of perfection. There would be no more interesting chapter in the history of invention than one descriptive of the genesis and development of the automatic loom, but it is not admissible here. The machine must be described as it now exists.

Fig. 566 shows in detail the working parts of a plain loom, and, as this is the foundation on which others are constructed, its description will suffice for all, except in the parts that are added to secure modified results. The frame-work *a*, roughly speaking, describes the figure of a cube, within which,

566.



and attached to the sides thereof, are the working parts. The shaft, carrying the balance-wheel *b*, extends through the centre of the frame, and projects about 12–18 in. beyond, for the reception of the driving-pulleys, one fast, the other loose. A brake-wheel is usually carried upon this part. The shaft has its bearings in the sides of the frame. Just within the frame, at each side, this shaft is cranked, and by means of arms, is attached to the slay or lathe *c*, which oscillates upon the "slay-swords" *h*, on the centre *i*, called the swing- or rocking-rail. The slay *c* has many parts. Its upper surface from end to end forms the shuttle-race—the ground over which the shuttle passes backward and forward between the shuttle-boxes *f*. The reed occupies the space *d*, its frame fitting into grooves at the top and bottom, where it is retained in position by the "slay-cap" *e*. The shuttle-box is formed by the side *f* and a board at the back, and the end plate which closes its extremity. The "fly-spindle" *g* has one end inserted in the spindle-stud near *d*, the other passing through the end plate into a socket on the top end of the spring, which is secured by a screw-bolt to the slay *c*.

The taking-up roller *j* is actuated through the series of wheels at the end of the loom by means of the oscillation of the slay-swords *h*, communicated through the pin *l*, bracketed to the sword *h*, and called the "monkey-tail," which works in the slotted lever, oscillating on a fixed pin at the centre. The opposite end of this lever carries a catch, which actuates a ratchet-wheel placed inside the frame. As this wheel revolves, it is secured at every advance by a holding click. Its axle extends through an adjustable bracket, and carries the change-wheel, which gears into and gives motion to the taking-up wheel *o*, revolving on a fixed pin. This wheel has 120 teeth, and on its boss is cast a pinion of 14–20 teeth; this gears into the beam-wheel *p*, which may have 75–90 teeth, according to the series adopted. The change-wheel *n* may have any number of teeth from 18–75, but when the cloth requires a very large one, the effect is obtained by giving the actuating-catch a double lift. The number of teeth in the change-wheel regulates the speed of the taking-up roller *j*, and thereby the number of picks—threads that cross the warp—per inch. The roller *j* drives the cloth roller *k* by friction, contact being preserved by the weighted levers *g'*. These complete the movements obtained directly from the top- or driving-shaft of the loom. The crank-shaft pinion-wheel, containing usually 37 teeth, gears into the tappet-shaft wheel, with twice the number of teeth. The top-shaft therefore makes two revolutions while the tappet-shaft *r* makes one, the reason for which will be obvious. On the shaft *r*, immediately inside the frame, one at each side, are the picking-cones *s*. As the shaft revolves, these strike the bowls *t*, carried on the bottom of the vertical picking-shafts *u*. The points of these cones are set on the shaft exactly opposite to each other, so that their strokes shall exactly alternate. The sharp impact of the cone *s* upon the bowl *t*, which is bolted in a slot of the shaft *u*, causes the latter to perform about ⅛ rev. When this shaft is at rest, the picking-stick *v*, carried on the top of the shaft *u*, has its head *w* over the end of the shuttle-box *f*; and the partial revolution, caused by the action of the picking-cone, sharply sends it forward to the position shown in the drawing. A leather band descends from *w*, and is attached to the picker upon the spindle *g*, as shown in Fig. 570, the sudden drag upon which projects the shuttle to the opposite box. The tappets are two excentrics *x* on one boss, firmly secured on the middle of the shaft *r*. These, as the shaft revolves, alternately depress the two levers *z*, which work upon a pin fixed to the frame of the loom at the back, their opposite ends moving in the slots of the treadle-grate *y*. When the beam *a'* contains a warp, this is drawn over the carrier-beam or roller *b'*, and the healds are suspended from the heald-shaft, by means of cords attached to straps securely fixed upon the bosses of the shaft. Similar cords, on the bottom staves of the healds, receive into loops two long pieces of wood, called "lambs," from which descend rods connecting them with the treadles.

The operation may now be described. The loom having been supplied with a warp, which is carried upon the flanged beam *a'*, the healds are attached as described above, the reed is secured in the space *d*, fitting into grooves in the slay and slay-cap *e*, the warp is drawn over the breast-beam *d'*, the edges being previously secured upon fluted rollers, called temples, under the cover *e'*, of which there is a corresponding one at the opposite side. From *d'*, the warp passes obliquely down to and under the roller *f'*, thence upon the taking-up roller *j* and to *k*, where the end is secured in a slot extending across its length.

When the other parts are adjusted, as may be required for the particular kind of cloth to be made, the shuttle is supplied with weft, and placed in the box, and the spring lever *k'* is pushed to the opposite extremity of the slot, where it is retained by a projection, and guides the strap from the loose to the fast pulley of the loom, causing all the parts simultaneously to commence working. The slay is drawn back by the crank-shaft, the warp is opened by the tappets, and the shuttle is projected through the open shed, leaving a thread in its track. The slay advancing, carrying the reed, presses home the weft thread to a given position near the temple-rollers, when the warp closes, and, securing it in that position, opens in the opposite direction, the threads that were down before being now uppermost, when the loom swiftly returns the shuttle, which again leaves a thread in its track, to the box whence it first started, all the other parts of the loom repeating their action; and so on consecutively.

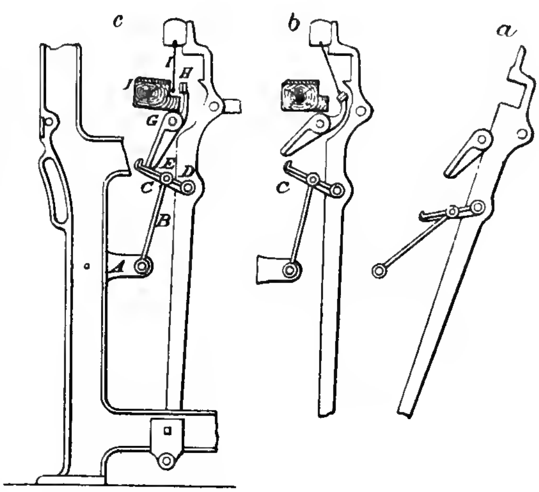
The speed of a loom is described by the number of picks—the times it throws the shuttle across the warp—per minute. The modern plain loom as described, will pick 200–240 times a minute, according to its width, which is measured from the reed-space. The narrowest looms run quickest. A loom working at 220 picks a minute therefore weaves 2¾ in. of cloth, containing 20 picks a ¼ in. in that time. This, however, is not a uniform pace; allowances have to be made for stoppages for replenishing the shuttles with yarn, piecing broken warp threads, &c., &c.

All the movements of the loom are purely automatic, including self stopping, when the weft breaks. The stopping arrangement is an ingenious piece of mechanism, and has tended greatly to perfect the action of the loom, and render it more productive. It was patented in 1841 by William Kenworthy and James Bullough, both of Blackburn. The latter we believe was the inventor. In the slay, at the end of the reed-space, is fixed a small grate, shown in the drawing by three vertical lines. Opposite this grate, carried on a rod called the "fork-holder," is a three-pronged fork, with the prongs bent downwards about 1 in. from their base. The opposite end of the holder is inserted into the boss of a lever j', which moves on a stud at its extremity, seen near the spring lever k'. A double lever, forming an obtuse angle, moves on a fixed pin at the angular point; one portion which rises above the breast-beam d' carries a head almost like a hammer, from which it has received that name. This head is recessed at the middle, so that it will receive a hook on the handle of the fork, which is bent at its extremity into that form. The second part of the lever extends from the pin obliquely to the tappet-shaft r, on which is fitted a bowl. As the shaft revolves, the bowl lifts the last-named lever, which causes the hammer of the second to be drawn backwards every time the slay c, carrying the reed d, pushes home a thread of weft. The fork-grate in the slay is thus brought to a position in which the prongs of the fork would pass between its bars, but are prevented from doing so by the presence of the thread of weft. The prongs in consequence are depressed, which raises the opposite extremity with the hook, thus allowing the hammer-lever to perform its traverse without producing any effect. But the moment the weft thread is broken, or disappears from exhaustion of the supply, the fork passes into the grate, its hook is caught by the hammer, and being drawn back, the lever j', into which the fork-holder is inserted, is carried with it, which pushes the spring lever k' out of the recess in the slot, when it moves to the position shown in the illustration, and shifts the driving strap from the fast to the loose pulley, thus stopping the loom.

Another important contribution to the perfection of the loom was made by the same inventor and a relative, Adam Bullough. This was the loose-reed. Previously to 1847, the reed was held fast in the slay, which was the cause of great damage to the warp when, from any accident, the shuttle failed to get to the box to which it had been despatched, and remained in the shed. The warp threads covering the shuttle, not being strong enough to arrest the impact of the slay, the obstructing shuttle would be driven away by the breakage of the warp. This damaged the cloth, and occasioned a great loss of time to effect repairs. The fast-loom had a provision to prevent this, but it was far from certain in its action, and compelled the loom to be run at a slow pace, seldom exceeding 150 picks a minute. The invention of the picking method described above, and its subsequent improvement, has enabled the fast-reed loom to be run at a much greater speed than formerly; but for light goods, the loose-reed is safer. The fast-reed loom is retained for making heavy goods.

A chief objection to the loose-reed loom for heavy goods is that the reed is driven out of its position by the necessarily heavy blow required to drive home the weft in heavily picked cloth. Recently, however, this has been obviated by an invention brought out by Thomas Sagar, machinist, Burnley, which is illustrated in Fig. 567. The bracket A (Fig. c) fixed to the loom side has attached thereto the link B, the opposite end of which is connected with a catch-lever c at the point E. The catch has for its fulcrum a pin in the slay-sword D On the under surface of the slay J, is a rod, which carries several fixed levers, holding the retaining-board H, the function of which is to keep the reed I in position. Previously the reed has been held here by pressure simply, and it has been difficult, if not impossible, to apply sufficient pressure to drive home the weft in strong cloths, and yet allow the reed to be thrown out by any obstruction as shown in the illustration (Fig. b). By this arrangement, however, this object is secured.

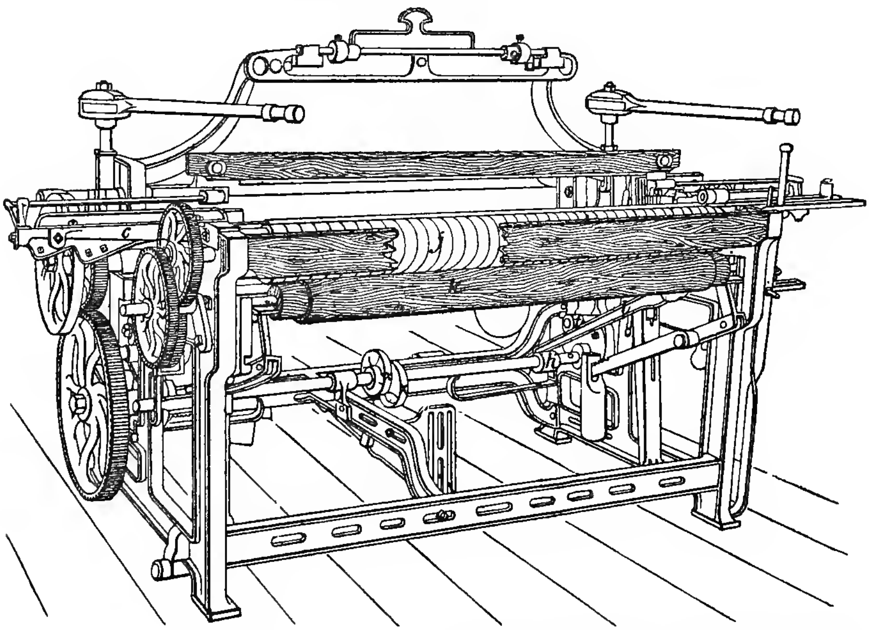
587.



The different parts are actuated as follows:—As shown in Fig. c, when the reed is advanced to the fell of the cloth—the point where the pick is left—the catch C is lifted by the link B into a position where it holds the lever G, thereby locking the reed as firmly as it is held in the fast-reed loom. As the slay recedes, the distance between the fulcrum of the link B and the catch C increases, by which the latter is drawn down to the position shown at Fig. a. Whenever the catch C is brought below the end of the lever G, the reed is quite loose, and liable to be thrown out by the least obstruction. This is its state in every part of the traverse, until it is brought within $\frac{1}{2}$ in. of the fell of the cloth, when it locks perfectly fast, being released when it has receded a similar distance. As exhibited here, it requires slay-swords specially cast; but an alternative arrangement has been devised, capable of being adapted to existing looms. By this invention, the advantages of the loose-reed loom for speed and safety, and of the fast-reed loom for wide range of work, are combined.

Another improvement has just been perfected by George Keighley, also a Burnley machinist. This is illustrated in Fig. 568. In this, the wooden beam forming the slay has been replaced by a light cast-iron one, which is not liable to warp or swell with changes of temperature—a fault frequently experienced in the wooden slay. The shuttle-boxes are comparatively open at the back;

568.



and the slot for the picker-foot also goes through the plate, which arrangements secure steady running, and perfect cleanliness in the cloth, waste being thrown out, instead of accumulating in the slot, and being carried by the shuttle into the shed.

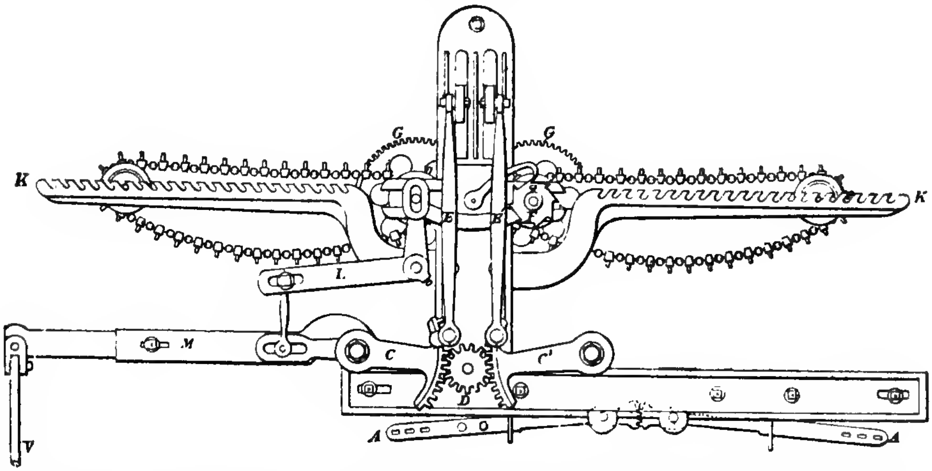
In the same loom, the taking-up beam *j* has been moved from the position it occupies in the ordinary loom, to the place of the breast-beam which it substitutes. The advantage of this is that the space within which the width of the cloth can contract—viz. between the fell and the point of contact with the taking-up roller—is greatly diminished, thereby relieving the strain upon the ends of the healds and reed. The roller being carried further into the frame, gives more space for the weaver in the passage, and affords more room for other necessary duties, such as oiling, sweeping, pulling out the finished pieces, and " gaiting " warps.

The plain loom, with a slight modification of the frame, is easily fitted for the reception of the jacquard attachment for the production of figured goods. The ordinary jacquard in the cotton trade is chiefly used in the Bolton and Ashton districts; but, as it is common to all the textile industries, its description will come more appropriately under other manufactures.

A modification of the jacquard, called the "dobby," is in extensive use in E. Lancashire, and more particularly in Blackburn, for making fabrics for the Indian market. These are chiefly goods with coloured and figured borders, such as have been manufactured by the native Hindoo weavers for ages. A great trade has sprung up in these goods within the past twenty years, and the dobby appears to have been invented to meet its requirements.

There are many descriptions of dobbies, but it will suffice to notice the most recent and improved. This is one invented by Ainsworth, of Preston, and made by Willan and Mills, of Blackburn. Fig. 569 shows it in elevation. In working, it is fixed upon the top of the loom. With the dobby, the pattern is obtained by pegs, inserted according to the requirements of the design, in holes made in the bars of a lattice, each of these bars being the equivalent of a card in the jacquard. In the latter machine, the warp threads are worked in single ends; but in the dobby, in groups of healds upon staves, according to the requirement of the design. In the dobbies that have hitherto been in general use, considerable defects have existed, owing to many of their parts not being direct and positive in their action. In this instance, these defects have been almost obviated. The jacks A A¹, the wires connected with the former, the lattice for giving the patterns, and the racks K K¹ for carrying them, are not changed. The knives, however, instead of being connected by straps, have their ends projecting outside the frame of the dobby, and are attached by

569.



link-rods E E¹ to studs on the toothed sectors C C¹. These are geared together by the carrier-wheel D. The lever M is fixed on the same shaft as the sector C, and is moved up and down by the rod V, which is actuated by a crank, fixed on the extremity of the tappet-shaft of the loom. The rod V, passing downwards on the outside of the loom, is out of the way of the warp—an unusual advantage. The two lattices are worked by cylinders, mounted on a carriage, and geared together by the wheels G G. This carriage moves to the right or left at every pick. On its movement to the right, the ratchet-wheel F is pulled round by a catch, which causes the two lattice-cylinders to perform part of a revolution, and brings fresh bars of each lattice in a position to act on the wires of the dobby. The motion of the carriage is obtained by a bell-crank lever L, which is connected with another, fixed to the shaft carrying the sector C and the lever M. The lever M is lifted by the crank on the tappet-shaft; and the jacks and knives, worked from the right hand, are lifted also; whilst those on the left are lowered, and *vice versâ*. When the jacks fall, the healds are drawn downwards by spiral springs, to which they are attached beneath.

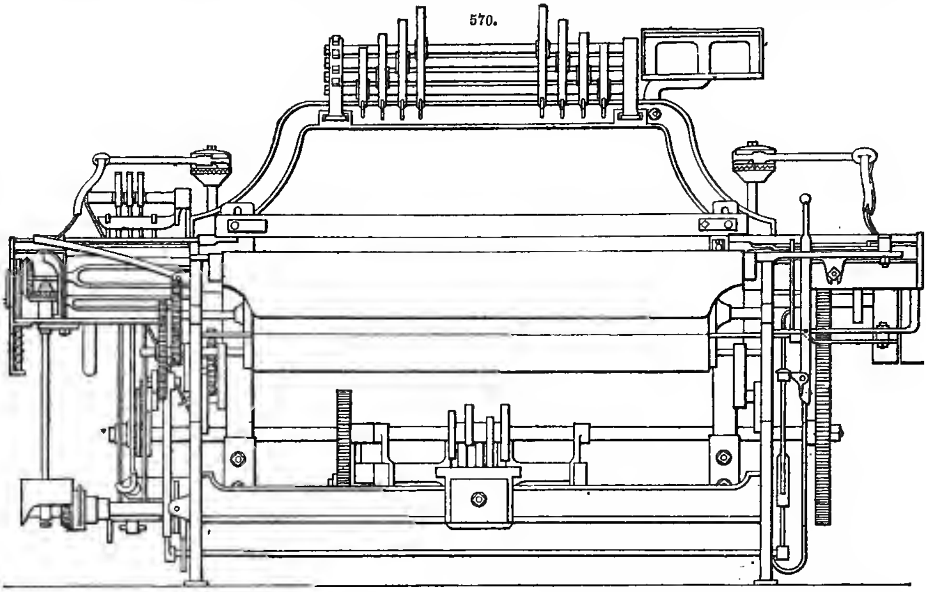
The capability of the plain loom is much increased by the introduction of special tappets. Of these, there are many descriptions, ranging between the three-leaves twill pattern, to the section-tappets, known by the name of the late Bennett Woodcroft. Even to enumerate them would occupy too much space.

The check or shuttle loom is supplied with two or more boxes, at one end of the slay, for the reception of shuttles containing different colours and counts of wefts, by means of which a striped warp of coloured yarns can be crossed with similar or contrasting colours. In most cases, the shuttle-boxes are arranged horizontally over each other, at one end of the slay, and are elevated into or depressed from the level of the shuttle-race, as occasion may require. This is accomplished by means of levers, actuated on the jacquard principle, the metallic cards of which are set to produce any given pattern. With "rising-boxes," as this arrangement is called, it is possible to have six boxes thus superposed. With this plan, as with all in which boxes are set at one end of the slay, the shuttle must make two picks, having to return to the box from which it has been despatched. There is, however, another arrangement, called the "pick-and-pick" plan, in which there are an equal number of boxes at each side, by means of which a single thread of any colour or quality desired can be put in as desired; or any other odd number. This is useful where ornamental threads are required to be used economically, or to give peculiar effects.

In other cases, the superposition of the boxes is departed from, they being arranged to revolve around a centre. Fig. 570 shows one of this description. The driving-gear is removed to the side on which the pulleys are placed, in order to make room for the parts necessary to work the boxes, which revolve around a centre. The arrangement by which this is accomplished is remarkably neat and effective, the boxes being geared with and moved by a pair of bevel wheels, which quite prevent back-lashing in working. There is a repeating motion for the jacquard cards, by means of which any number of picks can be obtained from any card, to produce any size of pattern. The arrangement for moving the boxes is very simple, yet certain of result. At the option of the superintendent, it can be set as a "skipping-motion"—that is it can be made to select any box of the six, as may be required.

In finishing this brief delineation of the numerous machines employed in the manufacture of cotton, it is incumbent upon the author to acknowledge obligations to the leading machinists of the country, who have promptly responded to inquiries for information concerning their specialities, and,

570.



by furnishing drawings and photographs, have enabled this article to be enriched with illustrations of the latest improvements that have been introduced to the notice of the trade. The names of several have been mentioned in the course of the article. Amongst others, without being invidious, mention may be made of Dobson and Barlow, of Bolton, whose cards are illustrated; Curtiss, Sons, and Co., Manchester, to whom the illustrations of the mule are due; Howard and Bullough, Accrington, whose drawing and roving-frame, electric stop-motion, and Rabbeth-spindle ring-frame and spindle, have been described; and Booth and Co., Preston, for the Booth-Sawyer ring-spindle. In the manufacturing section, the winding, warping, and sizing-frames of Howard and Bullough's make are illustrated; whilst the plain loom is a representative of the Blackburn make, by Henry Livesey, Limited. The names of others are mentioned in connection with their specialities.

Commerce.—There remains to briefly consider the products of the above processes in their commercial aspect.

Cotton, having passed through the first series of machines, in which it has been transformed into yarn, becomes a commercial article, and appears in the market under various forms, the chief of which may be enumerated as follows:—Grey yarns (natural colour) grouped in Nos. or counts of 4's–8's, 8's–16's, 16's–24's, 26's–30's. These are warp yarns, and are generally sold in ranges of these Nos. at one price, in either cop or bundle form—mostly the latter—for export to foreign markets. Bundles are 10 lb. packages for low and medium Nos. and 5 lb. for fine counts.

The cop yarn trade is confined to this country, and near districts on the Continent, such as France, Belgium, Holland, and Germany. For the home trade, yarn is packed in large wicker baskets, called "skips," which, when emptied, are returned to the spinner. When sent abroad, it is packed in large barrels or casks. The Nos. of yarn exported are chiefly the above-mentioned series; and, in addition, a less quantity of 40's, 50's, and 60's to India.

Home trade Nos. include all counts from about 12's to 250's. From 12's to 24's warp yarns, and from 16's to 40's weft yarns are consumed in the manufacture of domestics, T. cloths, and similar goods; 28's to 32's or 36's, with wefts from 30's to 54's are used in making shirtings for India and China, and for printing cloths; 40's warp yarn forms the base of what is known as the Jaconet range of goods, with wefts from 50's to 70's; 60's yarn along with 60's to 90's weft, enters into the composition of Mulls. These represent leading staples in yarns; intermediate in one form or another, there are a great variety besides, which compose special makes of cloth. Yarns known as medium fine Nos. are used in the manufacture of fine jaconets and muslins, made in Glasgow, and in Tarare (France), to which places Bolton yarns are largely sent, whilst the finest Nos. from

100's to 300's are consumed in the manufacture of lace at Nottingham, and in various Continental centres of the same industry.

Yarns are spun with different amounts of twist in them, and are known as hard-, medium-, and soft-twist. The first are chiefly exported to the Levant, the second constitute the bulk of all, whilst the last are designed principally for hosiery purposes.

In addition, there are printed, dyed, and bleached yarns, mainly used in the coloured-goods trade, and exported for use in the same section in foreign countries.

Twofold yarns in nearly all Nos., qualities, and conditions, are also obtainable, doubled by the wet and dry processes, gased, and polished.

Yarns are chiefly sold on the Manchester Exchange, where spinners and manufacturers meet daily, though the principal assemblies take place on Tuesdays and Fridays. Quotations are always on the basis of 1 lb. weight, and contracts are made for 5000–200,000 lb. at a time. Private spinners mostly employ agents to sell their productions. Some confine it to one; others will accept the services of all comers who can bring them orders. The great joint-stock spinning companies employ sharp young men as salesmen, who endeavour, though not always successfully, to sell their production themselves. The yarn agent is in many cases the spinner's banker, making prompt payment against the deliveries of yarn, and occasionally allowing draughts in advance to those in needy circumstances. Successful agents have a large turnover, and sometimes make great fortunes, though in times of depression, and bad trade, risks are enormous, and losses heavy.

The commission allowed for this service is a matter of arrangement, and is generally 1 per cent. for the service, and 1 per cent. for guaranteeing payment of the account. Sometimes the spinner accepts the risk himself, when he only pays the first-mentioned amount. The buyer who buys his yarn on short credit—that is for the account to be due 14 days after date of invoice—obtains 2½ per cent. discount. Long terms, for which 1½ per cent. discount is given, consist in deliveries made one month being paid for at the expiration of the month following. Shipping terms differ from both of these, being an allowance of 3 months' credit net, or, for cash, a deduction of interest on the amount of invoice at 5 per cent. for 95 days, payment in 14 days.

The conduct of a spinning business is comparatively simple, when contrasted with manufacturing. The manufacturer, unless he is engaged in producing a staple class of goods, before he can accept an order with safety, must make an elaborate calculation of the cost of producing the article, which, if the price offered will not cover, and allow a sufficient margin for contingencies and profit, is generally declined. Frequently a considerable portion of a market day is spent in making these examinations, notably by makers of specialities.

The following are the chief staple goods in the trade and the particulars of manufacture as generally produced:—

Domestics: stout cloths for the home and Continental trade, made in three widths, 28 in., 32 in., and 35 in., with 12–16 warp threads, and about the same number of weft threads, in the ¼ in. of cloth; the length is usually 75–100 yds. a piece. The counts of yarn are generally—for the warp, from 16's to 24's, with wefts from 20's to 36's. One of these cloths would be technically described as follows:—32 in./100 yds., 16 × 16 threads, 20 lb. T. cloths are identical textures made in 24 yds. lengths for export. Mexicans are a better quality of the above, and made in both lengths. Shirtings for India and China are usually 39 in., 45 in., and sometimes 54 in. wide. They were formerly made with 32's and 36's yarns, 16 × 15 threads, and 37½ yds. long; but legislation affecting the Indian tariff, with severe competition, has considerably modified these particulars. Great quantities of the 39 in. width are made; the weight is usually 8¼ lb.

Printing cloths are woven in long lengths, usually 116–120 yds., 32 in. wide, and 32's by 40's, 50's, or 54's weft, according to stipulation. It is not often that the weight of these goods is regarded, the counts of the yarn being stipulated for and guaranteed. Having to undergo treatment subsequent to manufacturing, there is no inducement to adulterate them by means of size. Jaconets form another series of goods manufactured for Eastern countries; they are made from 40's warp, and 50's–60's wefts, in various widths, reed, and pick, as the warp and weft are technically called.

Mulls are a finer series, in all respects like the above, with the exception of yarns, which are usually 20 hanks finer in both threads.

Dhooties are either of shirting, jaconet, or mull texture, in the body of the cloth, but having tape, coloured, or coloured and figured borders. These are also for India, the figured work being produced by the aid of the "dobby" attachment to the loom.

Home trade domestics, mediums, and longcloths are similar in nearly all respects to those described above, but are usually made from much better material, and have more care bestowed upon them in the manufacture. They are well represented by the series produced by several of the leading firms, whose trade marks are well known in all drapers' shops.

In coloured goods, there is an immense variety, to enumerate which would be tedious to the reader. Their general divisions must therefore suffice. These are regattas, checks, ginghams, nankeens, denims, grandrills, jeans, mottles, ticks, &c., &c.

The great series of fancy goods include quiltings and check, figured, and lace muslins, satteens, royal ribs, piqués, fancy drills, and numerous other examples of a kindred nature.

Moleskins, cords, velvets, and velveteens constitute a large and important division by themselves, called "pile-cloths." In the latter class, textures of great beauty, scarcely distinguishable from silk, are produced at remarkably low prices.

The manufacturing districts of Lancashire, in which all the above goods are made, form an irregular triangle of about thirty miles on each side, composed of the eastern and south-eastern portions of the county. In this district, are situated the numerous centres of industry engaged in the manufacture of cotton into its multitudinous products. A line drawn from Preston in the north-west to Colne on the eastern border of the county, would leave Blackburn, Burnley, and Accrington a little to the south, and would extend about twenty-five miles; thence southward by Todmorden, Rochdale, Oldham, and Staley Bridge to Stockport would form another line about thirty miles in length; and a third, from Stockport viâ Manchester, Bolton, Wigan, and Preston, would complete the description. The cotton industry to a limited extent exists beyond these lines, but has no feature that needs remark. Almost each centre possesses special characteristics, and a description of these will include all beyond the boundary lines. Preston is chiefly distinguished for its production of mediums, longcloths, and muslins, mostly for the home trade. It also spins most of the yarns required for their manufacture. Blackburn, about nine miles distant therefrom, is a great weaving centre, possessing about 60,000 looms in the town; whilst in the adjacent towns and villages, mostly within a compass of five miles, this large number is more than doubled. The looms of Blackburn, Darwen, Oswaldtwistle, and Church, are usually engaged upon the production of goods for Eastern markets, such as shirtings, jaconets, mulls, and dhooties. Accrington, five miles to the east of Blackburn, from the earliest days of the cotton trade has been a considerable centre of calico-printing and dyeing, and this fact has influenced the character of its textile productions. Cloths suitable for dyeing and printing are its chief make, to which about 12,000 looms are devoted, Rishton, Harwood, and Openshaw supplement these with about 8000 looms, engaged on the same goods. Burnley has achieved a reputation for the manufacture of printing cloths of the lighter character, suitable for export prints. Of these it makes large quantities, possessing about 30,000 looms, chiefly engaged upon them, to which Padiham and Colne, in the neighbourhood, add a considerable number. Todmorden produces mainly T. cloths and China drills. Rochdale makes a similar class of cotton goods, though perhaps rather better in quality, along with a small quantity of coloured goods and velvets. Oldham, besides being the chief spinning centre of the world, having millions of spindles, has a considerable manufacture of special fabrics, such as velvets, cords, and many fancy fabrics used for costumes. Ashton, Staley Bridge, and Stockport, the two former, like Oldham, besides being engaged in spinning the same class of yarns, have a great weaving industry, making principally home trade shirtings and the best class of printing cloths. There is now comparatively little manufacturing in Manchester, the little there is being mostly located in Pendleton on the north-western side of the city. The fabrics in vogue in this district and neighbourhood are coloured goods of all descriptions, as also at Radcliffe, a small town about five miles from the city. Bolton is chiefly distinguished for its production of medium fine yarns, and after these, quiltings, figured counterpanes, and fancy muslins. The various towns in the Rossendale valley have a divided industry, the cotton section, which is the largest, being representative of most of the others described, though domestics and T. cloths are the principal. The aggregate of looms in this district will probably be 40,000.

A few words regarding the present extent and commercial importance of the cotton manufacture to the United Kingdom, will fittingly conclude this paper. When it is considered that this vast industry has sprung from the labours of a few men of humble origin, it may tend to secure to inventors a little more of the regard which is justly their due. According to a recent Parliamentary return, cotton-mills are now found in almost every part of the kingdom, but the industry is mainly concentrated in Lancashire, Yorkshire, Cheshire, and Derbyshire. In Scotland, its chief seat is in the counties of Renfrew, Ayr, and Lanark; whilst in Ireland, there are only 6 cotton-mills reported as existing. The summary on the opposite page, reproduced from the return, will be useful for purposes of comparison.

Since these returns were procured, there has been a slight increase in most departments. Numerous mills belonging to the great joint-stock companies in Lancashire had not received their full complement of machinery when the late severe depression came upon commerce and industry. The recent revival has caused these to be filled up, so that the number of spinning spindles will now be near 41,000,000 whilst the power looms will probably reach 520,000. The total number of persons employed in tending them and the preparatory machinery, will approach 500,000. This vast number will be nearly doubled, if we include therein the people who are indirectly dependent upon it for subsistence, such as machinists, bleachers, finishers, dyers, printers, and those persons engaged in the commercial section of the business from the time when cotton arrives in Liverpool, until it leaves the country as a finished article, or reaches the home consumer.

SUMMARY OF COTTON FACTORIES.

	Number of Factories.	Total Number of Spinning Spindles.	Total Number of Doubling Spindles.	Total Number of Power Looms.	Total Number of Persons Employed.
England and Wales:					
Factories employed in Spinning	1,119	23,676,184	3,857,524	..	141,801
Factories employed in Weaving	733	..	..	218,898	102,783
Factories employed in Spinning and Weaving	582	14,813,681	292,920	271,062	202,721
Factories not included in either of the above descriptions	145	..	..	..	4,203
Total	2,579	38,489,865	4,150,444	489,960	451,508
Scotland:					
Factories employed in Spinning	37	587,699	512,974	..	13,510
Factories employed in Weaving	30	..	.	13,649	7,903
Factories employed in Spinning and Weaving	14	373,560	13,620	8,616	8,124
Factories not included in either of the above descriptions	8	..	..	..	238
Total	89	961,259	526,594	22,265	29,775
Ireland:					
Factories employed in Spinning	3	35,562	1,480	..	304
Factories employed in Weaving	2	..	..	1,956	978
Factories employed in Spinning and Weaving	1	41,234	252	730	338
Factories not included in either of the above descriptions	..	..	..	..	..
Total	6	76,796	1,732	2,686	1,620
Grand Total of Cotton Factories	2,674	39,527,920	4,678,770	514,911	482,903

When the trade is in a normal state of prosperity the consumption of cotton amounts to about 60,000 bales a week, which, averaging 450 lb. each, equals 24,000,000 lb. Assuming the raw material to cost 6*d.* a lb., we have an expenditure on that account of 600,000*l.* a week, to which 3*d.* a lb. must be added for the cost of spinning and 3*d.* for weaving, which brings the weekly turnover to 1,200,000, or about 62,500,000*l.* per annum. This figure is considerably increased by the cost of processes subsequent to spinning and manufacturing, such as bleaching, dyeing, and finishing. The quantity and value of cotton manufactures exported from this country have been for the past three years—unfavourable in both respects—as follows:—

	1877.	1878.	1879.
	Lb.	Lb.	Lb.
Cotton yarn	227,651,402	250,631,800	235,625,500
Cotton manufactures:	Yards.	Yards.	Yards.
Piece goods, white or plain	2,699,282,118	2,539,166,400	2,652,440,900
" " printed, dyed, or coloured ..	1,125,255,197	1,067,298,400	1,057,726,500
" " of mixed materials (cotton predominating)	13,283,535	12,200,500	14,481,400
Total of piece goods	3,837,820,850	3,618,665,300	3,724,648,800
Total values	£64,635,403	£61,121,784	£58,982,029

The United Kingdom possesses more than half of the cotton spindles in the world, the aggregate of other countries being about 32,000,000, bringing the present total to 73,000,000 spindles. The

32,000,000 spindles abroad, consume about as much cotton as those of England, owing to the fact that the average count of yarn spun upon them is much lower abroad than here.

The competition of the various countries where cotton manufactures have been established has never yet been formidable, even in their own markets, unless backed by protective tariffs of an almost prohibitive character. These circumstances show their unfitness to compete in neutral markets, which are therefore left almost exclusively in our possession. Were it not for the exception of a few specialities, this qualification would be unnecessary.

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R. M.

CRUCIBLES (Fr., *Creuset;* Ger., *Tiegel*).—See Clay; Glass; Graphite; Pottery.

DISINFECTANTS.—The three chief disinfectants, from a commercial point of view, are carbolic acid, in various forms, bleaching powder (chloride of lime), and sulphurous acid (burning brimstone). There are a number of patented compounds in the market, having more or less valuable qualities; but, as none of them is possessed of any property not equally attainable in the three products above mentioned, two of which are now staple manufactures, they do not warrant any special description. Carbolic acid being the type of a perfect disinfectant, the whole subject of deodorizers, disinfectants, and antiseptics, has been fully discussed under that head (see Coal-tar Products—Carbolic acid, pp. 671–680). The reader may also refer to the article on Bleaching Powder (pp. 456–470).

DRUGS (Fr., *Drogueries;* Ger., *Droguerien*).

The term "drugs," in its widest sense, embraces all substances employed in medicine; it is, however, especially applied to those derived from the animal and vegetable kingdoms, notably the latter. In this article, attention will be confined to such of these as possess some commercial importance.

A remarkable feature of this class of raw products is the ignorance which enshrouds their production, and the uncertainty in the quality and quantity of their supply. With the one notable exception of cinchona, drug-yielding plants have nowhere been made the object of systematic cultivation; this wide and remunerative field seems to have been persistently overlooked by British planters in all parts of the world. It therefore happens that, for our supplies of many of the most important medicines in every-day use, we are dependent upon the poorest peasants and shepherds, in Europe; upon wandering tribes of Tartars, Yuruks, and Arabs, in Asia; upon Nubians, Kaffirs, and Hottentots, in Africa; and upon the lowest classes of Indians in N. and S. America. As a natural consequence of the ignorance and poverty of the collectors, the plants are seldom gathered at the best season; they are often replaced by worthless, and even injurious, substitutes; they are prepared and transported in the most careless manner; they are furnished in very irregular quantities; and wasteful collection, in some instances, threatens them with extermination.

While the historical, chemical, microscopical, and purely botanical features of the principal drugs have been fully treated in such able works as the 'Pharmacographia,' and 'Medicinal Plants,' there exists but very meagre and scattered information as to their growth and preparation. The object of the present article is to set forth all available knowledge upon points interesting to growers and merchants.

Aconite (Fr., *Aconit*; Ger., *Eisenhut, Sturmhut*).—The roots and leaves of *Aconitum Napellus* are largely prescribed: a tincture of the former is used as an anodyne liniment; from the leaves and small shoots, is prepared an inspissated juice, of somewhat uncertain action. In Kunawar, the tubers are eaten as a tonic, under the name of *atis* (*v. post*—Atees). The plant is widely diffused in mountainous districts. Throughout the Alps, it is common up to 6500 ft.; and on the Pyrenees, on the mountains of Germany and Austria, and in Scandinavia, it is also known. Its range eastwards extends through Siberia, over the Himálayas at elevations of 10,000–16,000 ft., and in China generally, being cultivated both for use and ornament in the northern part of Szechuen. In W. England and S. Wales, it has been sparsely naturalized; in the New World, it is found on the Pacific ranges of N. America. As an arrow-poison, it was used by the ancient Chinese, and perhaps the aborigines of Gaul, and is still in favour among some hill tribes in India. The dried root is somewhat tapering, usually 2–3 in. long, and ½ in. thick at the top; the fresh root has a sharp odour of radish, which is absent from the dried root; the flavour is sweetish at first, but soon becomes very acrid, followed by tingling and numbness. The bruised leaves have a herby odour; and a flavour at first mawkish, then burning. The preparation of the alkaloid has been described under Alkalies—Organic, p. 230. This market is not supplied from cultivated plants, but with wild roots collected by shepherds on the mountains of Europe, without regard to season or species, consequently the roots of several other species get mixed up. It is sold in bulk by the Continental druggists at about 4–5*d.* a lb., containing 150 or more roots. The root of masterwort (*Imperatoria Ostruthium*) has been found mixed with aconite. It may be distinguished by its aromatic odour, and more compressed, less conical, shape.

Aconite (Indian or Nepal), or Bish.—The highly poisonous roots of *Aconitum ferox* and some closely allied species are used as a source of aconitine, being considered more potent than the ordinary root. The plants are natives of the temperate and sub-alpine regions—10,000–14,000 ft.—of the Himálayas, in Garwhal, Kumaon, Nepal, and Sikkim, and the roots of the various species are gathered indiscriminately. That exported to us, however, is of uniform appearance, and probably from *A. ferox* only. The roots are conical, usually 2–3 in. long and about 1 in. thick at the top; often broken; blackish-brown without, horny and hard, from having been dried by fire; or sometimes white and starchy, and then less valuable. In the Indian bazars, the roots are found steeped in cows' urine, to preserve them from insects; in this state, they are suitable only for poisoning wild beasts.

Aconite (Japanese).—Under this name, has recently been imported from Japan, a root which possesses properties similar to, but stronger than, those of common aconite. It is believed to be the root of *Aconitum Fischeri.* Its active principle is allied to, but not identical with, that of European aconite. In appearance, it is less shrivelled, and rather shorter than the ordinary drug.

Ajowan, or True Bishop's-weed.—The spicy fruits of the *Carum Ajowan* (*Ammi copticum*; *Ptychotis coptica*; *Pt. Ajowan*) are used to prepare a distilled water, reputed to be carminative, and a good vehicle for nauseous medicines; their volatile oil may replace oil of thyme. The herb is an annual, cultivated largely in India, and in Persia and Egypt. The fruits resemble those of parsley in shape and weight; when rubbed, they exhale a strong odour of thyme; their flavour is biting and aromatic. They are now largely imported into Europe, especially Leipzig, for the manufacture of thymol, for which purpose they are more remunerative than thyme. They are sometimes confounded with the seeds of *Ammi majus* and *Sison Amomum*, as well as those of *Hyoscyamus niger.* The last-named, however, are kidney-shaped, and odourless.

Aloes (Fr., *Aloès, Suc d'Aloès*; Ger., *Aloë*).—The inspissated bitter juice of several species of *Aloë* forms a valuable purgative. The aloes plants, which must not be confounded with the Agaves—miscalled "aloes," nor with Lignum aloes—the resinous wood of *Aquilaria Agallocha* and some other trees, are indigenous to hot, arid districts in S. and E. Africa, whence some species have been introduced to N. Africa, Spain, and the E. and W. Indies. Some are stemless, others a few feet high, while in Namaqua and Damara Land, Transkei, and N. Natal, they have been found 30–60 ft. high. The commercial varieties of the drug are as follows:—(1) Socotrine and Hepatic aloes,—yielded by *Aloë Perryi*, a native of Socotra, the southern shores of the Red Sea and Indian Ocean, and perhaps Zanzibar; *A. officinalis, A. rubescens*, and *A. Abyssinica* are varieties, and probably contribute to the Red Sea produce. (2) Barbadoes and Curaçoa,—derived from *A. vulgaris*, indigenous to India, and E. and N. Africa, now found also in S. Spain, Canary Islands, Sicily, Greece, and W. Indies. (3) Cape,—best obtained from *A. ferox*, and hybrids between it and *A. Africana*, and *A. spicata*, also from *A. perfoliata* and *A. linguæformis*; less powerful from *A. Africana, A. plicatilis, A. arborescens, A. Commelini*, and *A. purpurascens.* (4) Natal,—from a gigantic species not yet identified. The varieties of the plant used, and the modifications of the plan of extracting the juice, cause the drug to vary considerably in opacity, fracture, texture, colour, and consistence. The peculiarity relied on by dealers to distinguish the drug is its odour, which accounts for Natal aloes being generally associated with the Cape drug, while Barbadoes and Curaçoa varieties are never confounded.

Culture and Preparation.—In Barbadoes, the plants are grown 6 in. apart, in rows 1–1½ ft. asunder, in well-manured ground; they are weeded, but pulse or yams are raised between the rows. The plants should survive several years, though the leaves, 1–2 ft. long, are annually cut. This operation is performed in March to April, in the heat of the day. The leaves are excised close to the plant, and immediately placed, cut downwards, in a V-shaped wooden vessel, 4 ft. long, 12–18 in. deep, sharply inclined, so that the escaping juice flows down its sides, and escapes into a receptacle at the lower end. Each trough, of which there are generally five, takes about ¼ hour to fill; by the time the fifth is full, the cutters return to the first, and throw out the exhausted leaves, which are neither pressed, infused, nor boiled, and are valueless save as manure. When the juice has filled the receptacles, it is removed for evaporation; this may be done at once, or postponed for weeks or months without injury to the juice. The usual apparatus is a copper vessel, having a large ladle at the bottom, which catches the sinking impurities, and is periodically emptied. A very superior quality is said to be produced by employing a vacuum pan. A little of a superlative kind is made by exposure in a shallow vessel to solar heat till dry; but the time and trouble render the method unprofitable. As soon as the workman judges the inspissation to have reached the proper point, the thickened juice is poured into gourds or boxes to harden. When gourds are used, a square hole is made to admit the drug, and is then nailed over with a piece of calico. The industry is confined to a few small cultivators, without knowledge or means to improve it. The preparation in Curaçoa, Bonaire, and Amba (Dutch W. Indies) is practically the same.

The African modes of manufacture are still more primitive. In Cape Colony, the operator spreads a goat-skin in a shallow dished hollow, in dry ground, and lays the leaves on it in a circle, the cut ends inwards. Additional layers are piled up in the same way, the ends always projecting so as to drip into the central hollow. When the skin is nearly full of juice, its contents are emptied into an iron pot, and there boiled in the most careless manner. The industry is almost confined to the Bastaards and Hottentots, who adopt it only when more profitable work fails. In Natal, the process much resembles that in vogue at the Cape, but it is better conducted. The leaves are sliced obliquely, and the juice is left to exude in the sunshine; it is then boiled down in iron pots, and stirred as it thickens, to prevent burning. While still hot, it is poured into wooden cases, ready for shipment. The preparation is performed by Kaffirs, employed by British and Dutch settlers. In Socotra, aloes forms the most important vegetable production. The plant flourishes in a wild state on the sides and summits of the limestone mountains, at elevations of 500–3000 ft. above the plains. The plant prefers parched and barren spots, and is most abundant on the western side of the island. Formerly the whole island produced aloes, the cultivation of which was monopolized and farmed out by the Sultan; now everyone is free to gather the plant, without payment of any impost. The leaves are plucked at all seasons, placed in a skin, to preserve the escaping juice, and thus conveyed to the ports of Tamarida and Colesseah. The product is much deteriorated by the careless manner of the collecting and packing. It arrives at Zanzibar from Socotra, in a very soft state, packed in goat-skins; it is there transferred to wooden cases, in which it concretes, for shipment. The skins are washed, and the aloetic liquor is evaporated, to avoid waste.

Commerce.—(1) Socotrine (Bombay, East Indian, or Zanzibar) aloes, called also "Hepatic," when opaque and liver-coloured, is imported in kegs and tin-lined boxes viâ Bombay, the Zanzibar aloes usually in monkey-skins; its colour is dark reddish-brown; its odour resembles myrrh or saffron. It is usually soft in the interior, but hardens by keeping, losing about 14 per cent. in weight. When quite liquid, it is known as "liquid Socotrine aloes," or "aloë juice," and is often sour and spoilt. The so-called "Mocha" aloes is a very inferior, dark, fœtid variety, brought to Aden from the interior of Arabia. The imports into Bombay in 1876–7, were 204 cwt.; in 1877–8, 634 cwt. The Socotrine aloes is valued at about 25 rupees a cwt.; the black, at 10 rupees. (2) Barbadoes aloes is hard and dry, chocolate-coloured, and with dull waxy fracture; its odour is distinct from, and more disagreeable than, that of the Socotrine drug. It is imported in boxes and gourds, containing 10–40 lb. or more. "Capey Barbadoes" is the same drug with smooth glossy fracture; by keeping, it passes into the common sort. The exports from Barbadoes, in 1871, were 956 cwt. Curaçoa aloes is distinguished from the preceding by its odour. It comes to us viâ Holland, in boxes of 15–28 lb. Barbadoes aloes is worth about 60–190*s.* a cwt. (3) Cape aloes is distinguished by brilliant conchoidal fracture, and a peculiar odour resembling those of other varieties added to a sourish taint. The degrees of brilliancy of the fracture and of the colour of the powder are a basis for its division into several qualities. The exports from Port Elizabeth, in 1878, were 73,214 lb., valued at 658*l.*; in 1877, 3259 lb., valued at 40*l.* The approximate prices in the home market are—good, 40–42½*s.* a cwt.; inferior, 36–39*s.* a cwt. This variety is not admitted into English medicine, but is esteemed on the Continent, and chiefly consumed there. (4) Natal aloes is greyish-brown, mostly opaque, like the hepatic, and quite unlike the Cape drug, except in odour. It is prepared in the district between Pietermaritzburg and the Quathlamba mountains, particularly in the counties of Mooi River and Umvoti, at altitudes of 2000–4000 ft. The exports commenced in 1869 with 38 cwt.; in 1872, they were 501 cwt. The approximate market price is 48*s*. a cwt. It yields a pale greenish-yellow powder. (5) Hepatic aloes was a term originally applied to the opaque liver-coloured kind of Socotrine aloes; but Natal aloes is often sold' under this name. True hepatic aloes has an odour like Socotrine, and gives an orange powder. The price is about 40–80*s*. a cwt.

Ammoniacum.—The hardened milky juice of the stem of *Dorema Ammoniacum* is administered as an expectorant, and used in some plasters. (See Resinous Substances.)

Angostura, Cusparia, or Carony (Fr., *Ecorce d'Angusture de Colombie;* Ger., *Angostura-Rinde*).—The bark of *Galipea Cusparia* (*G. officinalis, Bonplandia trifoliata, Cusparia trifoliata*) is a valuable tonic in dyspepsia, dysentery, and diarrhœa, but is going out of use. The tree is a native of Venezuela, and is said sometimes to attain a height of 70–80 ft., but generally does not exceed 12–15 ft. It is abundant on the mountains of San Joaquin de Caroni, in 7°–8° N. lat., near Cumana, and in the districts of Tumeremo, Uri, Alta Gracia, and Cupapui, eastward of the Caroni river, and near the Orinoco. The bark occurs in pieces of various sizes, either flattish or in quills. Its fracture is brittle and resinous, its flavour is bitter, and its odour musty and nauseous. Its local names are *Orayura, Quina de Caroni*, and *Cascarilla del Angostura;* it is said to be a valuable remedy for the bilious fevers of the country; and, in a bruised state, is used by the natives for intoxicating fish. Very little of it is exported directly; it passes principally viâ Trinidad, where it is packed in cases for export. The bark is sometimes confounded with that of the closely allied *Esenbeckia febrifuga* (*Evodia febrifuga*) of Brazil, which is distinguished by its dark inner surface and by being non-aromatic. Copalchi bark has also been sold for it in this country. It has a pleasantly aromatic taste, and a whiter coat, under which the bark is marked with minute pits. Nux vomica bark has occasionally been found mixed with this drug; it is not aromatic, and can only be distinguished by an expert. The value of Angostura bark is about 3–4*s*. a lb.

Areca, or Betel.—The seeds of *Areca Catechu* have long been esteemed by Asiatics as a masticatory, supposed to sweeten the breath and promote digestion; but only recent experiments have proved its value for the expulsion of worms (both *lumbricus* and *tænia*) from men as well as animals. (See Nuts.)

Arnica (Fr. and Ger., *Arnica*).—From the roots of *Arnica montana*, is prepared a tincture for application to bruises and chilblains, and occasionally taken internally as a stimulant and diaphoretic. The plant is a perennial, found in the meadows of the central and northern parts of the N. hemisphere (except the British Islands), favouring the uplands in central and W. Europe, and the lowlands in colder climes. In the Arctic latitudes of Asia and America, the leaves become so narrow as apparently to constitute another species. The root has a herbaceous, slightly aromatic odour, and a somewhat acrid flavour; it is sometimes adulterated with the root of *Geum urbanum*, which has a purplish centre, and a clove-like and astringent flavour. The flowers were probably first employed in making the tincture in Germany, but are not now officinal in the British Pharmacopœia. Arnica root is worth about 1*s*. 4*d*. a lb.

Asafœtida.—The gum-resin derived from several species of *Ferula* is reputed stimulant and antispasmodic, and is much employed on the Continent, but little in Britain. In the East, it is used as a condiment, and as food. (See Resinous Substances.)

Atees or Atís.—The root of *Aconitum heterophyllum* has long been known in India as a tonic and aphrodisiac, and has recently been extensively prescribed as an antiperiodic in paroxysmal fevers. The plant is 1–3 ft. high, and grows in the temperate districts of the W. Himálayas, at altitudes of 8000–13,000 ft., as Simla, Kumaon, and Kashmír. The root has a bitter but not acrid flavour, is of a dirty-white colour, and in shape less conical than aconite root. The name is used for several other roots, including *A. Napellus* (*v. ante*—Aconite), and the tasteless root of *Asparagus sarmentosus*, &c.

Bael, Indian Bael, or Bengal Quince.—Almost every part of *Ægle Marmelos* (*Cratæva Marmelos*) has some medicinal value; a decoction of the bark of the root is used against melancholy, and palpitation of the heart, and in intermittent fevers; the leaves are made into poultices for ophthalmia, and are employed in decoction for asthma; but the principal virtue lies in the fruit, which acts as a tonic and astringent in diarrhœa, and as a laxative in constipation, and has been commonly used in India and Ceylon for centuries, as a specific against dysentery. The fruit is dried in slices when half ripe, but is also sometimes collected when fully ripe, and dried whole. The tree is common throughout Hindostan, Ceylon, Java, Sumbawa, Celebes, and Amboyna; it is wild and gregarious in the Coromandel Ghâts, and the W. Himálayas, up to 4000 ft.; and promises to flourish in the hotter parts of Australia. Its ordinary height is 30–40 ft. The fruit somewhat resembles an orange, but has a woody shell, and though not eaten as dessert, its juicy pulp is made into jam with sugar, or into a refreshing drink with sweetened water; when wild, it is flavourless and hard. The astringent rind yields a yellow dye. The fruit is sometimes replaced by that of the wood-apple (*Feronia Elephantum*), and even by pomagranate peel.

Barberry (Indian).—The wood and root of several Indian species of *Berberis* were long employed in the preparation of an extract, commonly used in various forms of eye disease, and known to the ancients as *Lycium*, and in the bazars as *Rusot* or *Rasot;* it is now replaced by a tincture of the bark of the rhizome and rootlets, extensively administered in the treatment of Indian fevers, diarrhœa, and dyspepsia, and as a tonic. The three species yielding the drug are—(1) *Berberis Asiatica*, distributed throughout the dry valleys of Bhotan and Nepal, westwards along the Himálayas to Garwhal, and in Afghanistan; (2) *B. aristata*, in the temperate altitudes (6000–10,000 ft.) of the Himálayas, in the Nilgiris, and in Ceylon; (3) *B. Lycium*, peculiar to dry, hot portions of the Himálayas, at 3000–9000 ft., not used in this country as yet.

Bearberry (Fr., *Busserole;* Ger., *Bärentrauben*).—The leaves of *Arctostaphylos Uva-ursi* (*A. officinalis, Arbutus Uva-ursi*) are valued as an astringent tonic in affections of the bladder. The plant is a small evergreen shrub, widely distributed in the N. hemisphere; it occurs in Scotland, N. England, and Ireland, on the chief mountain ranges of Central and S. Europe, in Russian Asia and N. Europe, in Iceland, and in N. America. The leaves are ⅝–1 in. long, and ¼–⅜ in. wide, dark-green in colour, with a very astringent flavour, and when powdered, a tea-like odour. They are sometimes confounded with those of the red whortleberry, or cowberry (*Vaccinium Vitis-idæa*), which are dotted underneath, and have revolute margins.

Belladonna, or Deadly Nightshade (Fr., *Belladone;* Ger., *Belladonna, Tollkraut*).—The root of *Atropa Belladonna* is used chiefly for the preparation of atropine, also an anodyne liniment; from the fresh leaves, an extract is made; and from the dried ones, a tincture. The plant is a tall smooth herb, growing in the clearings of woods in Central and S. Europe. It is found doubtfully indigenous in some of the S. counties of England, chiefly on chalky soil, and is cultivated at Hitchin. It is also sparingly cultivated in France and N. America; in a wild state, its range extends eastwards to N. Asia Minor, Caucasia, and the Crimea.

The root is fleshy and tapering, and attains a length of 1 ft., and a thickness of 1–2 in.; when fresh, it is rough, and earthy-brown externally, but creamy-white internally; its odour is earthy; its flavour is scarcely apparent at first, but soon becomes powerfully acrid. The root occurs in commerce in a dried state, as rough pieces of dirty-grey colour, and with an earthy odour resembling liquorice root. The smaller roots are the better, as the bark is considered to contain the greatest proportion of the alkaloid principle. Its preparation has been described under Alkalies—Organic, p. 230. Our supplies are drawn chiefly from Germany, and are of poor quality; a much better article is produced from home-grown roots, washed, sliced, and gently dried. The close resemblance of the roots of two or three species of *Mandragora* causes them to be easily mistaken for the drug. The leaves of belladonna are 3–6 in. long, bright-green in colour, acutely ovate, smooth, quite entire at the margin, soft and juicy; when bruised, they emit an offensive, herby odour, which disappears on drying; the flavour of the dried leaves is bitter and unpleasant; the loss by drying is about 84 per cent. of the weight. The root, when scraped with the nail, shows white beneath the epidermis. Marshmallow root, which is sometimes mixed with it in commerce, has a fibrous fracture; that of belladonna is short. Japanese belladonna root, recently offered for sale in this country, is the root or rhizome of *Scopolia Japonica*. It differs from the true drug in being twisted, marked with circular scars or discs, and in not showing a white interior when scraped with the nail. It contains atropine. Belladonna root is worth about 1*s*. a lb.

Black roots.—The root of *Leptandra Virginica* yields leptandrin, a cholagogue lately introduced from the United States. The root is branched, and blackish externally. Another plant, *Pterocaulon polystachyum*, is called "black-root" in Georgia, but is of a different shape, being somewhat bulbous or turnip-like.

Boldo.—The leaves of *Boldoa fragrans* (*Peumus Boldus*) are used in Chili for diseases of the liver, and for syphilis, and have been imported into this country of late years. The leaves are oval, about 1 in. long, and ⅔ in. wide, rather rigid, with recurved margins, and very rough to the touch. Their taste slightly resembles that of lemon thyme, or verbena.

Bonduc (Fr., *Bonduc Cniquier;* Ger., *Guilandine, Schnellerkäse*).—The powdered kernels of the fruit of *Cæsalpinia Bonducella* (*Guilandina Bonducella*) are largely employed in India, either alone or with black pepper, as a tonic and febrifuge. The plant, which seems to be commonly confounded with the much rarer species *C. Bonduc*, is very widely distributed in the maritime regions of Tropical Asia, Africa, and America. It is found all over India, under the name *Nata*, and besides being administered, is mixed with castor-oil for application in hydrocele. In Cochin China, the leaves are considered deobstruent and emmenagogne, and the root astringent, while an oil from the former is used in convulsions, palsy, &c. In Amboyna, the root is employed as a tonic. In the W. Indies, the plant is called "horse-nicker," or "chick-stone," and is commonly used for fences, while the seeds are made into ornaments. It thrives in Egypt, and might probably be grown throughout the Mediterranean basin. The seeds are often washed upon the shores of Scotland, and are there called "Molucca beans"; another name for them is "grey nicker seeds (or nuts)." The yellow seeds, similar in shape and size, sometimes mixed with them, are those of *C. Bonduc:* neither is used in this country.

Broom-tops (Fr., *Genêt-à-balais*; Ger., *Besenginster*, *Pfriemenkraut*).—The young herbaceous branches of *Cystisus Scoparius* (*Spartium Scoparium*, *Sarothamnus vulgaris*), or the common Broom, are dried, and from them is prepared a decoction, used as a purgative and diuretic; the fresh juice, preserved by adding alcohol, is similarly employed. The plant is a woody shrub, 3–6 ft. high, growing gregariously in uncultivated sandy places. It is common throughout Great Britain; on the Continent, it is abundant in the Rhine Valley, S. Germany, and Silesia; but it is absent from the Alps, and many parts of Central and E. Europe, though found in Central and S. Russia, and eastward of the Urals. The fresh branches, when bruised, emit a peculiar odour, which disappears on drying; their flavour is a nauseous bitter. The stems are angular, and differ in this respect from a shrub very similar in appearance, which is common in gardens, and has smooth round stems —*Spartium junceum*.

Buchu, Bucchu, Bucha, or Buka (Fr., *Bucco*; Ger., *Buku*).—The leaves of three species of *Barosma* are a valuable remedy in disorders of the urino-genital organs; and in the Cape, are much used infused in water, wine or spirit, as a popular stimulant and stomachic. The three species are *B. betulina*, *B. crenulata* (*crenata*), and *B. serratifolia*; the two first are found in Worcester and Clanwilliam divisions, north and north-east of Cape Town, the last is met with further south, in Swellendam. The leaves of each species are gathered and despatched separately; those of *B. betulina* are considered of least value, and fetch the lowest price. They appear to contain almost equal proportions of essential oil (see Barosma Camphor, p. 578); they possess a peculiar penetrating odour, and a strong aromatic flavour. The use of the drug was acquired from the Hottentots; it is now largely consumed in Great Britain and America. The exports from Cape Colony, in 1872, amounted to 379,125 lb.; the price in the home market varies from 2*d.* to 1*s.* 3*d.* a lb. The leaves of *Empleurum serrulatum* are occasionally imported and sold as *B. serratifolia*: they differ in not having the odour of buchu, and in the leaves being longer, and sharply pointed. The flowers, fruits, and leafy twigs of the plant are often mixed with the leaves.

Buckthorn (Fr., *Neprun*; Ger., *Kreuzdorn*).—From the juice of the berries of the common buckthorn (*Rhamnus cathartica*), is prepared a syrup, used as a powerful purgative, principally for animals; but in the provinces, it is given to children after measles, &c., as a domestic medicine. The shrub is distributed throughout England, but is common only in certain districts, the fruit being collected chiefly in Herts, Bucks, Oxford, and Wilts. Its range extends from Norway, Sweden, Finland, and Siberia, into S. Russia, Caucasia, and N. Africa. The fruit is gathered when ripe, in the autumn, and the juice is generally expressed by the collectors. The fresh juice has a sp. gr. of 1·070–1·075, a repulsive odour, a sweet, but afterwards very bitter, flavour, and a green colour, which becomes red on keeping. The berries contain colouring matters (see Pigments—Sap-green).

Cajuput.—An essential oil, distilled from the leaves of *Melaleuca Leucadendron*, is in frequent use externally, as a rubefacient, and is occasionally administered as a stimulant, antispasmodic, and diaphoretic. (See Oils.)

Calabar-bean, Ordeal-bean, Eseré-nut, Chop-nut (Fr., *Fève de Calabar*; Ger., *Calabarbohne*).—From the seeds of the fruit of *Physostigma venenosum*, is prepared an alcoholic extract, employed chiefly in ophthalmic cases, for contracting the pupil of the eye, and occasionally administered in tetanus, neuralgia, rheumatism, &c. The plant is a perennial climber, resembling the "scarlet-runner," but reaching a height of 50 ft., and having a woody stem 1–2 in. thick. It is indigenous to the neighbourhood of the mouths of the Niger and Old Calabar rivers, on the Guinea Coast, also on the Cameroons and the Gold Coast, and has been successfully introduced into India and Brazil. Each fruit contains two or three seeds, the "beans," $1\text{–}1\frac{3}{8}$ in. long, $\frac{3}{4}$ in. broad, and $\frac{1}{2}\text{–}\frac{5}{8}$ in. thick, weighing about 65–70 gr. each; they possess no more flavour than an ordinary bean, and are devoid of odour while in a dry state, but on boiling them, or evaporating their alcoholic tincture, a cantharides-like odour is emitted. The shells of the beans also contain the active principle. The beans have long had a reputation as an ordeal poison of tropical W. Africa, but have only recently appeared in commerce. In common with the large seeds of *Entada scandens*, a *Mucuna*, and several other leguminous seeds, Calabar beans are known to the natives as "Garbee beans"; hence arises the common admixture with, or substitution of, other seeds with the Calabar beans. The latter vary much in the quantity of alkaloid they contain, a feature probably dependent upon the time at which they are collected; the finest beans are usually the richest. A small grub sometimes devours the interior of the seed; but the excrement of the insect is as powerful as the seed itself, the active principle undergoing no change by passing through the body of the grub. The general price is 2*s.* 6*d.*–3*s.* 6*d.* a lb., falling to 9*d.* when abundant. The beans contain two active principles: eserine or physostigmine, and calabarine, the former only being used in medicine. It readily decomposes in presence of ammonia or other alkali, forming a red fluorescent body called rubreserine. Beans which have a red tint internally are, therefore, of inferior quality. Recently a longer bean, yielded by *P. cylindrospermum*, has on one or two occasions been imported. It is richer in active principle than the ordinary kind.

Calumba, or Colombo (Fr., *Colombo*; Ger., *Kalumba*, *Columbo*).—A tincture, or an aqueous infusion, of the root of the Kalumb (*Jateorhiza palmata*) is much used as a mild tonic. The plant is a large-leaved perennial climber, indigenous to the forests of E. Africa; it is most abundant in the island of Oibo, and on all the coast between that Portuguese settlement and the banks of the Zambesi, for a distance of 15–20 miles inland. According to one author, it is cultivated on the islands of Oibo and Mozambique; but a later traveller says that it is never cultivated. The plant was long since introduced into Mauritius, and still thrives there; a specimen from Madagascar is at Kew. The roots are dug up in the dry season (March), or when the natives are not employed in agriculture. The tap-root, which is perennial, is not used, but only such off-shoots from its base as are of sufficient size, yet not so old as to be fibrous. Soon after digging, the rootlets are cut into slices, strung on cords, and hung in the shade to dry. Those pieces are best which, on exposure to the sun, break short; those which are soft or black are of inferior quality. When they reach this market, they measure 1–2 in. wide, and $\frac{1}{8}$–$\frac{1}{2}$ in. thick; they are light and corky, and easily broken; their colour, a dull greenish-yellow, is often modified by washing; they have a musty odour, and a nauseous bitter flavour; they are often much bored by insects. The drug is shipped from Mozambique and Zanzibar, both direct to Europe, and viâ Bombay and other Indian ports. In 1781, it was valued at 64*s.* a lb.; it is now worth 35–60*s.* a cwt. Among the Africans, its reputation as a cure for dysentery, and as a general remedy, is very widespread.

Camphor.—The stearoptene obtained by distilling chips of *Cinnamomum Camphora* possesses stimulant properties, and is widely used in medicine, both externally and internally. (See Camphor; Resinous Substances—Camphor.)

Canella, or Canella Alba (Fr., *Canelle blanche;* Ger., *Canella*).—The bark of *Canella alba* has aromatic stimulant properties. The tree grows to a height of 20–30 or even 50 ft., in the Bahamas, several of the W. Indies (Barbadoes, Cuba, Guadaloupe, Jamaica, Martinique, St. Croix, Trinidad), and in S. Florida. The bark is collected by subjecting it first to a gentle beating, to remove the suberous layer, and an additional one to effect a further separation; it is then peeled off, and dried, ready for export. It is now shipped solely from the Bahamas (Nassau, New Providence I.), where it is called "Whitewood bark," or "Cinnamon-bark"; the exports, in 1876, were 125 cwt.; the market price is about 24–30*s.* a cwt. The drug reaches us in the form of quills, 2–8 in. long, $\frac{1}{2}$–2 in. wide. It has a bitter, pungent, acrid flavour, and an agreeable cinnamon-like odour, which it retains for centuries; even its corky coat is fragrant. Its medicinal use in Europe is decaying; as a condiment, it is used by the W. Indian negroes. It is often confounded with Winter's-bark. The powder mixed with aloes forms the Hiera Picra of the druggists' shops.

Cantharides, or Spanish Flies (Fr., *Cantharides;* Ger., *Kanthariden*).—Vesicatory or blistering beetles are the only important medicinal insects of the present day. Principal among them are Cantharids of several species, belonging to the *Coleoptera*, or Beetle-tribe. The cantharides of commerce are furnished chiefly by *Cantharis vesicatoria* (*Lytta vesicatoria*), common in Spain, Italy, Sicily, France, Germany, Hungary, Russia, and Siberia. This species finds its favourite food in the leaves of the ash; but the lilac, privet, and jasmine, and more rarely, the elder, rose, apple, and poplar are also frequented by the insects. They swarm like bees, and emit an odour which may be perceived at a distance, and often serves as a guide to their whereabouts. They are caught in May, June, and July, the time chosen being late evening and early morning, when their wings are wet with dew; the trees are shaken, and the falling insects are gathered on cloths, killed by vinegar fumes, dried in the sun, and put up in glass-stoppered bottles, great care being required to guard against the ravages of mites and other minute pests. The flies are so light that fifty scarcely weigh a drachm, yet they are often shipped by tons. The supply varies greatly from year to year, and is furnished mostly by Mediterranean ports. Sometimes considerable quantities are obtained from Russia, in cases of 160–170 lb.; these insects are remarkable for their large size. The value of cantharides varies from 1*s.* 6*d.* to 4*s.* 6*d.* a lb. Adulteration is often attempted by mingling other insects, e.g. *Melolontha vitis, Chrysomela fastuosa, Cetonia aurata* (*Scarabæus auratus*), which possess no stimulating property. The value of cantharides is entirely due to the presence of a vesicating principle termed "cantharidin," which is obtained by digesting the pulverized flies in alcohol, adding water, and distilling off the spirit. This principle is said to reside almost wholly in the softer parts of the body, and is perhaps most largely developed in the blood. The flies do not lose their virtue by keeping, and their efficacy is due in some measure to their food. A blind preference seems to be shown for samples of the most brilliant green colour, which is not an indication of superiority. If allowed to become damp, their vesicant property is impaired.

The above described species is that most generally known in Europe; but several other varieties of *Cantharis*, as well as some totally distinct insects, possess similar properties, and may be substituted for it. They are chiefly as follows:—(1) *Apteropasta segmentata*—found with *C. albida*, and equally plentiful. (2) *Cantharis* (*Lytta*) *adspersa*—known as *Bicho moro* in the Argentine Republic, where it is common, and destructive in gardens; also in the Banda Oriental, and Mendoza. (3) *C.* (*Macrobasis*) *albida*—numerous in Texas, New Mexico, and on the plains. (4) *C.* (*Lytta*) *atomaria*—in Brazil. (5) *C. atrivittata*—in Texas, probably in abundance. (6) *C.*

(*Epicauta*) *cinerea*—throughout all the States eastward of the Rocky Mountains, and in many parts of Canada; in the S. States, its size increases; its vesicatory power fully equals that of *C. vesicatoria*. (7) *C.* (*Lytta*) *gigas*—in Guinea. (8) *C.* (*Pyrota*) *mylabrina*—abundant throughout the whole region from Kansas to Mexico. (9) *C. nigricornis*—on the Paraná. (10) *C. Nuttalli*—extremely abundant in Kansas and Colorado. (11) *C. punctata*—in Siberia. (12) *C.* (*Lytta*) *ruficeps*—in Java and Sumatra, and a variety in China. (13) *C.* (*Lytta*) *violacea*—in India. (14) *C. vitidipennis*—in Chili; probably the most efficacious of the Argentine species, and common along the whole west side of the Republic, at the foot of the Cordillera. (15) *C.* (*Lytta, Epicauta*) *vittata*—common in the United States and Canada, but most abundant north and west of the Carolinas, extending towards the Rocky Mountains; in the south, replaced by the very closely allied *C. lemniscata;* quite equal to common cantharides as a vesicant, but much smaller, and therefore more difficult to gather. (16) *C.* (*Pyrota*) *vittigera*—on the Paraná. (17) *C. vulnerata*—extremely abundant throughout the entire Pacific region west of the Sierra Nevada; this species may be found commonly on a variety of *Baccharis*, and has proved to be powerfully vesicant. (18) *Cysteodemus armatus*—very plentiful in Arizona and the deserts of California, wherever the Grease-wood (*Larrea Mexicana*) thrives; its size varies much; its vesicatory properties are, perhaps, too slight to render it of much value. (19) *Horia maculata*—in the Argentine Republic; over 1 in. long. (20) *Lydus algiricus var. indicus*—Pondicherry. (21) *L. trimaculatus*—in S. Europe, from Italy to the Caucasus. (22) *Meloë angusticollis*—in the E. States, and in many parts of Canada; sometimes congregated under stones. (23) *M. Klugii*—in the Banda Oriental. (24) *Mylabris Cichorii*—the Telini-fly of India; on the flowers of wild chicory and other *Compositæ;* also ranges from Egypt, Italy, and Greece, to Central Asia and S. China; contains more cantharidin than *C. vesicatoria*, and is now common in European commerce. (25) *M. phalerata*—in China. (26) *M. pustulata*—in large numbers all over S. India at certain seasons. (27) *M. syriaca*—in Syria and Persia. (28) *Pseudomeloë miniaceo-maculatus*—in the interior of the province of Buenos Ayres; not common. (29) *P. sanguinolentus*—in Mendoza, Argentine Republic. (30) *Tegrodera erosa*—plentiful in S. and Lower California. (31) *Tetraonyx violaceopennis*—in Brazil. Three species of *Tetraonyx* are found in the Argentine Republic: one in Tucuman, two in Mendoza. Dr. Armstrong found at the Cape of Good Hope great numbers of a species of *Cantharis* better and stronger than the common fly.

Chinese cantharides are often to be met with at the London drug sales. In colour and size, they differ from the Spanish, being larger, and having transverse bands of yellow on a black ground. They consist chiefly of two species of *Mylabris*, *M. Cichorii* and *M. phalerata*, mixed in variable proportions; the latter are larger than the former, but similar in colour. Chinese cantharides frequently contain more cantharidin than the Spanish flies, but the yield is uncertain. Both contain a fatty matter, removable by bisulphide of carbon, in which cantharidin is insoluble. Recent researches show that *Cantharis* (*Lytta*) *adspersa* is a valuable source of cantharidin, being richer than the Spanish fly.

Capsicum.—The fruit of more than one species of *Capsicum* possesses a pungency which renders it useful as a local stimulant, in the form of gargle, and liniment; it is also administered to assist digestion. Its principal application, however, is as a condiment. (See Spices.)

Cascarilla, Sweet-wood, or Eleuthera (Fr., *Cascarille;* Ger., *Cascarill*).—The bark of *Croton Eluteria* is prescribed as a tonic, in the form of an infusion or a tincture. The plant is a shrub, usually 3–5 ft. high; it is indigenous only to the Bahamas, where it is pretty plentiful, especially in the islands of Andros, Long, and Eleuthera. The drug occurs in quills and fragments, generally of very small dimensions, and derived from young wood. The colour of the cortical layers changes from pale-red in young bark, to deep-red in older samples. The surface is often coated with a minute lichen, which gives it a chalky-white appearance, speckled with small black dots (*apothecia*), about the size of a pin's head. By this character, and its aromatic taste, it is distinguished from Pale Cinchona bark, which it otherwise resembles. The flavour of the bark is bitter and nauseous; its odour is very fragrant and agreeable, and is abundantly emitted on burning, hence the drug is a favourite ingredient in fumigating pastilles. Packed in sacks, it is shipped from Nassau (Bahamas) in varying quantities. The exports, in 1876, were 1093 cwt. The market value is about 17*s.*–24*s.* 6*d.* a cwt. The natives of the Bahamas employ the cortex, and tender shoots, for the preparation of decoctions, and select the leaves for medicating their warm baths.

Another species, called Jamaica, or Caribbean, Cascarilla (*Croton Sloanei*), is indigenous to Jamaica, and very abundant there; but it is unknown in the Bahamas, and though employed medicinally by the colonists, does not enter into commerce. A third species is the Smooth-leaved, or False Bahama Cascarilla (*C. lucidus*), locally termed "False-sweetwood bark." It is common in the Bahamas and most of the W. Indies; its bark outwardly resembles the genuine drug, but is slightly bitter and astringent, and not aromatic, and is reddish externally, with the inner surface finely striated; it forms an occasional adulterant of the true bark, and appears to possess emetic properties. *C. Cascarilla*, which originally yielded the drug, is now extirpated, or nearly so. *C. niveus* (*Pseudo-china*), yielding Copalchi-bark, or Quina blanca, sometimes called Cascarille, is a native of Mexico, Central America, Colombia, Venezuela, and the W. Indies; it grows to a height of 10 ft., and furnishes quills of bark 1–2 ft. long. It presents no resemblance to Cascarilla, but has been sold in London for Cusparia bark (see Angostura.)

Cassia (Fr., *Casse Canefice;* Ger., *Röhrencassie*).—The pulp extracted from the pods of *Cassia Fistula* (*Carthartocarpus Fistula; Bactyrilobium Fistula*) forms one of the ingredients of the well-known lenitive electuary, and is in common domestic use as a mild laxative in S. Europe. The tree, 20–50 ft. high, is indigenous to India, up to 4000 ft. on the outer Himálayas, and probably also in the country of the Dor, Tropical Africa; it is now acclimatized and partially cultivated in Brazil, W. Indies, and Egypt. The ripe legume is a dark chocolate-brown cylinder, 1½–2 ft. long, and ¾–1 in. thick, divided into 25–100 cells, each containing a seed, embedded in a soft saccharine pulp. In the fresh fruits, the cells are filled with this pulp; but on their arrival here, the latter appears only as a thin layer of a viscid substance, of mawkish-sweet flavour. To prepare the pulp for use, it is separated from the pods, by crushing them, digesting them in hot water, and evaporating the strained liquid. The pulp is occasionally imported as such, but is much inferior to that newly prepared. The drug comes to us principally from the W. Indies; in a minor degree also, from the East. Its market value is about 55–7*s.* a cwt. The pulp yielded by the legumes of some other species of *Cassia* is occasionally employed. That of *C. grandis* (*Brasiliana*), a native of Brazil and Central America, is bitter-astringent; that of *C. moschata*, growing in Colombia, is sweetish-astringent. In Martinique, Liberia, Senegal, the Gaboon, Mauritius, &c., the roots of *C. occidentalis* are used as a diuretic, and its leaves as a purgative; the chief value of the plant lies, however, in its seeds, which, when roasted, are largely employed as a substitute for coffee, under the name of "negro-coffee," or *café négre.* (See also Spices—Cassia.)

Castor.—Castor consists of the preputial follicles of the common beaver (*Castor fiber*). It is imported from Hudson's Bay, in the form of flattened fig-shaped sacs, blackish and wrinkled externally, reddish-brown with a resinous fracture internally, and a characteristic disagreeable odour. It melts when heated. Formerly it was imported also from Siberia, but Russian castor is practically unknown at the present day. The drug has had a high reputation as an antispasmodic, in hysteria and nervous diseases.

Castor Oil.—The leaves of the Castor-oil plant (*Ricinus communis*), applied in decoction to the breasts of women, are said to promote, and even occasion, secretion of milk. The principal value of the plant, however, lies in its seeds, from which is obtained the well-known purgative oil. (See Oils.)

Cebadilla, or Cevadilla (Fr., *Cévadille;* Ger., *Sabadillsamen, Läusesamen*).—The seeds of *Asagræa officinalis* (*Veratrum officinale, Sabadilla officinarum, Schænocaulon officinale*) are employed as a source of veratrine. The plant is a native of Mexico and Guatemala, and is found in grassy portions of the E. face of the Cofre de Perote range, and in Orizaba, near Teoloso, Huatusco, and Zacuapan, down to the sea, besides being cultivated near Vera Cruz, Alvarado, and Tlacatalpan. Another form of the plant is abundant near Carácas, on grassy slopes at 3500–4000 ft., and southwards on the uplands of the Tuy valley; it largely contributes the drug. The seeds are inodorous, and possess a bitter acrid flavour; their powder causes violent sneezing when inhaled. Freed from their capsules, they have been of late years shipped in large quantities to Europe. From La Guayra and Porto Cabello, 2500–3000 cwt. are sent annually to Germany; the total export from the former port, in 1876, was 690 cwt., of which 510 cwt. went to Germany. The local value is about 14*s.* a cwt.

Chamomile (Fr., *Camomille Romaine;* Ger., *Romische Kamille*).—An infusion or extract of the flowers of the Common, or Roman, Chamomile (*Anthemis nobilis*) is in general use as a stomachic and tonic. The plant is a small creeping perennial, abundant on the commons of S. England, and reaching to Ireland, but absent from Scotland, except the isles of Bute and Cumbrae; plentiful also in Central and W. France, Portugal, Spain, Italy, and Dalmatia, and doubtfully native in Central and S. Russia. The plant is largely grown in Kieritzsch, and near Zeiz and Borna, in Saxony; to some extent, in Belgium and France; and about 50 acres of it are cultivated at Mitcham, in Surrey. The following details refer more especially to the last-named locality:—

Sets are generally cut from the roots, each root affording 3–4 dozen, and these are placed about 18 in. apart, in rows 1 yd. apart. The beds need constant hand-weeding, the spaces are forked over at the beginning of winter, and the exposed and loose roots are covered with fresh mould. The plants are occasionally raised from seed, when introducing a fresh stock. The best time for planting is March; but it is also sometimes done in April, and even in the autumn. The crop is in perfection in July, lasting till September, and in some seasons till October. The best weather is alternate sunshine and sharp showers. The best soil is stiffish black loam; light sand causes the plants to become weak; clay is too heavy. Change of ground, every 2–3 years, is beneficial; manuring should be very slight, or it will cause an excess of stem and leaf, and reduce the crop of flowers. The gathered flowers are placed on canvas trays in a drying-room, heated by a stove, where they remain for about one day. The crop ranges from 3 to 10 cwt. an acre, and averages about

4 cwt. Single flowers give greater weight than double; but, having a lower value, they yield about the same. Gathering and drying cost about 42*s.* a cwt.

The flowers of the wild plant are never met with in commerce, only those of the cultivated form. They vary according to locality and degree of cultivation: the best are of large size, very double, and of a good white colour, the last quality depending much upon fine dry weather at the flowering period; the inferior are only partially double, and have a yellowish or brownish centre. They are known respectively as "double" and "single," and vary widely in price. Home-grown flowers fetch 2–3 times as much as foreign; the ordinary value is about 2*l.*–5*l.* a cwt. The flowers have a powerful odour, and a very bitter flavour, and yield about ⅘ per cent. of essential oil. At Mitcham, oil is distilled from the whole plant, after gathering the best flowers. The fresh wild plant is sometimes sold for making extract; but the latter is unfit for medicinal use. The flowers of *Matricaria Chamomilla*, under the name of "German chamomile," are occasionally to be seen in the London drug market. They are never double flowers, and are distinguished also by having a hollow conical disc, without scales, inside the flower heads. In Germany, they are preferred to the Roman chamomile.

Chaulmugra.—The seeds of *Gynocardia odorata* yield an oil, which has been used in the East from time immemorial, for the cure of skin diseases, scrofula, &c. Its powerfully alterative nature has recently attracted the attention of Europeans, and it is now largely prescribed in consumption and rheumatism, and as a specific against syphilis. (See Oils.)

China-root (Fr., *Squine;* Ger., *Chinawurzel*).—The fibrous roots of *Smilax China* here and there swell into large tubers; these maintain a high reputation in China and India as a remedy against syphilitic and rheumatic diseases, a reputation formerly enjoyed also in England, but latterly ignored. The plant is a thorny climbing shrub, indigenous in Nepal, Sikkim, Kasia, and Assam, in China, Cochin China, Formosa, and the Loochoo islands, and generally throughout Japan. The tubers are dried, and trimmed of excrescences, entering into commerce in the form of irregular cylinders, about 4–6 in. long and 1–2 in. thick, and covered with a shining rusty bark. The export of the drug to Europe is principally from Canton, the quantity, in 1872, amounting to 51,200 lb.; since then, no separate account seems to have been taken. The trade between Chinese ports is much more significant; the shipments from Hankow, in 1878, were 11,656 *piculs* (of 133⅓ lb.), valued at over 23,000*l.*, and from Kiu-Kiang, 6750 *piculs*, worth about 14,000*l.* The price of the drug in the English market is about 30*s.*–35*s.* a cwt. Several other species of the plant, which belong to the same family as the more popular Sarsaparilla, have at least a local reputation and use. Thus *S. glabra* and *S. lanceæfolia* are common in India and S. China, and yield tubers scarcely differing from the commercial drug; the W. hemisphere furnishes a number of species, some of whose tubers have been occasionally imported from Puntas Arenas (Costa Rica) as "Western China root": they are chiefly—*S. Pseudo-China*, and *S. tamnoides*, in the U.S., southwards from New Jersey; *S. Balbisiana*, common in all the W. Indies; *S. Japicanga*, *S. syringoides*, and *S. Brasiliensis*.

Chiretta.—*Ophelia Chirata* is a herb, possessing a strong bitter tonic principle, much valued in India, little used in England, and ignored on the Continent. When cheap, however, it replaces gentian in cattle-foods. An inferior kind, derived from *Ophelia angustifolia*, with the woody portion thicker, and containing no pith, is occasionally imported. It gives a paler and weaker infusion. (See Spices.)

Cinchona, or Peruvian Bark (Fr., *Ecorce de Quinquina;* Ger., *Chinarinde*).—The barks of a number of plants belonging to the genus *Cinchona*, and the alkaloids prepared from them, constitute the only reliable remedy against fevers, and form the most important of our vegetable drugs. The subdivision of the genus into species and varieties is a subject on which botanists are widely at variance; for the purposes of this article, moreover, it will suffice to confine attention to those species which afford a bark used in pharmacy, or employed for the manufacture of the alkaloids. The home of the genus is a district of S. America, lying on the W. side, between 10° N. and 22° S. lat., chiefly on the E. slopes of the Cordillera of the Andes, at an average altitude of 5000–8000 ft. The maximum elevation is about 11,000 ft., the minimum, 2600 ft., the decrease taking place as a higher latitude is reached; the most valuable kinds are not found below 5000 ft. Variety of soil has less influence upon the plants than climatic conditions; these latter, in the natural habitat of the plants, are extremely changeable as regards sunshine and moisture. While a passing temperature of but little above freezing may be borne by the hardiest kinds, the majority prefer a mean of about 12°–20° (54°–68° F.). Manuring increases appreciably the proportion of alkaloids.

The production of commercial barks is limited to about a dozen species. Of these, three only are admitted for pharmaceutical use, the remainder being employed only in the manufacture of the alkaloids. The former are:—(1) *C. officinalis*, of several varieties; native of Ecuador and Peru, forming a large tree; yields "Pale," "Loxa," or "Crown" bark, found in quills sometimes 1 ft. long, ⅛–⅜ in. thick. (2) *C. Calisaya*, of many varieties; native of the warmest woods of the slopes bordering the valleys in the Bolivian provinces of Enquisivi, Yungas de la Paz, Larecaja (Sorata), Caupolican (Apolobamba), and Muñecas, and the Peruvian province of Carabaya, at elevations of

5000–6000 ft.; attains great height and size; affords "Calisaya," "Bolivian," or "Yellow" bark, the most important of those commonly used, found (*a*) in flat pieces, 1 ft. or more long, 1–4 in. wide, and $\frac{1}{8}$–$\frac{3}{8}$ in. thick (= "flat"), and (*b*) in tubes $\frac{3}{4}$–$1\frac{1}{2}$ in. thick (= "quill"). (3) *C. succirubra*, native of all the Andean valleys debouching on the plain of Guayaquil, but now almost confined to the woods of Guaranda, on the W. slopes of Chimborazo, at 2000–5000 ft.; forms a tree of 50–80 ft.; yields the "Red" bark, so named from its distinctive colour; is held in least esteem in England, but when of deep brilliant tint is readily sold at a high figure for the Parisian markets. The members of the second class are principally:—(1) *C. macrocalyx*, of Peru, affording "Ashy Crown" bark; its sub-species *C. Palton* yields "Palton" bark, much used for making quinine. (2) *C. lanceolata*, of Peru, yields "Carthagena" bark, confounded with "Palton," but not so good. (3) *C. lancifolia*, of New Granada, affords "Columbian" bark, very largely used for quinine; a variety gives "Soft Columbian" bark. (4) *C. pitayensis*, of New Granada, furnishes "Pitayo" bark, very valuable for the preparation of alkaloids, being the chief source of quinidine. (5) *C. australis*, of S. Bolivia, produces a poor bark, often mixed with Calisaya. (6, 7, 8) *C. Peruviana*, *C. nitida*, and *C. micrantha*, all of Peru, contribute "Grey," "Huanuco," or "Lima" bark, chiefly employed on the Continent. (9) *C. cordifolia*, of New Granada and Peru; some of its varieties furnish a portion of the "Columbian" bark, and are used for the preparation of alkaloids. A new variety, called *China cuprea*, has recently appeared in the London market. Its inner surface is very smooth. It contains about 2 per cent. of quinine, and but little resinous matter.

The collection of the bark in S. American forests is an arduous occupation, followed only by the Indians and half-breeds. The stem of the tree is first freed from parasitic growth, and is then beaten, to remove the sapless outer bark. Vertical and cross cuts are next made in the inner bark, as high as can be reached; the tree is felled, and the inner bark is completely stripped off. The latter is then dried, by sun-heat where possible; failing that, the bark is spread on hurdles over a camp-fire. The thinner pieces roll up into "quills," while the thicker portions are kept flat by weights. The bark of the roots is sometimes added. When dry, the barks are sorted according to size, sometimes pressed, and packed in parcels of 100 lb. and upwards, in serons of raw bullock-hide, or in wooden chests. In this state, the drug is carried to the coast for shipment to Europe.

The destructive and wasteful manner of collecting the bark, pursued by the inhabitants of the natural home of the tree, has led to its extermination in many places, and it is now confined within very narrow limits. The value of the drug in tropical medicine has compelled us to attempt its cultivation in most of our Colonies, and more especially in India, in order that we might not be dependent upon countries which produced it in insufficient quantity, yet monopolized the supply. The introduction of the trees into India was successfully accomplished, in spite of extraordinary difficulties, by the rare intelligence and energy of C. R. Markham, C.B., F.R.S., and those who assisted him. The cultivation of cinchona is now a recognized branch of the planting industry of India, Ceylon, W. Indies, &c., and is largely carried on by the Dutch in Java. The following account of the culture and barking of the trees, and the preparation of the alkaloids, has reference specially to India; it will be supplemented by a brief notice of the condition of the enterprise in other countries.

CULTIVATION.—Neglecting, for the moment, to specify the localities where cinchona cultivation promises to be a success, it will, perhaps, be better first to indicate the necessary natural conditions, and the methods which have been adopted after years of experience.

Climate.—None of the medicinal cinchonas survive frost; they prefer a moderate and constantly equable warmth, the most congenial temperature for yellow and red barks in company being about as follows:—Max., 34° (92°–4° F.); min., 4°–5° (40°–1° F.); mean max., 27° (80·6°–81·6° F.); mean min., 15°–16° (59·3°–61° F.); mean, 21°–22° (70°–71·26° F.) Excessive moisture is prejudicial, and a sudden burst of sunshine after protracted wet also does harm, while all species can withstand drought; a constant alternation of showers and sunshine is most favourable. The annual rainfall may be about 100–150 in., and should be uniformly distributed, and gentle in character. Hail does not commit permanent damage; but storms of wind are very injurious, especially to yellow barks. Elevation will of course vary with latitude and other conditions. In the Nilgiris, yellow barks succeed best at 4500–6000 ft.; crown barks, up to 8500 ft.; red and grey barks, best within the yellow zone, but nowhere well. In Sikkim, yellow and grey barks thrive at 800–5000 ft., best at 1500–3500 ft.; red, at 1500–3000 ft.; crown, not at all.

Soil and Drainage.—The trees prefer a rich soil, and thrive better on newly cleared forest-land than on grass-land; but the crown barks do fairly well in poor ground. While a free and friable surface-soil is beneficial, an open subsoil is absolutely necessary. The least stagnation of water at the roots is fatal to all species; perfect drainage must, therefore, be secured by a sloping situation, and other conditions.

Collecting Seeds.—The seeds mostly ripen during the dry season following the rains, and should be carefully gathered just as the vessels begin bursting. The latter are then spread in shallow boxes, to dry until the seeds fall out, the desiccation being best accomplished by placing them in a draught during the day, covering them from rain, and from dew at night. They soon lose vitality, and should be sown at once; they are best transported in porous cloth, ventilation being essential. About 20,000–25,000 plants are produced by 1 oz. of clean seed.

Propagation by Seeds.—The seeds germinate best at 18°–21° (65°–70° F.), tolerating a max. of 26° (80° F.), and a min. of 13° (55° F.). During the cold season, they are sown under glass; but during hot weather and rains, in open beds, sheltered by thatched roofs, about 5 ft. above the soil in front, and 2 ft. behind. The best soil is rich, mellow vegetable-mould, alone, or mixed with clean, sharp sand. This is sifted, and spread in layers 2–3 in. deep and 5 ft. wide, on beds of cleared ground, of any convenient length, running E. and W., and with the open side towards the N. To prevent water lodging in them, they must slope to one side, a condition best attained by forming terraces on a hill-side, and providing a path and a drain to each. Before sowing, the soil is rendered uniformly firm (but not hard) and smooth, by working it through the hand and gently pressing it down. The seeds are then placed loosely in bags, and immersed in cold water, undergoing twelve hours' soaking if fresh, but only six if they have been kept for some time. When taken out, they are gently stirred with dry sand, to separate them, and are thickly scattered on the beds, and lightly covered with a sprinkling of dry sand, intended only to steady them and get them into contact with the soil, and not to cover them; the beds may then be very gently pressed with a smooth board. Water is applied in the morning, and, if necessary, during the day, but not at late evening; deluging must be avoided, while a uniform moisture is maintained; the temperature of the water should approach that of the air. Additional shade and shelter have sometimes to be provided. Under glass, extra careful shading is necessary; and, after watering, especial care must be taken that the leaves become quite dry, before closing the frames. Every precaution will have to be taken against damping off; in very wet weather, the plants are sometimes infested by a fungus, whose ravages may be checked by gently stirring the soil. Germination takes place in 2–6 weeks.

Pricking out Seedlings.—When the seedlings have 2–3 pairs of leaves, they are put out into nursery-beds, resembling the seed-beds, but having a thicker layer of soil. They are best removed by inserting a small stick beneath them, and loosening the soil, so that they may be lifted out by the leaves, without the least injury to the rootlets. Holes 1½ in. apart, in lines 2 in. apart, deep enough to receive the outstretched roots of the plants, are made by means of a stick; into these, the seedlings are carefully placed, and the earth is filled in and pressed round, so as to thoroughly occupy the hole. Sometimes the seedlings are placed first in shallow boxes, which can be put under glass if necessary. When 4 in. high, the plants are re-transplanted, at distances of about 4 in. each way; and when they have reached 9–12 in., they are placed in their permanent situations. The seedlings may be hardened before the final transplanting, by removing the thatch for about a fortnight, commencing only in dull, cloudy weather. From the sowing to the final transplantation, some 8–12 months are required, during which the soil must be kept uniformly moist without being wet.

Propagation by Cuttings.—Cuttings planted in the open air and partially shaded will form roots in 3–5 months, and this is perhaps the easiest, cheapest, and safest plan of propagation, especially for inexperienced cultivators. It is, however, very slow; and when a rapid increase of plants is required, a propagating house must be used. In either case, the cuttings are selected from wood of the current year's growth, preference being given to young shoots springing from the lower part of the stem; they are removed in pieces about 3–5 in. long, just below the point where a pair of leaves grow. Young unexpanded leaves, if any, are left on the cutting; but larger ones are pinched off at the base. Red bark cuttings may be put out in beds, such as have been described for seedlings, or in boxes 2 in. deep, filled with mould and sand, and covered with a layer of sand to promote drainage; they take root in 2–4 months.

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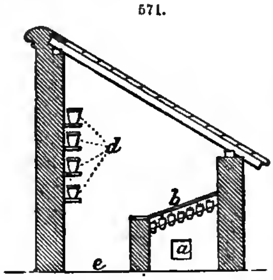

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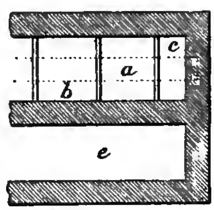

The principles of the propagating house are shown in Figs. 571 and 572; *a* is a flue leading from a furnace, and having a gradual rise towards the exit end; it passes beneath the cases *b*, filled with pots; *c* is a water-tank, placed over the flue, in order that its contents may be warmed; *d* are pots, placed on shelves attached to the wall, between and below the windows; *e* is a path. The cuttings as prepared are placed in 4-in. pots (Fig. 573); the cuttings *a* are set in a layer of pounded brick-dust *b*, under which is the ordinary potting mould *c*, resting upon a stratum of moss *d*, and a potsherd *e*, to facilitate drainage. These pots rest as at *b* (Fig. 571), in a bed of damp sand, exposed to a bottom heat of about 24° (75° F.). The atmosphere of the house is kept moist by means of a very fine syringe, but the cuttings must never be watered. When the cuttings have become rooted in the propagating cases, the pots are bodily removed to other cases, where the plants are hardened off; when sufficiently hardy, they are taken up, and placed singly in pots about 3½ in. deep and 2 in. in diameter, formed of a mixture of cow-dung and sand, as shown in Fig. 574. Before use, these pots are dried in the sun, which renders them as strong as an ordinary pot; when buried, they become sufficiently soft to be penetrated by the roots, but remain sufficiently cohesive to bear handling. They are made by hand at the rate of 400–500 a day, and cost but 1 per cent. of the price of an ordinary flower-pot.

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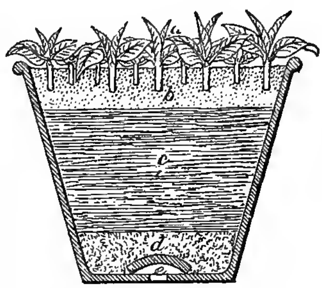

574.

When the plants are to be put out in their permanent positions, they are removed bodily in the pots, and transported on deal trays; holes are prepared for them at distances of 2½ in. apart, and the plants and pots together are placed in the holes, and filled round with earth up to the level of the stem, as shown in Fig. 575. This done, the plants are at once shaded with rough slabs of wood, arranged as shown in Fig. 576; and when they have grown above the wood, they are protected from chafing, by a grass rope twisted round the top.

Layering.—A method by which a far greater number, and more rapid succession, of cuttings may be got from a plant is that known as "layering," illustrated in Fig. 577. The operation consists in bending the branches of the plants into the soil, and cutting them half through at the bend; the object of this is to cause roots to spring from the cut portion of the branch, which is placed in the soil for that purpose. The juice of the plant escapes so rapidly from the cut as to induce decay, unless at once absorbed; this end is attained by placing a piece of thoroughly dried brick *a* in the slit formed by detaching the tongue *b*. The latter is then kept down, if necessary, by means of the peg *c*. When it would be inconvenient to bring the branch down to the soil, the latter may be raised in boxes. The best season for layering is during the rains. When well rooted, say in 3–4 months, the layers are separated from the parent plant, and removed to glazed frames, where they are placed about 6 in. apart in good soil. Here they become established as "stock plants," and yield a constant succession of cuttings. In taking these, whole shoots must not be removed, but a few buds must be left to provide new shoots. Cuttings from stock plants are treated in the same way as any others.

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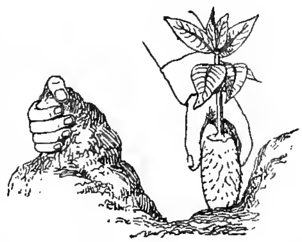

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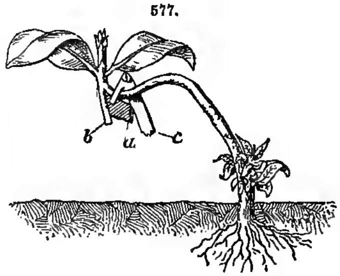

Propagation by Buds.—A method of propagation which gives a large number of plants from a limited supply of wood is occasionally practised; it consists in removing the buds with leaves attached, and placing them in pots plunged into damp sand, and treating them generally the same as cuttings. Roots are formed in 3–6 weeks, success depending entirely upon supplying sufficient moisture, without overdoing it.

Planting.—When a site has been chosen, in accordance with the conditions noted in previous paragraphs, the natural vegetation is completely removed. In very exposed situations, occasional strips of forest may be left as a break-wind; but they must be sufficiently far from the plants not to incommode them by their roots, or by falling over them. The felling, clearing, burning, lining, pit-digging, and filling operations are precisely the same as in coffee culture, and will be found fully described on p. 692, the size of the pits being 12–15 in. deep and 18 in. square. Sometimes trenching or deep hoeing have been performed previous to planting; but besides being expensive, they are objectionable on steep ground, as favouring wash. Occasionally the size of the holes is increased to 2 ft. each way. The beds of hardened plants ready for putting out are deluged with water over-night, so that the soil may be cohesive. On a day when the earth is moist, and the weather cloudy and damp (but not in heavy rain), the plants are taken up with abundance of soil around their roots, and are placed in the filled holes *as quickly as possible;* a space quite deep enough to receive the largest root without doubling is made by one hand, while the plant is inserted in the ground by the other; the soil is then filled in around, and thoroughly pressed down as the operation proceeds. The position of the plants in relation to the surface of the ground is indicated in Fig. 578; it is essential that they should stand on elevations, drained from above by a ditch, so as to prevent the possibility of earth being washed down and covering the bark—a circumstance that is sure to be attended by fermentation, followed by a fungus that destroys the bark and kills the tree. In the early days, the plants were put out much too wide apart; it is evident that no species will ever attain great size in India, and close planting has the advantage of affording shade to the roots, and reducing the growth of weeds, which are otherwise a source of much expense. Should the trees crowd one another, they can be thinned out, and thus yield an early crop of bark.

578.

Shading and Staking.—In some localities, protection from the sun may be necessary. For this purpose, natural forest trees are quite inadmissible; the requisite shade is readily afforded by erecting, on the sunny side of each plant, a rough bamboo framework, thatched with grass or ferns, or by sticking leafy branches in the ground, &c. Where much staking would be required, cinchona cultivation had better not be attempted, because great expense would be entailed, and small success achieved. Some support, however, is occasionally demanded, when the method illustrated in Fig. 579 may be resorted to. The great danger to be avoided is the chafing caused by the swaying of the plant; a soft material, such as grass rope, is therefore employed, and care is taken that it shall embrace the branches, without ever coming into contact with the bark of the stem. Staking is commenced when the plants are 1–1½ ft. high.

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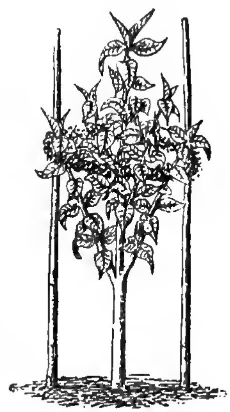

Weeding and Pruning.—The eradication of weeds, especially several species of grass, resembling the "couch-grass" of England, must be periodically performed, either by cutting them off, pulling them up by hand, or light hoeing. A superficial hoeing just around each tree is, indeed, beneficial, whether weeds are present or not; but deep hoeing would destroy the roots of the cinchona plants. Pruning must be restricted to the removal of such branches as would naturally fall in course of time, or such as project to the injury of neighbouring trees.

Manuring.—The application of manures is unattended by any apparent increased growth of the trees; but, except in the case of red barks, is accompanied by a marked increment in the proportion of alkaloids contained in the bark. Dung applied to crown bark, 3–4 times in 5 years, increased the alkaloids 2·81 per cent., thus raising the value of the bark by about 2*s.* 6*d.* a lb.; 1 lb. of guano per tree, gave 2·5 per cent. increase (1*s.* 6*d.* a lb); ¾ lb. sulphate ammonia gave 1·22 per cent. increase.

Diseases.—Two distinct forms of disease are said to attack the plants: the one, constitutional, affecting the whole plant, and generally fatal; the other, local, and not dangerous. The former is almost identical with the "canker" of English gardeners, and is induced solely by inefficient drainage; it is first manifested by the discoloration and falling of the leaves, followed by shrivelling of the tissues from the roots upwards, and quickly terminating in the death of the plant; it is neither infectious nor contagious, but purely local, and due only to excess of moisture in the soil. The second form of sickness appears in patches on the stem and branches, quite local in character; very rarely it involves the whole stem, when death may result, but frequently the diseased spots are thrown off, and replaced by new healthy bark, and when much affected trees are cut down, the stumps throw up vigorous shoots; its cause is not yet well explained.

Harvesting the Bark.—In S. America, barks of all sorts and ages are collected indiscriminately, and in such a way as to kill the trees; such a system was evidently inadmissible in the case of cultivators, and the several improved plans proposed will now be described. The first of these is known as "mossing," and is illustrated in Fig. 580. Two parallel cuts *c* are drawn down the stem, the strip of bark *a* included between them is then raised from the incisions, and pulled off carefully from the bottom upwards, great care being taken not to injure the *cambium*, or sappy matter, left in the hollow; immediately the bark is removed, a thick coating of moss *b* is bound around the wounded stem. By this process, the *cambium* granulates, and forms a new bark. It is essential to observe that the moss is free from lichens. The strips of bark removed are about 1–1½ in. wide; such a number are taken as the tree will afford, leaving intermediate strips of somewhat greater width. At the end of 6–12 months, the bands left in the first instance are taken in the same way; in 12–22 months, the parts first stripped will be covered with new bark ready for re-stripping. The advantages claimed for this plan are that a crop of bark equal to half the total trunk-bark of the tree can be taken annually, without damage to the tree; and that this bark is richer in total alkaloids, and especially in crystallizable quinine, than natural bark. It appears, however, that this increase of total alkaloids is not observable in the renewed bark of trees at the maximum yield (over 8 years); but the proportion of quinine is augmented, and the value of the bark as a source of pure quinine is thereby raised. The enrichment of the renewed bark is said to be at the expense of the bark outside the mossed region; and it is said that the renewal is prevented, or much retarded, by the least injury to the *cambium*. Further, the cropping cannot be depended upon oftener than once in 2–3 years; and this rapid cropping tends to shorten the lives of the trees. Finally, the operation can only be performed when the air is quite moist, and therefore at a time when the bark can least easily be dried. In some instances, too, the plan has been frustrated by the renewing bark being devoured by ants, who found an asylum in the moss. On the other hand, a number of trees which were left bare (unmossed) after the barking, renewed their bark fairly well. When sufficient supplies of moss cannot be procured, as for instance in Coorg, a substitute is found in detached leaf-stalks of the plantain, and the leaves of wild cardamom, or of ginger. These should be applied in a dry state, and not with a smearing of clay, as has sometimes been done.

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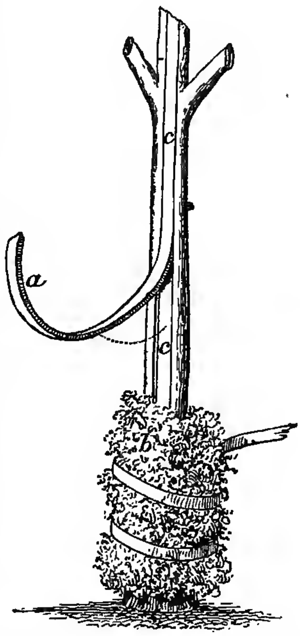

An alternative to the mossing system is that described as "coppicing." The trees are cut down near the ground, and of the shoots which spring up from the stump, or "stool," as it is termed, one or more are left to grow. The alkaloidal richness of the bark is supposed to attain its maximum at the eighth year, which period might be chosen for the coppicing, and a regular succession of shoots be cut as required. As yet, this plan has not received the same study or encouragement as the preceding, and against it are alleged the following objections:—That the stool frequently fails to send up shoots; that the rate of growth is slower than in young trees; and above all that for every 6 lb. of trunk-bark per tree by the mossing system, only 1½ lb. of mixed trunk and branch bark were obtained by coppicing, but these 6 lb. included 3 lb. of original bark. It is probable, as King suggests, that a compromise between the two systems will ultimately be adopted, mossing for a time and coppicing when the vitality of the trees begins to be impaired. As a matter of fact, much remains still to be learnt as to the natural longevity of the trees, the effects of shade at all ages, the respective value of the bark from different portions of the tree, and other points of great importance, which can be elucidated only by intelligent experiments conducted on a large scale.

Removing and Drying the Bark.—At some seasons, the separation of the bark from the wood is very easily effected, and these should be chosen for the operation. Felled trunks and branches are scored with a number of longitudinal and transverse incisions, which liberates the bark; smaller branches and twigs are subjected to whittling, and as much of wood as possible is excluded. As soon as removed, the bark is spread to dry on split bamboo shelves in rough temporary sheds; the process can be completed only with artificial heat, for which purpose the partially dry bark is conveyed to the drying-house, a stone building, erected near the alkaloid manufactory, provided with shelves, and heated to a temperature exceeding that of the outer air by about 10°–15° F. The heat must never rise so high as to affect the chemical composition of the bark. After proper drying, the bark can be stored without suffering deterioration.

THE ALKALOIDS AND THEIR PREPARATION.—Of the alkaloids present in cinchona barks, the four possessing remedial value are—stated in order of merit—quinidine, quinine, cinchonidine, and cinchonine. Their relative and total proportions are each subject to great variation, in fact no two samples of the bark are alike. Until recently, quinine was the only member of the group admitted into use; but experiment has shown that cinchonidine and cinchonine are very little inferior to the former as a febrifuge, and it is probable that they will not be thrown away in future. Quinidine is in too small proportion to deserve special notice. Though it is impracticable to state the percentage of alkaloids, individually or collectively, in each species of bark, the latter are nevertheless distinguished by well-marked characteristics, a knowledge of which is essential for their most economical and suitable employment. Pale or crown bark is rich in crystallizable quinine and is highly valued by the manufacturers of quinine sulphate in this country. Yellow bark is even more highly esteemed for this purpose. Red bark, on the other hand, while as rich as either of the others in total alkaloids, contains only little quinine, and that difficult of extraction. Moreover, this species is hardier, grows better, and yields about $\frac{1}{3}$ more bark than *officinalis*, so that as a source of total alkaloids it is more deserving of attention than the other two, though inferior to them if they could be got to grow as luxuriantly. The red bark, too, is the most valuable for the preparation of tonic decoctions, tinctures, &c., largely used in Europe; and in consequence of this fact, its price in Western markets is but little, if at all, inferior to that of the kinds richer in quinine. Planters who intend cultivating cinchona need to study these points, in connection with the market which is open to them. The barks best adapted for quinine-making fetch the best prices in European markets, and will probably continue to do so. Red bark, though nearly as dear at the moment, will doubtless recede in price when production increases, as the demand for that kind is limited in Europe; it is, however, the only kind likely to be used in the East for the local manufacture of a febrifuge, as efficient as, while much cheaper than, sulphate of quinine. Two conditions bearing upon this part of the subject are:—(1) That high temperature increases the cinchonidine at the expense of the quinine, so that barks grown at a low elevation (or even at a high elevation, if exposed to sunlight), will be richer in the former and poorer in the latter, while a low mean temperature, within certain limits favours the production of quinine; (2) That deprivation of light, without impeding the access of air and sun-heat, materially increases the proportion of total alkaloids.

The preparation of quinine and cinchonine has been already described under Alkalies—Organic (see p. 231). The manufacture of a cheap febrifuge has engaged the serious attention of the Indian government, resulting in two such products,—Broughton's "amorphous quinine," and "the febrifuge," called "quinetum" by Dr. de Vrij. The former is prepared in the following way:—

Strips of the bark are placed in a copper pan with sulphuric acid ($1\frac{1}{2}$ per cent. for trunk-bark, 1 per cent. or less for prunings, &c.), and a quantity of water from the fourth extraction (*v. post*); the whole is boiled for 1 hour, then subjected to a strong screw press, the liquid being caught in a wooden vat. The bark is reboiled with liquor from a third extraction, with an additional $\frac{1}{2}$ per cent. of acid, for 1 hour, and is again squeezed. A third boiling is given in liquor from a fourth extraction, and, after squeezing, the bark is finally boiled with fresh water, sun-dried, and used as fuel. The resulting concentrated decoction is evaporated to $\frac{1}{8}$, and cooled; it is then decomposed by addition of milk of lime in slight excess, which precipitates the alkaloids, with formation of insoluble lime salts; after standing for a day, the precipitate is filtered off, squeezed, dried, and powdered. The powder is then placed in the apparatus shown in Fig. 581; A B C D is a sheet-iron cone, traversed by an upright tube E, terminating above in 4 open arms, and supported below on a flat iron disc C D. A copper vessel F G fits closely to the lower end of the cone. The latter is suspended, and connected, through the tube H, with a simple worm tub. The cone is packed with the precipitate up to E, the lid is put on, and alcohol is added slowly from above, till F G is about $\frac{1}{3}$ full of the saturated spirit, which is then carefully neutralized by dilute sulphuric acid. The cone is then connected with the condenser through H, and a fire is lighted below. The spirit boiling in F G rises in vapour through E, passes out at the openings, and condenses so as to form a liquid stratum above the precipitate. This is observed by the gauge B I; uncondensed vapour passes through H, and is caught. A small quantity of spirit, by constant circulation, extracts all the alkaloids without waste. The alkaloid in F G is neutralized with dilute acid every two days. When the precipitate no longer contains any alkaloid, F G is removed, and the alcohol is distilled off; the alkaloid is washed with water, while the alcohol is recovered with a maximum loss of 6 per cent. The alkaloid is treated suddenly with about 10 times its bulk of cold water, which separates the black resin present; the addition of a little dilute acidulated solution of sodic sulphide will remove any copper accidentally present. The alkaloid solution being still coloured, a small quantity is precipitated by dilute caustic soda, the colouring matters falling at the same time. The whole is then filtered through cloth; and the alkaloid is precipitated by caustic soda, filtered, pressed, dried, and powdered. Potash may replace soda, if more easily or cheaply procurable. This process was

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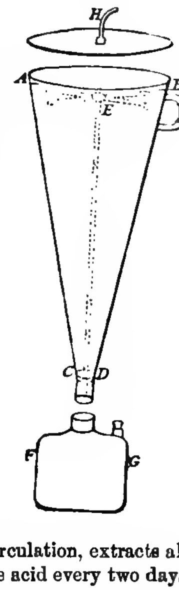

employed to produce 600 lb. of alkaloid in the Nilgiris; but the product was found to cost more than ordinary commercial quinine, assuming the value of dry trunk-bark at 2*s.* a lb., and branch-bark at 6*d.* The yield of alkaloid is, however, naturally much greater.

The second method, adopted by Wood, in Sikkim, is much simpler:—The dry bark is crushed into small pieces—not powdered—and is put into casks, where it is macerated in the cold with very dilute hydrochloric acid; the liquor is then run off into wooden vessels, and mixed with an excess of strong solution caustic soda; the precipitate formed is collected on calico filters, and well washed with water. The precipitate is then gently dried, and powdered, constituting the crude febrifuge, which requires purifying. This is performed by dissolving the product in dilute sulphuric acid, and adding a small quantity of a solution of sulphur in caustic soda. After 24 hours, the liquor is carefully filtered; the filtrate is mixed with caustic soda, and the resulting precipitate is collected on calico, washed with a little water, dried, and powdered; it is then ready for use.

The operation is conducted in casks, worked in sets of three. Each cask receives 1 *maund* (82 lb.) of dry bark, which will undergo four successive macerations of half a week's duration, the liquor being passed through the three casks in rotation. The liquor used for the 4th (last) maceration is acidulated water; when drawn off, it forms the liquor for the 3rd cask; thence it is conducted to the 2nd cask; and finally to the 1st cask, containing new bark, whence it is run off for precipitation. When starting anew, each cask will contain dry bark, so that the system of rotation is not brought into full operation till after the first fortnight. The liquor for precipitation is run into tubs; the others are drawn into buckets, for transference to the respective casks. Acidulated water is made in a vat, by adding 1 gal. hydrochloric acid to 100 gal. water. The weight of acid used in the exhaustion is 6½ per cent. of the weight of dry bark. The caustic soda solution consists of 1 part of the alkali dissolved in 3 parts of water; it is stored in iron vessels. The quantity required for precipitation of the bark liquor is judged of by the curdy appearance assumed by the precipitate; every 100 lb. of dry bark consume about 6½ lb. of the alkali.

Filtration of the precipitate is commenced on the following day, when the liquor is transferred to the calico strainers, previously wetted. The first portions that run through are returned, until the passing liquor has a bright ruby colour; it is then allowed to flow away by a drain. When all the liquor has drained off, water is passed through the precipitate, until it ceases to acquire a red tint. The alkaloids on the filter should then exhibit a uniform cream-colour. The precipitate is dried, reduced to fine powder, and stored in suitable bins.

During the drying of the precipitate, a slight reddish-brown colour is developed; this is removed by the following process of purification:—14 gal. of water are mixed with 2 pints of sulphuric acid, and 20 lb. of the dry powder; about ½ pint of solution of sulphur in caustic soda is stirred in, and the whole is left for 24 hours. It is then filtered through calico into a clean vessel, care being taken to get the liquor perfectly bright; about 6 gal. of water are used to wash the sediment left on the filters; the clear filtrate is thoroughly mixed with soda solution, to precipitate the alkaloids; the precipitate is collected on calico, washed with a small quantity of water, drained, dried, and reduced to fine powder. Wooden vessels are not so suitable for this operation as are those of enamelled iron, or earthenware.

The bark used is exclusively dry *succirubra*, and care is taken to mix the root-, stem-, and branch-barks together, as nearly as possible in the proportions in which they are yielded by the plantations. Green bark would not be available at all seasons; and it has been found that the trifling cost of drying the bark is more than repaid by the better product.

The purified febrifuge is a fine white powder, which, however, acquires a slight buff tint by keeping. It never agglutinates, and is freely soluble in weak acids, such as lemon-juice, &c. The cost price of this febrifuge is estimated at 1*s.* 9*d.* an oz.; it is as efficient as quinine at 9*s.* an oz.

Distribution of the Cultivation.—The cultivation of cinchona, both in government gardens and by planters, though principally by the former, has been instituted in many parts of India. The chief plantations are those in Sikkim and the Nilgiri Hills. The coffee planters in the Wynaad have put out many red barks, but the results are not encouraging. A small estate above the Kolúr Ghât, in S. Canara, has been abandoned. In 1871, a plantation was commenced on the Mahendra mountain, in Ganjam. Similar attempts on the Nulla Mully Hills were rendered abortive by the hot weather. In Coorg, results are said not to justify maintenance of the plantation. The Travancore Government opened an estate at Peermede, near Maryville, which has given good promise of success. In the Pulney Hills, planting has been tried in several places; the trees thrive well, but their bark is not rich in alkaloids. Under very adverse conditions, trees put out in the Tinnivelly Hills have done remarkably well. The result of an experiment with red barks on the Shevaroy Hills is very favourable. In the Kangra Valley, despite every attention, the trees succumbed to frost. The same result was obtained after protracted experiments in many parts of the Dún and Kohistan of the N.-W. Provinces and Punjab. The Mahatleshwar Hills, in Bombay Presidency, presented favourable conditions of soil and situation; but extreme climatic changes proved insurmountable obstacles. The Sittang Division of British Burma has been found well adapted to cinchona cultivation, though the trees do not attain great size. Success has also attended the experiments in the Khasia Hills (Nuuklow), in Assam. One new variety of *C. officinalis*, with pubescent leaves, cultivated in India, yields a remarkably rich bark, containing 6 per cent. of quinine, and 5 per cent. of cinchonidine.

In Ceylon, cinchona is exciting an attention second only to coffee, and is being largely grown in combination with that staple. Red bark flourishes at 2000–4500 ft.; yellow, and crown, at 4000 ft. and upwards. The last-named is recommended as a break-wind for coffee—a piece of advice that does little credit to its author. The island exported 95,000 lb. of bark between Oct. 1, 1878, and April 8, 1879.

Cinchona cultivation promises to confer great benefits upon the W. Indies. The plants of *C. officinalis*, *C. succirubra*, and *C. Calisaya* thrive eminently well in Jamaica, reaching, in 8 years, a height of about 30 ft. The enterprise is now an established agricultural industry. The plants are best placed at about 12 ft. apart, or 300 to the acre. The Government plantations yielded, in 1877, some 3000 lb. of merchantable bark. The mountains of St. Andrew, and a great portion of the Blue Mountain range, offer suitable sites. It is probable that *C. officinalis* will be superseded by the other species. In Dominica, the flanks of the Couliabon range are said to afford a district where the conditions of climate, elevation, and soil appear to be peculiarly favourable.

Efforts have for some time past been made by the United States Government, to introduce cinchona into some of the S. States, notably Florida and California. Hitherto, the exigencies of climate have proved an invincible drawback; but it is said that the district of San Diego, in California, offers fair promise of success.

In Java, the cultivation of several species is very largely carried on, principally by the Dutch Government. The plantations are chiefly in the Preanger Residency, at elevations of 4000–6000 ft., where the mean temperature is about 16°–18° (60°–65° F.); but the experiment is also being made in the Passocrocan Residency, and in Sumatra. Some 2000 acres are occupied by the Government gardens, which contain over two million trees, principally *Calisaya Ledgeriana*, and *Haskarliana*. The harvesting of the bark is performed chiefly by the mossing system; coppicing and uprooting are not unknown. Lately, the plants have suffered much from attacks of *Heliopeltis theivora*, a hemipterous insect which devours the tea-plant. Its ravages are most serious on low-lying ground; above 3000 ft., it is rare; above 6000 ft., it is harmless.

The cultivation has also been extended to Bourbon, Mauritius, St. Helena, Guadaloupe, Brazil, the Azores, Algeria, &c. St. Helena contained 4000 plants in 1870, all in a very promising condition. In British Honduras and Jamaica, the trees flourish remarkably well.

Commerce.—The imports of the bark into the United Kingdom, in 1878, were as follows:—From New Granada (Colombia), 21,719 cwt., value 362,433*l.*; Peru, 12,022 cwt., value 184,949*l.*; Ecuador, 8926 cwt., value 151,075*l.*; British E. Indies, 4597 cwt., value 75,299*l.*; France, 1818 cwt., value 22,096*l.*; United States, 1095 cwt., value 15,515*l.*; Chili, 1057 cwt., value 12,848*l.*; Germany, 1023 cwt., value 15,931*l.*; Danish W. Indies, 800 cwt., value 13,440*l.*; Central America, 336 cwt, value 6461*l.*; other countries, 493 cwt., value 7329*l.* Our exports in the same year were:—To France, 18,935 cwt., value 281,615*l.*; Holland, 15,431 cwt., value 267,305*l.*; United States, 3555 cwt., value 39,044*l.*; Germany, 2760 cwt., value 34,883*l.*; Italy, 1524 cwt., value 18,007*l.*; other countries, 576 cwt., value 6923*l.*

The produce of Ecuador, together with a considerable quantity of Pitayo bark, imported from the Bay of Chaco, is shipped principally from Guayaquil. In 1878, the export amounted to 19,800 quintals (of nearly 2 cwt. each), and was valued at 59,400*l.* The distribution was as follows:—To the United States, 9243 quintals; England, 9145; other European countries, 1412. In 1877, the total export was but 9882 quintals. The barks of Central Peru, from Huanuco to Cusco, find an outlet through Callao; those from N. Peru, through Payta. The valuable produce of Carabaya and the high valleys of Bolivia, is shipped principally at Arica. Occasionally also Bolivian and Peruvian barks find their way across the continent, and are despatched to Europe from a Brazilian port. The Colombian (New Granada) barks are exported from Santa Marta and Savanilla; the latter port despatched nearly 2000 tons in 1877, and the whole State exported nearly 3500 tons in the same time. Much of the Santander bark goes down to Maracaibo, and takes the name of that place. Some Venezuelan bark leaves Puerto Cabello. The S. American barks are almost invariably found to consist of inferior kinds, mixed in variable proportions with those of better quality. Hence chemical analysis is requisite in order to determine their value. The barks richest in quinine are generally bought up by manufacturers of quinine sulphate, the inferior samples finding their way into the ordinary drug sales. The Indian, Ceylon, and Java barks are of more uniform quality; the chief annual sales of the two former barks take place in London, and of the Java barks at Amsterdam, in the month of May. At present, the red bark comes over in the largest quantity, and is much superior to that from S. America.

The selling price of cinchona barks in the London market exhibits singular differences, which cannot be referred to the proportion of alkaloids present, and seems to depend upon the outward appearance of the sample, the reputation of the estate producing it, or inequality in the cost of extracting the alkaloids. In illustration of the fact that alkaloid percentage does not govern the price, may be quoted the results of a sale of Madras government barks. In the following tables, the price per unit of quinine is estimated from the price per lb., and the analysis of the bark; the first three alkaloids are estimated as crystallized sulphates, the cinchonine as alkaloid; probably the quinine would be the only alkaloid which would influence the price:—

I. Crown Barks.

Price.		Analysis.			
Per lb.	Per unit of Quinine.	Quinine.	Quinidine.	Cinchonidine.	Cinchonine.
10*s.* 3*d.*	23·56*d.*	5·22	0·11	1·14	0·28
10*s.*	22·73*d.*	5·28	0·25	1·13	0·13
9*s.* 9*d.*	24·99*d.*	4·70	0·17	0·78	0·30
9*s.* 7*d.*	21·63*d.*	5·27	0·28	0·77	0·15
9*s.* 3*d.*	20·03*d.*	5·54	0·09	1·14	0·42

II. Red Barks.

Price.		Analysis.			
Per lb.	Per unit of Quinine.	Quinine.	Quinidine.	Cinchonidine.	Cinchonine.
6*s.* 2*d.*	19·1*d.*	3·87	0·14	2·82	2·30
	21·3*d.*	3·46	0·10	2·47	2·90
	20·4*d.*	3·62	0·07	2·34	2·60
6*s.*	19·05*d.*	3·78	0·12	2·07	3·12
	19·5*d.*	3·70	0·00	2·34	3·10

The relative prices of the cinchona barks brought into the London market are approximately as follows:—Cascarilla, 17–23*s.* a cwt.; Peru, crown and grey, 1*s.*–2*s.* 4*d.* a lb.; Calisaya, flat, 2*s.* 6*d.*–3*s.* 6*d.*, quill, 2*s.*–6*s.* 6*d.*; Carthagena, 1*s.* 1*d.*–3*s.* 5*d.*; Colombian, 1*s.*–5*s.* 9*d.*; Pitayo, 1*s.* 3*d.*–2*s.* 3*d.*; Red, 3*s.*–6*s.* 6*d.*; East Indian, 8*d.*–3*s.*, good and fine, 3*s.* 1*d.*–7*s.* 6*d.*

Cocculus Indicus (Fr., *Coque du Levant;* Ger., *Kokkelskörner*).—The fruit of *Anamirta paniculata* (*A. Cocculus, Menispermum Cocculus*) is employed in England as an ingredient of insect ointments, and has a place in the Pharmacopœia of India. The plant is a strong climbing shrub, growing from Orissa and Concan to Malabar and Ceylon, in E. Bengal, Assam, Khasia, and the Malay Archipelago. The fruits are stripped from the stems, and dried, when they resemble little round berries; they should be fresh, of dark colour, free from stalks, and with the seeds in perfect condition. The last-named are bitter, and consist, to the amount of half their weight, of oil (see Oils). The drug is imported from Bombay and Madras, principally for consumption on the Continent. Its wholesale value is about 7*s.*–9*s.* a cwt. This drug is sometimes confounded with laurel berries, from which its kidney-shaped and semicircular kernel distinguishes it.

Colchicum, or Meadow-Saffron (Fr., *Colchique;* Ger., *Zeitlosen*).—The "corm," or bulbous stem-base, and the seed, of *Colchicum autumnale* is largely prescribed in dropsy, gout, rheumatism, and cutaneous diseases. The plant is locally abundant in many parts of England and Ireland, and grows throughout Central and S. Europe up to an altitude of about 5500 ft., and in a great portion of N. Africa. In Britain, the corms are dug up in July, after the decay of the foliage, and before, or during, inflorescence, though, according to Schroff, their medicinal activity is greater when they are gathered in the autumn, after the appearance of the flower. Sometimes they are used in a fresh state, but more generally dry. The drying is usually effected by quickly subjecting the corm, in thin slices, to gentle heat in a stove, the membranes being afterwards sifted or winnowed away. By drying the corms entire in the sun, they preserve their strength for years. The best slices are white, clean, brittle, and crisp, without mould or stain, inodorous, and bitter flavoured. The seeds are gathered when ripe, and dried. In appearance, they resemble those of black mustard; but are larger, harder, and not pungent. The corms of several other, as yet undetermined, species of *Colchicum*, have a reputation in the East. Colchicum corms are worth about 8*d.* a lb.; the seeds, 9*d.*

Colocynth, Coloquintida, or Bitter-apple (Fr., *Coloquinte;* Ger., *Coloquinthe*).—The fruit pulp of *Citrullus Colocynthis* (*Cucumis Colocynthis*), in the form of an extract combined with aloes and scammony, is widely used as a purgative. The plant is found on the sea-sands of Portugal and

S.-E. Spain; in Morocco, Senegambia, and the Cape Verdes; very abundantly after rain on the sands of Nubia and Upper Egypt; in some of the Greek isles; in Cyprus, where it formed one of the chief products in the 14th cent.; in Syria, Arabia, Persia, and Ceylon; on the Coromandel coast, in Sind, and the Punjab; and in Japan. The fruit resembles an orange in size and shape, marbled-green when fresh, turning yellowish-brown when dried, and is filled with pulp containing 200–300 seeds. It occasionally occurs in commerce simply dried, and of a brown colour—Mogador colocynth; but more generally, it has first been peeled, and then appears as light balls of white pith—Spanish colocynth, often broken, and presenting a light-brown colour when the drying has been slow. The pulp is scarcely odorous, but possesses an intensely bitter flavour; it is usually retailed broken up, and deprived of the seeds, and is then known as "pulp," or "pith." The drug is imported from Spain, Mogador, and Syria, and varies in price from 8*d.* to 1*s.* 9*d.* a lb. Two other species are sometimes confounded with the true drug—*Cucumis trigonus* (*Pseudo-colocynthis*), of the plains of N. India; and *C. Hardwickii*, the "Hill Colocynth" of the natives of India. These are not met with in English commerce.

Copaiba.—The oleo-resin known as Copaiba or Capivi balsam, derived from several species of *Copaifera*, is largely employed in medicine, by reason of its stimulating action on the mucous membranes of the urino-genital organs. (See Resinous Substances.)

Coptis, or Mishmi-bitter.—The root of *Coptis Teeta* is used in India as a pure bitter tonic. The plant is a native of the Mishmi Hills, whence the drug is sent, in the form of slender rhizomes 1–2 in. long, by way of the Bramahputra into Bengal. It occurs in the bazars in little rattan bags, holding about ½ oz., and rarely appears on the London market. The drug is replaced in America by *C. trifolia*, a plant indigenous to the U.S., Arctic America, and both Russias. The Indian root is sometimes confounded with the yellow root of *Thalictrum foliolosum*, an abundant native of Mussúrí, the temperate (5000–8000 ft.) Himálayas, and the Khasia hills. To Bombay, coptis root comes from China, by way of Singapore. Two varieties occur in the Bombay market, called in China *Hwang-lien* and *Chuen-lien*; the former is bristly, and stouter than the latter, which is the only kind met with in the little rattan wicker bags. Coptis root is said to contain more berberine than any other known root, but it is doubtful whether its alkaloid is berberine at all.

Costus root.—The root of *Aplotaxis auriculata* occasionally appears in the drug market. It has been used as medicine in the East, and also as incense, from the earliest times till the present day. The root is of a dirty-white colour, in pieces 2-4 in. long and about 1 in. thick. It has a strong odour, partly like orris root, and slightly urinous. (See Elecampane.)

Coto.—The bark of an unknown tree growing on the banks of the river Mapiri, in Bolivia, has been largely imported into Germany, and more sparingly into this country, of late years, as a remedy for diarrhœa. It has a pungent, aromatic flavour, is of a reddish-brown colour, and sometimes becomes covered with an efflorescence of whitish crystals. Its active properties appear to be due to a white crystalline substance, called cotoin. Another variety, called Paracoto bark, is in thicker pieces, whose inner surface is rough, with longitudinal ridges. Its action is weaker, but similar in character. It contains paracotoin, and other crystalline bodies. True coto bark is much rarer in commerce than is paracoto.

Croton.—The oil obtained from the seeds of *Croton Tiglium* (*Tiglium officinale*) is administered as a powerful cathartic, and applied as a rubefacient. (See Oils.)

Cubebs (Fr., *Cubèbes*; Ger., *Cubeben*).—The fruit of *Piper Cubeba* (*Cubeba officinalis*) is very widely used in the treatment of gonorrhœa. The plant, a member of the pepper family, and a woody climber, is a native of Borneo, Java, and Sumatra. It is cultivated in many parts of Java, both in special gardens, and on the coffee estates; the fruit is sold to the Chinese, and carried by them to Batavia. It is also extensively grown in the Lampong district of Sumatra. The cultivation is very simple; on the coffee plantations, the seed is sown under the *dádaps* and other shade-trees, and left to climb as it will. The fruit is gathered when full-grown, but before it has ripened, and is then dried. It has a strong aromatic and slightly acrid-bitter flavour, and a pleasant aromatic odour. By dealers, the drug is judged according to the oiliness and odour of the crushed berries; the presence of pale smooth ripe berries, of dry appearance, lowers the quality. The best preparations of the drug are the berries deprived of their soluble (in water) constituents, dried and powdered, an alcoholic extract, or the separated resinous constituents. The drug is chiefly imported from Netherlands India, viâ Singapore, and is reshipped thence to British India, the United Kingdom, and the United States of America. In 1872, the imports at Singapore were 3062 cwt.; and the exports were:—to the United States, 1244 cwt.; United Kingdom, 1180 cwt.; British India, 104 cwt. The wholesale price is about 30*s.*–40*s.* a cwt. The great similarity of the fruits of other species of *Piper* renders their confusion with the true drug an easy matter; they are principally *P. crassipes* (*C. crassipes*), of Sumatra; *P. Lowong*, (*C. Lowong*) of Java; *P. ribesioides* (*C. Wallichii*); *P. caninum* (*C. canina*), throughout the Malay Archipelago. The confusion extends to *Laurus Cubeba*, of S. China.

Cumin, or Cummin (Fr., *Cumin*; Ger., *Mutter-* [&c.] *kümmel*).—The fruit of *Cuminum Cyminum* is extensively used in veterinary medicine. The plant has been introduced into Europe, and ripens its fruit as far north as S. Norway, but beyond Sicily and Malta it is unproductive; it is a native of the Upper Nile, and flourishes also in Morocco, Turkey, Arabia, India, and China. The seeds have a powerful aromatic flavour and odour. Their market value is now 20*s.*–50*s.* a cwt.; in the 13th–15th cent., when they were commonly used as a spice, the price was about 2*d.* a lb. Cumin is still an occasional ingredient of curry-powders. The quantity exported from Mogador, in 1878, was 50 cwt., value 60*l.*; of this, 13 scrons came to Great Britain, and the remaining 12 went to Portugal. Bagdad, in the same year, exported 177 cwt., valued at 300*l.*, to India and Europe. The seeds of *Carum nigrum*, which have the same flavour, are largely used in Indian curry-powder.

Curari, Woorari, or Wourali.—This name is applied to a powerful arrow-poison, prepared in British Guiana, from *Strychnos toxifera*, and other plants. In other districts of S. America, it is obtained from *S. Castelnæana*, &c. All the S. American species of *Strychnos* appear to possess similar properties to *S. toxifera*, which are exactly the opposite to those exhibited by the species of *Strychnos* found in India and the East generally. Curari has been imported into London in small gourds about the size of an orange, and has a bitter taste like aloes, which it resembles in appearance. It is much more rapidly poisonous when injected into the blood than when swallowed.

Dill (Fr., *Aneth*; Ger., *Dill*).—From the seeds of *Anethum* (*Peucedanum*) *graveolens* is distilled the well-known stomachic and carminative "dill-water." The plant is a native of the Mediterranean and Black Sea basins, is widely distributed as a weed as far north as Trondhjem, and is common in gardens, being extensively cultivated in many parts of India. The drug has a pleasant aromatic flavour and odour. The fruits of *A. Sowa* are sometimes sold in the London drug market for dill. They are narrower, more convex, and of a paler colour.

Dita, or Alstonia.—The bark of *Alstonia* (*Echites*) *scholaris* has tonic and antiperiodic properties, and has been extravagantly praised as a substitute for quinine. The plant is a handsome forest-tree, 50–90 ft. high, common from the Himálayas to Burma and Ceylon, and found in Java, Timor, the Philippines, E. Australia, and Tropical Africa. The bark is dirty-white in colour, almost devoid of odour, and has a pure bitter flavour, without aroma or acridity.

Alstonia constricta, the Queensland Fever-bark, is used in Queensland as a substitute for quinine in fevers. It occurs in large quills, with a corky surface, and yellow colour and fibrous texture internally, and has an intensely bitter flavour. It has lately come into extensive use in the United States.

Duboisia.—The leaves of *Duboisia myoporoides* have lately been introduced into this country as a substitute for belladonna in the treatment of diseases of the eye. The shrub is a native of Queensland, and occurs from Sydney to near Cape York; it is found also in New Caledonia and New Guinea. The leaves are lanceolate and smooth, tapering at both ends, about 2–3 in. long, and nearly 1 in. broad in the middle. The alkaloid to which they owe their activity, called duboisine, has recently been shown by Ladenberg to be identical with hyoscyamine. (See Narcotics—Pituri.)

Elecampane (Fr., *Année*; Ger., *Alant*).—The root of *Inula Helenium* is used in veterinary medicine; it is also employed in the manufacture of absinth. (See Alcoholic Liquors—Absinth.) The plant is distributed throughout Europe, occurring wild in Ireland and S. England, S. Norway, and Finland, and cultivated in Holland, England, Switzerland, and especially around Cölleda, near Leipzig. Eastwards, its range extends to the Caucasus, S. Siberia, and the Himálayas; westwards, to N. America. The root is gathered at the age of 2–3 years; when older, it is too woody. The larger roots are sliced up before drying; the smaller are dried whole. The dry drug is brittle, and of light-grey hue; it has a weak aromatic odour, resembling orris and camphor; its flavour is aromatic and slightly bitter; its effects are tonic. In Syria, the root of *Aplotaxis auriculata* (*A. Lappa*, *Aucklandia Costus*), which closely resembles the drug, is often mixed with it, and deserves examination.

Ergot of Rye, Spurred Rye (Fr., *Seigle ergoté*; Ger., *Mutterkorn*).—The spawn of the fungus *Claviceps purpurea*, produced on grasses of many genera, is employed in parturition. The fungus is to be found wherever cereals grow, but not in constant abundance; wet seasons are favourable to its production, while it diminishes before high cultivation, and is not always sufficiently plentiful for collection. The formation of the fungus is first intimated by the appearance, on the ears, of drops of a yellowish, intensely sweet, and unpleasantly odorous mucus, termed "honey-dew"; these dry up and disappear in a few days, and the grain is occupied by the mycelium of the young fungus. The cereal most commonly attacked is rye, which is then known as "ergot of rye" or "spurred rye," and almost exclusively supplies the commercial drug. The diseased grains are picked out at harvest-time, thoroughly dried, and kept in closed bottles, to prevent deterioration, and the attacks of mites. The drug is very largely produced in Galicia, also in Central and S. Russia, and in Spain; our imports are chiefly from Vigo and Teneriffe, and, in a less degree, from Odessa, Hamburg, and France. The wholesale value is about 3*s.*–3*s.* 3*d.* a lb. In some parts of France and Italy, ergots of wheat, which are shorter and thicker than those of rye, are picked out from corn which is to be made into vermicelli, and are said to keep better, and to cause none of the ill effects attributed to ergot of rye. Oats yield a more slender ergot, sometimes sold alone, or mixed with the common drug. Ergot of diss grows on *Ampelodesmos tenax*, in Algeria; it is much longer and narrower than ergot of rye, and is said to be much more powerful.

Fern [Male] (Fr., *Fougère mâle*; Ger., *Farn*).—An ethereal extract of the root of *Aspidium Filix mas.* (*Polypodium, Nephrodium*) is prescribed against all kinds of intestinal worms, but is most efficacious in cases of tapeworm. The plant is abundantly and widely distributed: it is met with all over Europe; in Russia, Central Asia, the Himálayas, China, Japan, Java, and the Sandwich Islands; from Algeria to the Cape, and in Mauritius; in Greenland, Canada, California, Mexico, Colombia, Venezuela, Brazil, and Peru. The root is collected from late autumn to early spring; after cutting off all dead parts, it is split, gently dried, coarsely powdered, and immediately digested with ether; extract prepared from stale root has very diminished power. The drug is sometimes adulterated with other species: those generally used for this purpose show only two pale dots (vascular bundles) in the transverse section of the leaf bases; male fern exhibits eight. The drug is worth about 1*s.* a lb.

Foxglove (Fr., *Digitale*; Ger., *Fingerhut*).—The leaves of *Digitalis purpurea* have a powerful effect on the action of the heart, and are administered as a sedative, and as a diuretic. The plant is common on silicious soils throughout Europe, but avoids limestone. The leaves are often deprived of their thick ribs, before being submitted to gentle heat; the odour of the dried leaf resembles tea, the flavour is very bitter. It is best to obtain the fresh flowering plant, so as to avoid confusion with the leaves of other plants. In *Digitalis*, the veins are continued alongside the midrib into the stalk of the leaf, a character not found in the leaves of other plants mixed with it. Foxglove leaves are worth about 8*d.* a lb.

Galbanum.—The gum-resin obtained from two or more species of *Ferula* is administered as a stimulating expectorant, and sometimes applied in plaisters. (See Resinous Substances.)

Gelsemium.—The underground woody stem and root of the Carolina jessamine (*Gelsemium sempervirens*) has lately been introduced as a remedy for neuralgia. In excessive doses, it causes complete muscular prostration, and sometimes death. The antidotes used are powerful stimulants. In the bark, especially of the young stems, exists a silky fibre.

Gentian.—The root of *Gentiana lutea* is largely used as a bitter tonic, but is more important as a condiment. (See Spices.)

Ginseng (Fr., *Ginseng*, *Ginsen*; Ger., *Ginseng*).—The root of several species of *Panax* is accredited by the Chinese with marvellous stimulative and restorative powers, the best varieties sometimes fetching their weight in gold; Europeans, however, discredit its potency. The drug is taken as an infusion, prepared by steam-heat, in a sort of double tea-pot; the dose is 60–90 gr., in the morning, repeated for 3–8 days, tea being meanwhile avoided for at least a month. The quality and price of the drug vary much according to locality of production, and species. The most valuable species is *P. Ginseng*, indigenous to almost every part of China; the best quality of the root was originally collected in Manchuria, till excessive consumption nearly exterminated the plant. The Corean growth is now held in highest estimation, while good qualities are also furnished by Mongolia and Manchuria. The plant has been introduced into Japan, and grows more luxuriantly than in its native soil; but it becomes an annual, and its root is thought to be less potent. Preference is given to the root of the wild plant, and its quality is supposed to increase with age. After collection, it is macerated and dried, and then appears in finger-like pieces, 2–4 in. long, hard, brittle, and translucent. It is stored in lead-lined boxes, within an outer case, the intervening space containing parcels of quick-lime, to maintain absolute dryness. A very inferior variety is the produce of *P. quinquefolium*, a native of N. America. This plant was found wild in the Alleghany and Rocky mountains, and has been spread by cultivation to most of the United States, and Canada. It grows readily, especially in high, rocky places. The root is 3–4 in. long, and 1 in. thick, carrot-like, and occasionally branching. It is collected, dried, and shipped in large quantities to China. The imports of all kinds into the ports of Canton, Hankow, and Kiungchow, in 1877, were:—Corean, 42 *piculs* (of 133⅓ lb.), value 7600*l.*; Japanese, ½ *picul*, value 80*l.*; American, 966 *piculs*, value 119,000*l.*

Guaiacum.—A blackish resin obtained principally from *Guaiacum officinale* is considered diaphoretic and alterative, and is often prescribed in gout and rheumatism. (See Resinous Substances.)

Gulancha, or Goolwail.—An infusion, or extract (*pálo*), of the stem, leaves, and root of *Tinospora cordifolia* (*Cocculus cordifolius*) is considered very useful as a tonic, antiperiodic, and diuretic. The plant is a tall, climbing shrub, native of India—from Kumaon to Assam and Burma, and from Concan to the Carnatic—and of Ceylon. The drug commonly exists as slices of woody stem, ¼–2 in. wide, inodorous, but of bitter flavour. A substitute possessing similar properties, and equally valued as a febrifuge, is yielded by *T. crispa*, indigenous to Silhet, Pegu, Sumatra, Java, and the Philippines.

Gurjun.—The oleo-resin, or balsam, yielded by several species of *Dipterocarpus*, is employed in the East as a substitute for copaiba. (See Resinous Substances.)

Hellebore (Fr., *Ellebore;* Ger., *Nieswurzel*).—Three kinds of Hellebore are known in medicine:—(1) Black hellebore is the rhizome of *Helleborus niger*, and is a drastic purgative employed in veterinary practice. The herb is indigenous to S. and E. Europe: it is often cultivated in English gardens, as the "Christmas rose"; and grows wild in Provence, Salzburg, Bavaria, Austria, Bohemia, Silesia, N. Italy, and Greece. It occurs in commerce in knotty pieces, 1–3 in. long, with a senega-like odour, and bitterish acrid flavour; it is imported from Germany, and worth about 56*s.* a cwt. It is very liable to confusion with the closely similar roots of *H. viridis*, which, in Germany, is valued at 3–5 times the price of the common drug; and it is occasionally adulterated with *Actæa spicata.* (2) White hellebore possesses emetic and drastic purgative properties, but is chiefly used as an insecticide, and as an ingredient of itch ointments. It is the root of *Veratrum album*, a plant inhabiting moist grassy spots on most of the mountains of Central and S. Europe, also found in Norway, both Russias, near the Amur, in N. China, Saghalien, and Japan. The drug occurs in conical pieces 2–3 in. long, and ¾–1 in. thick, usually without rootlets, with an alliaceous odour when fresh, and a sweetish bitter-acrid flavour; its powder produces violent sneezing. It is imported in bales from Germany, and distinguished as "Swiss" and "Austrian," the price being also 56*s.* a cwt. It is sometimes replaced by the root of *Veratrum nigrum*, a less potent drug. (3) American white hellebore is the root stem of *Veratrum viride*, used as a cardiac, arterial, and nervous sedative. The plant appears to be a variety of *V. album*, and is plentiful in swamps, from Georgia to Canada. The drug consists of the rhizome, cut lengthwise in halves or quarters, with pale rootlets attached, and dried. In the United States Pharmacopœia, it is officinal in the form of transversely cut slices, which are usually shrunken and curled by drying.

Henbane (Fr., *Jusquiame;* Ger., *Bilsenkraut*).—A tincture or extract of the leaves of *Hyoscyamus niger* is used as a sedative, and anodyne. The herb grows wild in England, and is also cultivated by physic gardeners. In Europe, its range extends from Portugal and Greece, to Norway and Finland; it occurs also in Egypt, Asia Minor, Persia, Caucasia, N. India, and Siberia; and has been introduced into N. America, and Brazil.

The following remarks refer to its cultivation at Mitcham, in Surrey:—The seeds are sown early in the spring; the annual plants are thinned, if necessary, and the crop is gathered about July–August. The biennial plants are transplanted in the spring of the second year, and the harvesting of the crop lasts from late May to early July. Change of ground is usually given every 3–4 years, but does not seem to be essential. At Banbury and Hitchin, only the biennial plant is cultivated. The "annual henbane" of English commerce is not the produce of the annual plant, but consists usually of the first year's leaves of the biennial plant, which are distinguished by the presence of leaf-stalks, and the absence of flowers. Biennial henbane consists of the flowering tops of the second year's growth, which are generally broken up small; it has no stalked leaves in it. The tincture of the biennial plant gives a milky solution when mixed with water, which is not the case with annual henbane. In Germany, the annual plant only appears to be known. The biennial is a much larger plant than the annual, and has more deeply cut leaves. It is a very uncertain crop, the seeds frequently remaining in the ground for a number of years before germinating, and the young leaves are infested by a small turnip fly and other insects. Hence the biennial drug varies much in price—from 4*s.* 6*d.* to 11*s.* a lb. The stem-leaves and stems of the plant are used for the preparation of extract or succus. Henbane is most active just before flowering. The plant grows best on well-manured, sandy, or chalky soil, especially near the sea. The fœtid narcotic odour of the fresh herb is much diminished in the dried drug. In S. Europe, the drug is replaced by *H. albus*, a native of the Mediterranean basin; and in the East, *H. insanus*, of Beluchistan, is sometimes smoked.

Iceland Moss (Fr., *Lichen [Mousse] d'Islande;* Ger., *Isländisches Moos*).—A decoction of *Cetraria Islandica* is given as a mild tonic, usually with more active medicines. The lichen is widely distributed in high latitudes and altitudes, as Siberia, Scandinavia, Spitzbergen, Greenland, and Iceland, in the mountains of Scotland, France, Spain, Italy, Switzerland, in the Carpathians, in N. America, and in the Antarctic regions. Sweden is, perhaps, the chief country which exports it, though it is collected for local use in Iceland, Canton of Lucerne, and Spain. In Iceland, where the lichen is not sufficiently abundant to supply local demands, it is gathered in June and July, and is used as a farinaceous food, rather than as physic. It is occasionally exported to Denmark, in small quantities, from Reykjavík. The value of the drug is about 40*s.* a cwt.

Ipecacuanha (Fr., *Ipécacuanha annelée;* Ger., *Brechwurzel*).—The root of *Cephaëlis Ipecacuanha* has long been known as an emetic, but has recently been recognized as a specific in dysentery, and second only to cinchona in degree of importance as a tropical medicine. The plant is a shrub, 8–16 in. high, a native of S. America, growing gregariously on raised patches in moist and shady forests. between latitudes 8° and 22° S. It flourishes best in Pará, Maranhao, Pernambuco, Bahia, Espiritu Santo, Minas Geraes, Rio de Janeiro, Sao Paulo, and in that part of Matto Grosso which is occupied by the valley of the Rio Paraguay; commercial supplies come chiefly from the district embraced between the towns of Diamantina, Villa Maria, Villa Bella, and Cuyabá (Matto Grosso); also from the neighbourhood of Philadelphia, on the Rio Todos os Santos, a feeder of the Mucúry. Besides the Brazilian localities above indicated, the plant flourishes in the valley of the Cauca, Colombia; and probably also in the province of Chiquitos, Bolivia.

The successful introduction of ipecacuanha into India has for some years engaged the attention of the Government. A great difficulty exists in the very slow growth of the plant, and the long period required to obtain anything like a stock, by the ordinary method of propagation by cuttings. According to J. McNab, propagation by root divisions offers great advantages. The roots are cut into transverse sections, and placed horizontally on the surface of a pot, prepared with white sand, and drained; the pot is put under a hand-glass, in a warm propagating bed, and kept moist. In a few weeks, the sections throw out buds, sometimes two or more at a time, in which case, the root may be severed so as to yield independent plants. As the buds grow, rootlets are formed on the nether side. Young plants can thus be rapidly produced, without injury to the parent. Supplies of plants or roots would have to be obtained from their native habitat. Their transport may be effected in Wardian cases; but McNab proposes a cheaper and safer plan, viz. to collect fresh roots or rhizomes, and after sealing the cut extremities, to place them longitudinally in a close-fitting packing-box of 1 in. wood, with a layer of fresh sphagnum moss between each two strata of roots. Where white sphagnum moss cannot be got, a substitute may be found in any moss, moistened, and squeezed to remove the excess. Failing any kind of moss, heavy soil from a depth of 6–8 in., retaining its natural moisture, may be used. In 1875, more than 100,000 young plants were growing in the Rungbee Botanic Gardens, Sikkim, having been raised by the root propagation system described above; in 1877–8, some 26 lb. of dried root were obtained from these plants, and employed medicinally. The cultivated drug exhibited a decided superiority over the native article imported from Brazil. It appears certain, however, that the growth of this valuable plant as an outdoor crop will never succeed in Bengal or Sikkim, the low night temperature of the cold season proving too severe for it. In Ceylon, there seems to be little disposition to attempt the cultivation. The only E. Indian locality which seems to promise any hope of the successful culture of the plant on an extensive scale is, perhaps, Singapore; the climate of the Botanic Garden there seems admirably suited to it.

In the Brazilian forests, the plant, there known as *poaya*, is found growing in clumps, under the dense shade of old trees. It is collected by grasping all the stems of a clump, and raising the mass by the help of a pointed stick, inserted beneath the roots and worked up and down to loosen the soil; the object is to get up the whole network of roots unbroken. The adhering earth is then shaken off, and the roots are thrust into a bag. Sometimes 30 lb. are thus collected by one man in a day; but the average does not exceed 10–12 lb., and some do not get more than 6–8 lb. The gatherers or *poayeros* assemble in the evening to weigh their gleanings, and spread them out to dry. Rapidity is desirable in this operation; the roots are exposed to the sun, and should become dry in 2–3 days, being housed at night to avoid the dew. After drying, they are broken up, the adherent earthy matters are sifted away from them, and the drug is packed in bales. The collecting is suspended only during the rains, when drying would be difficult; moderately damp weather, however, is beneficial, as assisting in the uprooting of the plant. To prevent extirpation of the plant, small fragments of the root are left in the ground, and covered over. The commercial drug is never thicker than $\frac{1}{5}$ in. and generally much less; its colour is dusky greyish-brown; its flavour is bitterish; its odour, faint and musty. The roots are hard and brittle; they always arrive much broken, and are frequently mouldy, and damaged by sea-water. The drug is imported in serons made of cowhide. The stem is often mixed with the root in considerable quantity. Such samples are inferior, as the activity resides in the bark, which, in the stem, is very thin. Our imports of the drug in 1870 (the last detailed return) were nearly 63,000 lb.

Owing to the monopoly of the collection, and the exhaustion of the most accessible ground, the wholesale price of the drug rose from 2*s.* 9½*d.* a lb. in 1850, to 8*s.* 8*d.* in 1870; it has since fallen from about 5*s.* 6*d.*–5*s.* 9*d.* in 1878, to 4*s.* 3*d.*–4*s.* 6*d.* in 1879.

Besides the Brazilian drug, another variety, called "Carthagena," or "New Granada," has, of recent years, been imported into London. It is a little less active than the ordinary drug, and differs from it principally in attaining a greater size ($\frac{3}{16}$ in.).

A few worthless roots are occasionally put upon the market under the pseudonym of the true drug. They are chiefly:—(1) "Large striated ipecacuanha," the root of *Psychotria emetica*, indigenous to Colombia; may be known by its remaining moist and tough, even for years, and by being larger than the true drug, and not annulated. (2) "Small striated,' probably from a species of *Richardsonia*; closely resembles the first, except in size. (3) "White" or "undulated," the root of *Richardia* (*Richardsonia*) *scabra*, exceedingly common in Brazil; it is paler than ipecacuanha, fissured on alternate sides, but not furnished with raised rings as in the true drug. (4) "False

Brazilian," the root of *Ionidium Ipecacuanha*, a plant of the order *Violaceæ*. It is called in Brazil *Poaya blanca*. The root is dirty-white, branched, much longer and less brittle than the true drug, and not annulated. It has repeatedly been offered in the London drug sales of late years. (5) In Mauritius, the leaves and root of *Tylophora asthmatica* are used as a substitute for ipecacuanha, under the name of *ipéca sauvage*, or *ipéca du pays*. In India, the same plant is used, and is known as "country," or "Indian" ipecacuanha.

Iridin.—This is a cholagogue principle, extracted from the root of *Iris versicolor*, much used in the United States, and to a certain extent in this country. The root is reddish internally, and has no odour.

Irish Moss, or Carrageen (Fr., *Mousse d'Irlande* [*perlée*]; Ger., *Knorpeltang*, *Irländisches* [*Perl*] *Moos*).—Carrageen, or more properly Carraigeen, is the seaweed *Chondrus* (*Fucus*) *crispus*, used in the form of jelly for consumptive patients. The plant is distributed along the rocky shores of Europe, from Gibraltar to the N. Cape; but is wanting in the Mediterranean, and infrequent in the Baltic. On the E. coast of N. America, it is abundant. The districts yielding the commercial weed are, however, very limited. It is gathered on the W. and N.W. coasts of Ireland, to be despatched from Sligo, and parcels of a good quality come occasionally from Hamburg; but the principal supply is sent from Boston, U.S. Though the plant is widely scattered along the coast of Massachusetts and other States, it is very generally infested with mussels and various minute mollusca, which circumstance unfits it for use. The gathering, or "mossing," is therefore confined to the rocks within a few miles of the Minot Ledge Lighthouse, Scituate, Plymouth County, Mass., where it forms a distinct industry. The "pull" begins late in the spring tide of the full moon of May, and lasts till early September. Previously, the "bleaching-beds" are prepared, by raking the stones off sandy plots on the beach. The rocks are reached in boats, the spring tides being chosen on account of the large space uncovered by the ebb of the tide at this season. The best growth is hand-pulled, with great care to ensure its freedom from shells and tape-grass; when properly cured, it fetches 2–3 times as much as the bulk of the crop, and is the only kind supplied to druggists. When the tide guards the best ledges, recourse is had to a long-handled iron rake, with which the plentiful commoner growths are torn from the submerged rocks. These are never free from weeds and shells; but, nevertheless, they form excellent material for the manufacture of size. The conteuts of the laden boats are spread to dry on the bleaching-beds, and then undergo repeated washing (in salt water), and drying, till sufficiently white. In fine weather, 6 washings will generally suffice; wet weather is fatal to the quality of the article, indeed it rapidly dissolves in fresh water. When cured, it is stored in shanties till the harvest is done, and is then picked over, and packed in barrels, about 100 lb. in each. The crop improves in quality, and increases in quantity, by repeated pulling. The annual harvest amounts to about $\frac{1}{2}$ million lb. The second quality is largely used for fining beer; while lower grades find an application in the sizing of cottons and paper, and in the stuffing of mattresses. In this country, it is sometimes used for feeding cattle. The commercial article frequently contains other seaweeds, as *Gigartina mammillosa* (*Chondrus mammillosus*), and *G. acicularis*.

Jaborandi.—The leaves of *Pilocarpus pennatifolius*, and possibly of *P. Selloanus*, have been largely imported during the last few years from Pernambuco. The leaves are blunt at both ends, about the size and shape of laurel leaves, leathery, smooth, and when held up to the light are seen to be full of oil dots. The odour is pea-like, and, as well as the flavour, is somewhat pungent. The leaves, when tasted, cause an abundant flow of saliva. When taken internally, they produce most profuse perspiration, and have been used for this purpose in medicine. The active properties of the drug are due to pilocarpine, an alkaloid which yields crystalline salts. Other plants are used in different parts of S. America, under the same name. The leaves of one of these, a species of pepper, have occasionally been imported by mistake from Rio Janeiro. The leaves are thinner, pointed at both ends, do not show oil dots when held up to the light, and are often attached to twigs which have swollen joints.

Jalap (Fr., *Jalap*; Ger., *Jalape*).—The root of *Ipomœa* (*Convolvulus*, *Exogonium*) *Purga* is very largely used as a brisk cathartic. The plant is a native of the E. slopes of the Mexican Andes, flourishing priucipally about Chiconquiaco, San Salvador, and neighbouring villages on the Cofre de Perote, at an altitude of 5000–8000, and even 10,000 ft., in the deep rich soil of shady woods, where the daily temperature is 15°–24° (60°–75° F.), and under the influence of an exceedingly moist climate. It grows well in S. England, under shelter and protection from frost; and would probably succeed in Madeira. It thrives remarkably on the Nilgiris, and in Jamaica. The tuberous roots are, in Mexico, unwisely dug up at all seasons, instead of only when the aërial stems have died down; the best are gathered in March–April. When fresh, they are whitish, scarcely odorous, and filled with a viscid juice of acrid flavour. The smaller ones are dried whole, the larger oues are first sliced or gashed. The dampness of the climate precluding suu-drying, the operation is performed by suspending the roots in nets over the seldom vacant hearths of the Indian huts, whence they acquire a smoky look and sooty smell. They usually require 10–14 days' drying, when they are carried by the Indians to Jalapa (whence the name of the drug), where they are bought by merchants, and despatched to Vera Cruz. The plant is now being partially cultivated by the Indians, which allows of the collection of its tubers in the proper season. The drying might be improved by slicing the fresh roots, and subjecting them to gentle stove-heat. The wholesale price of the drug is about 11*d.*–14*d.* a lb. for good samples; and 9½*d.*–10½*d.* for inferior and stems. Our imports in 1870 (the latest return) were nearly 170,000 lb. Its cultivation is now being energetically carried on in Jamaica, where a patch of ground less than 2 acres in extent has produced nearly 5000 lb. of the drug in a short time.

True jalap is marked more or less with small transverse whitish scars, the presence of which distinguishes it from the other varieties. Tampico jalap, the root of *Ipomœa simulans*, is frequently imported into this country in considerable quantities. It occurs in spindle-shaped or oval pieces, very much shrunken, and of a paler colour externally than true jalap. It much resembles Nepal aconite. It contains 11 per cent. of resin entirely soluble in ether, and is largely used in Germany for the preparation of jalapine, a purified form of the resin. The resin of true jalap—12–18 per cent.—is almost entirely insoluble in ether. Woody jalap, called also Orizaba root, male jalap, and jalap tops or stalks, *Ipomœa Orizabensis*, occurs in angular blocks, which are evidently pieces of a large root. It is easily distinguished by its fibrous character, the fibres projecting from the surface. It contains 11 per cent. of resin entirely soluble in ether; and is of rare occurrence in the London drug market.

Jew's Ear.—The fungus *Hirneola polytricha*, closely allied to the *H. auricula-Judæ* of Europe and N. America, is enormously consumed in China, in the shape of a decoction, for purifying the blood; also on fast days in lieu of animal food. The fungus is very abundant on decaying timber in all the forests of New Zealand, where it is collected, spread in the air or under sheds to dry, and shipped to Chinese ports. The price paid to the collectors is about 1*d.* a lb., the declared value of the export being at the rate of 4½*d.* a lb. The total exports during the 7 years ending 1878, were 838 tons. Another species of the fungus is gathered in Tahiti for the same market; 86 tons of this, valued at 2580*l.*, were exported in 1878.

Kava-kava.—The root of *Piper methysticum*, a native of the Fiji Islands, has lately been used in the United States, and in France, and to a slight extent in this country, as a remedy for gonorrhœa. The root is large, white, and woody, with a faint, agreeable, lilac-like odour. By the Polynesians, it is used as an intoxicating beverage.

Kino.—The gums known by this name possess astringent properties, and are occasionally administered on this account. (See Resinous Substances.)

Kokum-butter.—The fatty oil derived from the seeds of *Garcinia Indica* (*purpurea*), is well adapted for pharmaceutical preparations. (See Oils—Mangosteen.)

Koso, Cusso, Kousso, or Kosso.—The flowers of *Hagenia Abyssinica* (*Brayera anthelmin thica*) are employed as a vermifuge, for the expulsion of both *Tænia Solium* and *Bothriocephalus latus*. The tree—60 ft. high—is a native of the whole Abyssinian plateau, at 3000–8000 ft. altitude, and is commonly found about the villages; it also grows in Madagascar. The flowers have a herby tea-like odour, a bitter-acrid flavour, and a lightish-brown colour. They are commonly imported in cylindrical rolls, 1½ ft. long and about 3 in. in diameter. Red koso consists of the female flowers. The drug is brought to England viâ Aden or Bombay.

Lactucarium, Lettuce-opium, or Thridace (Fr. and Ger., *Lactucarium*).—The hardened milky juice of 3 or 4 species of *Lactuca*, is supposed to possess in a concentrated degree the soporific power ascribed to the lettuce; but its activity is exceedingly doubtful. The species yielding the drug are:—(1) *L. virosa* or Prickly-lettuce, common on stony land in Central, W., and S. Europe, especially in Spain and France; (2) *L. Scariola*, closely resembling the preceding, and a congener with it; (3) *L. altissima*, probably a variety of the last, indigenous to the Caucasus, and now cultivated in Auvergne, attaining a height of 9 ft., and thickness of stem of 1½ in.; (4) *L. sativa*, the garden-lettuce. In Germany, the drug is produced chiefly near Zell on the Mosel, where the plant is cultivated for the purpose. It produces a stem in the second year only. Just before flowering, in May, the stem is cut off at about 1 ft. from the top; a lateral slice is then removed daily till September, the juice that exudes from the wounded top being collected by the finger and dropped into earthen cups, where it solidifies, and is then turned out to dry in the sun, till it will bear cutting, when it is placed in the air on frames till thoroughly dry (several weeks). The district yields about 6–8 cwt. annually, valued at 6–14*s.* a lb. The Eifel district no longer furnishes any.

German lactucarium occurs in commerce in the form of angular pieces, of a brownish colour internally, opaque, and wax-like. French lactucarium is prepared of good quality at Clermont-Ferrand, in circular cakes of 1½ in. In Austria, about 35 kilos. yearly are made at Waidhofen, in small tears. A Russian variety is highly valued on the Continent. Formerly, only Scotch lactucarium was to be met with, and, after being long absent from the market, is again coming forward. It is prepared in the neighbourhood of Edinburgh, by collecting the juice in little tin cups, where it hardens, and is then turned out and gently dried, being broken up as the drying progresses; it thus results in irregular earthy-looking lumps, from 1 in. long downwards, deep-brown in colour, and having the odour of the Continental drug.

Lignum-vitæ.—The chips, shavings, and raspings of the heart-wood of two species of *Guaiacum* (*G. officinale* and *G. sanctum*) are employed as an ingredient of the compound decoction of sarsaparilla. The drug should be free from sap-wood, and from admixture with other woods. It should sink in water. It is also necessary to ascertain that the resin, on which the virtue of the wood depends, is really present, the chips being obtained from turners, and frequently mixed with the turnings of other woods. (See Timber.)

Lime-juice.—The prepared juice of lemons and limes is well known as an anti-scorbutic. (See Fruit.)

Liquorice (Fr., *Réglisse;* Ger., *Süssholz, Lakriz*).—The root of *Glycyrrhiza glabra* is used for the preparation of extract of liquorice, and the powdered root is employed in pill making. The plant occurs under several varieties over all the warmer parts of Europe, and eastwards into Central Asia. The officinal root is derived chiefly from two varieties:—(*a*) *typica*, a native of Portugal, Spain, S. Italy, Sicily, Greece, the Crimea, the Caucasus, and N. Persia, and cultivated in England, France, and Germany; (*β*) *glandulifera*, found in Hungary, Galicia, Central and S. Russia, Asia Minor, Armenia, Persia, Siberia, Turkestan, Afghanistan, and N. China. The cultivation of the plant at Mitcham, in Surrey, and at Pontefract, in Yorkshire, is on a very limited scale.

The soil must be a deep, sandy loam, free from stones, well trenched, and abundantly manured. The plants, set in rows, reach a height of 4–5 ft. When 3–4 years old, the root is dug up, for which purpose a trench is cut as deep as the former trenching, and a rope is attached to the head of the root, by which it is pulled up. It is seldom got up in an entire state. During the autumn, the principal roots emit horizontal runners; these are forked up, cut off close to the root stock, divided into pieces, laid in heaps out of doors, and covered with straw and mould during the winter. If these are not taken up, the ground becomes full of them, the main root does not grow so vigorously, and the crop is diminished. A fair crop is reckoned at 1 ton of roots an acre. The roots proper are washed, trimmed, and assorted, and sold either whole in a fresh state, or cut up and dried; the older "hard" runners are sold separately, and the younger "soft" ones are reserved for propagation. The English fresh root is externally of a bright-yellowish colour, flexible, tough, and fibrous; it has a peculiar earthy odour, and a distinct sweet flavour. The dried root enters into commerce either with or without its brown coat; in the latter case, it is termed "peeled," or "decorticated." "Spanish," "Tortosa," or "Alicante" liquorice root reaches us in bundles several feet long, containing unpeeled roots and runners, ¼–1 in. thick. That imported from Tortosa is usually in good condition; that from Alicante is often dirty and unequal, frequently showing the knobby crown of the root, and occasionally shipped loose or in bags. "Russian," of which much is used in England, is imported from Hamburg, both peeled and unpeeled, in large bales, consisting of pieces 12–18 in. long, and ½–2 in. thick. It is probably derived from *G. glandulifera*, and, as well as that met with in China, India, and the East generally, has a reddish tint, a scaly surface, and a slightly bitter after-taste. The runners or underground stems are less sweet than the true root, and have a distinct pith, at which part the transverse section generally shows a central depression. Our supplies of the root are drawn from Spain, Russia, and Germany, and are trifling in quantity. France imported over 4000 tons in 1872. China exports it in large quantities: in 1878, Hankow shipped 560 *piculs* (of 133⅓ lb.); Chefoo, 7951 *piculs;* and Newchang, 607 *piculs*. In the same year, Bagdad exported 2590 lb. of the root to India and Europe. The London market value fluctuates between 29*s*. and 30*s*. a cwt.

Manufacture of the Extract.—"Spanish juice," or "liquorice," or "Italian extract of liquorice," is very extensively prepared in S. France, Spain, Calabria, Sicily, Austria, S. Russia (Astrakan and Kasan), Greece, and in the neighbourhood of Smyrna. The roots are taken up during the previous winter, and stacked in a dry and sheltered place; they are placed upright, with layers of sand between, and a stratum some inches thick on the top. When required, they are carried indoors, and crushed under an edge-runner mill-stone; the pulp is then transferred to boilers set over a naked fire, and boiled with water; the decoction is run off, and the fibre is pressed in circular bags; the liquor is next pumped up into copper pans, for evaporation, care being necessary to avoid burning it. When of the proper consistence, the extract is removed while still warm, and weighed out into portions, ready to be rolled into sticks, which operation is performed by women's hands on a wooden table, the extract being moistened with oil to prevent adhesion. After being hand-rolled, the sticks are placed in marble or metal frames, when they are brought to the right dimensions. When stamped with the maker's name, they are stacked on boards in a room to dry. In the best establishments, vacuum pans are used for the inspissation. Of the dried roots, 100 lb. yield about 30 lb. of extract. The manufacture is best performed from November till March, warm weather causing the material to run; for this reason, it should not be shipped in summer. The sticks are bound with bay leaves, to prevent adhesion. In France, Egypt, and Turkey, an infusion of it is used as a cooling beverage; and in America, it is largely consumed in brewing, and in the manufacture of tobacco. The Calabrian factories produced 11,000 cases of 2 cwt. each in 1878. Our imports, in the same year, were:—From Italy, 8505 cwt., value 31,352*l.*; France, 6345 cwt., value 12,629*l.*; Turkey, 6207 cwt., value 12,157*l.*; other countries, 2285 cwt., value 5586*l.* The London market price is about 30–36*s.* a cwt.

Logwood.—A decoction of the chips of the heart-wood of *Hæmatoxylon Campechianum* is administered in diarrhœa; the chief use of the article, however, is in dyeing. (See Dye-stuffs.)

Lopez-root.—The root of *Toddalia aculeata* once had some celebrity in Europe as a remedy for diarrhœa. It is a thick, yellowish, woody root, with a pale-yellow corky bark. The plant is a prickly climber, indigenous to the Coromandel Coast, S. Concans, and Canara, the Indian Archipelago, S. China, Ceylon, Mauritius, and Bourbon. The root seems to have been occasionally brought to Europe from Goa; but it was always dear and rare, and confined to Dutch commerce, its price in 1828 being about 24*s.* an oz. It is largely used in Indian medicine; but is not now met with in this country.

Lycopodium (Fr., *Lycopode;* Ger., *Bärlappsamen, Hexenmehl*).—The minute spores contained in the capsules growing in the axils of the bracts covering the fruit spike of the common Clubmoss (*Lycopodium clavatum*) are employed by druggists for preventing the adhesion of pills when placed in boxes. Also, under the name of "vegetable brimstone," in pyrotechny. The plant, as well as *L. Selago*, is said to possess medicinal virtues. *L. clavatum* occurs throughout Great Britain, but is most plentiful on the moors of the N. counties; and is found on heaths and hills from the Alps and Pyrenees to the Arctic regions, in Central and E. Spain, from Asiatic Russia to the Amur and Japan, at the Cape, in N. and S. America, the Falklands, and Australia. The drug consists of a fine, odourless, flavourless, pale-yellow powder, floating on cold water without becoming wet, but sinking after boiling. In a slow heat, it burns gradually; but when thrown into a flame, it undergoes instantaneous combustion, accompanied by faint explosion. It is obtained by cutting off the tops of the plant as the spikes approach maturity—in July and August; these are taken home, and the powder is shaken out, and sifted. It is gathered principally in Russia, Germany, and Switzerland, the quantity varying greatly with the season. In 1870, France imported over 16,000 lb. of the drug, chiefly from Germany. Our imports are probably much less. The value of the article is about 2*s.* a lb.

Manna (Fr., *Manne;* Ger., *Manna*).—The saccharine exudation obtained principally from *Fraxinus Ornus* (*Ornus Europæa*), is a gentle laxative widely employed. The Manna-ash (*Fraxinus Ornus*) is a small tree, met with in Italy, Sicily, Corsica, Sardinia, Spain, Switzerland, Hungary, the E. coast of the Adriatic, Greece, European and Asiatic Turkey; *F. Bungeana* of N. China is probably also identical. The collection of the drug, which within recent times was carried on in the Tuscan Maremma and the States of the Church, is now confined almost exclusively to Sicily, though an inferior kind is still called after Tolfa, a town near Civita Vecchia. The Sicilian drug is chiefly produced in the neighbourhood of Capaci, Carini, Cinisi, and Favarota, districts lying about 20–25 miles W. of Palermo; also around the towns of Geraci, Castelbuono, &c., in the Cefalu district, 50–70 miles E. of Palermo. The best manna is produced on the plantations where the tree is cultivated. The trees are planted about 7 ft. apart, and the land is occasionally forked, weeded, and manured. When the trunk is at least 3 in. thick (in 8–10 years), the tree is first tapped. This consists in making a series of incisions in the bark, just deep enough to reach the wood, and about 1½–2 in. long; the first cut is made near the bottom of the tree; each day a fresh incision is made, immediately above, and about ½–1 in. from, the last; this is continued while the dry weather lasts, or till the branches are reached. The season extends from early July to late September, being at its height in July–August, when the trees have ceased to put forth leaves, and warm, dry weather assures a good harvest. Next year, the cutting is repeated on the opposite or uncut side of the tree; this is continued till about the 8th year; and at the 9th year, when the tree is becoming exhausted, it is cut all round, and afterwards felled, a single shoot being left, which will be similarly fruitful at the end of 4–5 years. A portion of the juice which exudes from the wounds is gathered by inserting sticks or straws, on which it coagulates, forming a superior quality of manna; on its first appearance, it is brown and bitter, but soon becomes solid, white, and sweet. Frequently, the juice is so fluid as to run down the bark of the tree, partly adhering to the stem, and partly falling to the earth, where it is caught on leaves of the fig and other trees. The bulk of the best commercial manna seems to be that collected from the bark, and known as *manna canellata*, or "Flake manna." The juice which exudes from the lower incisions is caught on tiles, or on pieces of the stem of the prickly-pear, and, being of inferior quality, is added to the drippings, and that which is scraped from the stem after removing the prime sticks, and is called *manna in sorte*, or "Small (Tolfa) manna." The gathering takes place once a week, in fine weather only; the drug being soluble in water, rain and dew are injurious. After collection, both sorts are spread on shelves in the sunshine to dry and harden. The finest manna occurs in stalactites 6–8 in. long, and 1 in. or more wide; crystalline, porous, friable, and yellowish-brown to white; brittle, crisp, and melting in the mouth with a flavour resembling honey. The deeper coloured gummy pieces are obtained from old stems, and from the lowest incisions, and sometimes owe their softness to the alteration in the juice caused by the unfavourable weather towards the end of the season. The gross returns of 1 *hectare* (2½ acres) of land under manna cultivation is estimated as follows:—*Manna canellata*, 13¼ lb., 5*l.* 6*s.*; *manna in sorte*, 207 lb., 28*l.* 4*s.*; wood cut down, 10*s.*; total, 34*l.* The London market value of manna is about 4*s.* a lb. Our imports in 1870 amounted to 230 cwt., value 4447*l.* The Sicilian exports (chiefly from Palermo) in 1871 were 3038 cwt., half of which went to France. Messina, in 1877, exported 4273 kilo. of *canelli*, and 186,664 kilo. *in sorte.*

Attempts have been made to introduce artificial manna made from glucose; and inferior grades of the drug are often manipulated so as to bear a close outward resemblance to the best flake manna. In some parts of Sicily, the common ash (*F. excelsior*) is also cultivated for the manna it yields.

It is necessary to remark that the modern officinal manna differs altogether from the manna of the Bible (said by some writers to be a kind of lichen, and by others to be a saccharine exudation from *Alhagi Camelorum*, or *Tamarix gallica var. mannifera*), as well as from the Oriental mannas of early European commerce, of which there are several kinds:—(1) "Alhagi-manna" consists of little, hard, dry tears, light-brown in colour, sweet-flavoured, and of senna-like odour, afforded by *Alhagi Camelorum*, a native of Persia, Afghanistan, and Beluchistan; it is collected near Kandahar and Herat, during the inflorescence of the plant, and exported to India, to the amount of about 1 ton yearly, valued at 30*s.* a lb. (2) "Tamarisk-manna" collects in drops on the slender branches of the tamarisk (*Tamarix gallica*), in June–July, and is due to the puncture of an insect (*Coccus manniparus*). It is produced especially in Sinai, where it is collected by the Arabs, in the cool of the morning, when it is solid, and disposed of to the monks of St. Katharine; it is also probably produced in the Punjab and in Persia, though in the case of the latter country, the manna sold there under the same Arabic name, is obtained from *Astragalus florulentus* and *A. adscendens*, in the hills S.-W. of Ispahan. (3) *Shir-khist* is said to be an exudation from *Cotoneaster nummularia* and *Atraphaxis spinosa*, and is imported into N.-W. India from Afghanistan and Turkestan. (4) "Oak-manna" is a saccharine exudation caused by the punctures of a *Coccus* on the small branches of *Quercus Vallonea*, and *Q. Persica*. It occurs in the neighbourhood of Diarbekir, in August, and is collected by wandering Kurds, at early morn, by shaking the trees over cloths spread on the ground, or by dipping the branchlets in hot water, and evaporating the liquid.

A number of other saccharine exudations, as well as some animal products, have been noticed by travellers, and designated manna. They are chiefly:—(1) "Briançón-manna," a white saccharine substance, found in the early moroing at midsummer on the leaves of the larch (*Pinus Larix*), on the hills near Briançon, and in Styria; (2) kindred substances have been gathered from *Pirus glabra*, *Salix fragilis*, and *Scrophularia frigida*, in Persia; (3) also from the cedar (*Pinus Cedrus*); (4) in Spain, from *Cistus ladaniferus*; (5) in Australia, from *Eucalyptus viminalis*; (6) *Tighala*, or "Trehala," is the cocoon of a beetle, *Larinus subrugosus* (and *maculatus*), found attached to twigs of *Echinops candidus*, in Syria and Turkey, where it commands a ready sale as food; (7) *Shukhur-ul-Ashr*, is a very similar structure made by *Larinus ursus*, on the Gigantic Swallow-wort (*Calotropis gigantea*), and used for food by the natives of India; (8) "Lerp-manna" is also an animal product, found in Australia.

Matico.—The leaves of *Piper angustifolium* (*Artanthe elongata*), softened in water, or powdered, are used externally to stop bleeding, and, in infusion, to check internal hæmorrhage. The shrub flourishes in the damp forests of Bolivia, Peru, Colombia, Venezuela, and Brazil, occasionally under cultivation; a stouter variety also inhabits the same territory. As it arrives here, in bales and serons, it consists of a compressed mass of leaves and stems, of light-green colour, agreeable herbaceous odour, and bitterish aromatic flavour. The drug is imported by way of Panama. Arica (Peru) in 1877 exported 19,773 lb., and Mollendo, in 1878, 29 quintals. The approximate market value of the drug is 1*s.* 6*d.* a lb.

A number of other plants are used in Central and Tropical S. America under the name of "matico." The principal are:—(1) *P. aduncum* (*Artanthe adunca*), widely distributed in tropical America; (2) *P. lanceæfolium*, in Colombia; (3) *Waltheria glomerata*, in Panama; (4) *Eupatorium glutinosum*, in Rio-bamba and Quito. The leaves of No. 1, as well as those of *P. angustifolium var. cordulatum*, both of which have smooth leaves, are occasionally imported mixed with, or substituted for, true matico. Another species, having an anise-like odour, has also been met with in the English drug market, under the name of matico.

Mezereon, or Spurge-laurel (Fr., *Mézéréon*, *Bois gentil*; Ger., *Seidelbast*).—The bark of *Daphne Mezereum* possesses alterative and sudorific principles, useful in venereal, scrofulous, and rheumatic diseases; in England, it is used internally only in the compound decoction of sarsaparilla; an ointment made from the bark is used for keeping blisters open. The shrub is indigenous to the hills of Europe, from the Arctic regions to Italy, and eastwards to Siberia;

it occurs also in a few counties of England, and its bark is collected for use in Kent and Hampshire. The bark, which is very tough and fibrous, is removed in long strips, and dried, whereupon it loses its unpleasant odour; it has a burning acrid flavour, and will cause vesication on a moist skin. It is stripped off in winter, and tied up in bundles. The bark of the root is most active. The drug is now principally imported from Germany. On account of its scarcity, the bark of *D. Laureola* is often substituted for it by English herbalists. In France, the bark of *D. Gnidium*, common in the Mediterranean basin, is largely used. In Borneo, a bark called *Merik*, from a species of *Wickströmia*, is said to possess identical properties. The approximate market value of Mezereon bark is 8*d*. a lb.

Nux-vomica (Fr., *Noix-vomique;* Ger., *Brechnuss*).—The tincture and extract of the seeds of *Strychnos Nux-vomica*, as well as the alkaloid strychnine, are well-known powerful remedial agents. The tree, of moderate size, is a native of India, especially the coast region, and of Burma, Siam, Cochin-China, and N. Australia. The seeds are compact and horny, their flavour is very bitter, and their colour light-greyish to greenish. They are flat and disc-like, about ⅘ in. in diameter, and 2 lines thick. They are generally steamed, and dried quickly, to soften them before powdering. Their approximate market value is 6–9*s*. a cwt. The drug is largely exported to this country from Bombay, Madras, and Calcutta. The preparation of the alkaloid has been described under Alkalies—Organic (see p. 231).

Pareira-brava (Fr., *Butua, Pareira-brava;* Ger., *Grieswurzel*).—The root of *Chondodendron tomentosum* (*Cocculus Chondodendron, Botryopsis platyphylla*) is prescribed in affections of the bladder, and in calculus, and has very wide uses in Brazil. The vine-like shrub is a native of Peru and Brazil, especially on the hills between the Copacabana and the Rio de Janeiro, and near San Sebastian, and is widely diffused in the tropics of both hemispheres. The drug occurs as long, woody roots, 1–2 in. thick, often much smaller; it has a bitter flavour, and scarcely any odour. They are of a blackish colour externally, with a few transverse ridges. The stem, which is less valuable, generally occurs in commerce mixed with the root, in the proportion of 3 to 1. It is of a pale colour, and is often dotted with small warts. The approximate value of the drug is 1*s*. a lb. The great difficulty in obtaining the true drug has caused it to be almost completely replaced by inferior, and sometimes worthless, substitutes, under its assumed name. The principal of these are:—(1) Stems and roots of *Cissampelos Pareira*, imported from Jamaica in 1866–8, to the amount of 300 lb., by Allen and Hanburys; (2) The woody stem and root of an undetermined plant of the same order as the true drug, collected in Brazil, and characterized by excentric pith and incomplete woody rings. It possesses medicinal virtues, and is known as "Common false Pareira." (3) A valueless kind, distinguished by absence of bitterness, and a well-marked central pith. (4) The stems and roots of *Abuta rufescens*, of Brazil and Cayenne, called "White Pareira"; (5) The stem of an unknown plant of Cayenne and British Guiana, called "Yellow Pareira."

Pellitory (Fr., *Pyrèthre salivaire;* Ger., *Bertramwurzel*).—The root of *Anacyclus* (*Anthemis*) *Pyrethrum* is used chiefly as a sialogogue for toothache, and sometimes in the form of tincture as a stimulant. The plant is a native of N. Africa, especially Algeria, and grows on the plateaux that separate the coast districts from the interior desert. The drug consists of single roots, 3–4 in. long, ⅜–½ in. thick, having a slight aromatic odour, and a pungent flavour, and causing a peculiar tingling sensation, and an extraordinary flow of saliva. It is collected principally in Algeria, and despatched from Oran and Algiers; large quantities also are shipped from Tunis to Leghorn and Egypt, being imported from Tebessa, in Algeria, to the amount of 50,000 lb. yearly. It has long been an article of export to India; its wholesale price is about 70–76*s*. a cwt. The drug is replaced in Germany, Scandinavia, and Russia, by the slender, tufted root of *A. officinarum*, cultivated in Prussia and Saxony; it is as pungent as the preceding.

Pennyroyal (Fr., *Menthe-pouliot, Pouliot-vulgaire;* Ger., *Polei*). — The distilled water of *Mentha Pulegium* is carminative and antispasmodic, and is used like peppermint-water. The infusion is used as an emmenagogue. The herb is common in S. Europe, and its range extends to Britain, Denmark, Sweden, Asia Minor, Persia, Algeria, Madeira, Teneriffe, and Abyssinia; it has also been introduced into N. and S. America, and must not be confounded with the *Hedeoma pulegioides* of the former. The plant is cultivated at Mitcham, and usually sold in a dried state; it has a strong fragrant odour, and a highly aromatic flavour. It is occasionally distilled for its essential oil, of which it should yield about 12 lb. an acre; it is, however, very variable in this respect, and the commercial drug is principally imported from France and Germany, where it is more readily and cheaply produced. The approximate market value is 6*d*. a lb.

Peppermint (Fr., *Menthe-poivrée;* Ger., *Pfefferminze*).—An aqueous or spirituous solution of the essential oil of *Mentha piperita* is a grateful stimulant, frequently added to other medicines. (See Oils.)

Peru-balsam.—The oleo-resin obtained from *Myroxylon* (*Myrospermum*) *Pereiræ* is occasionally used in ointments, and, internally, in asthma and chronic coughs. (See Resinous Substances.)

Podophyllum (Fr., *Podophyllée*; Ger., *Entenfuss, Fussblatt*).—The rhizome and rootlets of *Podophyllum peltatum* are used for the preparation of podophyllin, now largely employed as a purgative and cholagogue. The herb grows in moist, shady places along the E. side of N. America, from Hudson's Bay to New Orleans and Florida. As imported, the drug consists of flattened pieces, 1–4 in. long, and having a heavy, unpleasant, narcotic odour, and bitter-acrid, nauseous flavour. The active principle lies in the resin. It is prepared by exhausting the powdered drug with alcohol, caused to percolate through successive quantities; the tincture is then poured into much water, acidulated with hydrochloric acid (1 measure in 70), and the precipitated resin is dried at 32° (89° F.) max. The colour of the podophyllin is lighter in proportion as the quantity of water used is greater. It is largely produced at Cincinnati, and other towns of America, and in England. The virtues of this plant have been long known to the Indians. The leaves contain the same principle as the roots; the yellow, pulpy fruit, called May-apple, is occasionally eaten. The approximate value of podophyllin is 1*s*. a lb.

Poppy (Fr., *Pavot*; Ger., *Mohn*).—The heads of *Papaver somniferum* are in common use, in the forms of syrup and extract, as a sedative; and, in hot decoction, are sometimes applied as an anodyne. The familiar plant is cultivated on a small scale in England, for medicinal purposes. To ensure a pale colour, and retain the form of the capsules, the stalks of the nearly ripe fruits are bent, so as to make the capsules hang down; they are then allowed to dry on the plant. In Eastern countries, poppies are much more extensively grown, for the preparation of opium. (See Narcotics—Opium.)

Quassia, or Bitter-wood (Fr., *Quassia, Bois amer*; Ger., *Quassia*).—The raspings and shavings of the timber afforded by *Picræna* (*Quassia, Simaruba, Picrasma*) *excelsa*, and other species, are tonic and stomachic. The principal supply is now furnished by the tree named above, the Bitter-wood or Bitter-ash of the W. Indies. In France and Germany, use is made of the wood of *Quassia amara*, or Surinam bitter-wood, a native of Panama, Venezuela, the Guianas, and N. Brazil. A third substitute is the bark of *Q. Simaruba* (*Simaruba amara* [*officinalis*]), indigenous to Cayenne, Guiana, and Jamaica, and called Mountain-damson, bitter-damson, or stave-wood. The bark of *Samadera Indica*, of Ceylon, contains apparently the same principle. (See Timber.)

Quince (Fr., *Coing*; Ger., *Quitte*).—The seeds or pips of the fruit of *Pirus Cydonia* (*Cydonia vulgaris*) are used in decoction, as a demulcent application in cutaneous diseases; occasionally, in eye-lotions; generally, by the natives of India, as a tonic and restorative; and by Europeans, in dysentery; but especially to make bandoline for the hair; and in the arts, for marbling books. The tree flourishes in W. Asia, from Caucasia to the Hindu Kush; in the Mediterranean basin; and in temperate Europe; but it will not ripen in Scotland, Christiania, and St. Petersburg. It also grows at the Cape. The seeds have a mahogany-brown colour, and, when broken, the odour and flavour of bitter almonds. They are imported to England from Hamburg (often quoted as "Russian"), S. France, and the Cape. India imports them largely from the Persian Gulf, and viâ Afghanistan. The approximate market value of quince seed is 1*s*. a lb.

Rhatany (Fr. and Ger., *Ratanhia*).—The root of *Krameria triandra* is a valuable astringent, though not largely used in Britain. The shrub grows luxuriantly in the sands of the Cordillera of the Andes at altitudes of 3000–8000 ft. Its roots are collected principally in the districts lying to the N., N.-E., and E. of Lima, as Caxatambo, Huanuco, Tarma, Janja, Huarochiri, and Canta; also near Lake Titicaca, and in N. Peru. The roots now found in commerce are much smaller and more fragmentary than formerly; a dried extract, resembling kino, once imported from S. America, has disappeared. Several of the 20–25 other species of *Krameria*, natives of the W. hemisphere, possess astringent roots, which are also found in English commerce; they are chiefly:—(1) "Pará," "Brazilian," or "Ceará," furnished by *K. argentea*, of N.-E. Brazil, gathered in the dry parts of Minas Geraes and Bahia; (2) The root of *K. cistoidea*, of Chili; (3) "Savanilla," or "New Granada," derived from *K. tomentosa* (*Ixina, grandifolia*), a shrub found on arid lands in the Jiron valley, at Socorro, and near Santa Marta and Rio Hacha, in Colombia; also in British Guiana, and in Pernambuco and Goyaz. This root is less common in British commerce than "Pará"; but is probably superior in medicinal qualities; (4) A root ascribed to *K. secundiflora*, of Arkansas, Texas, and Mexico, is unknown in the market. The wholesale value of the ordinary drug is about 2–5*d*. a lb. The root of *K. triandra* has a rough surface and splintery fracture; that of Pará, a smooth surface with numerous transverse cracks, and short fracture; that of Savanilla is similar to the last, but paler. The roots of *K. cistoidea* and *K. secundiflora* do not occur in commerce in this country.

Rhubarb (Fr., *Rhubarbe*; Ger., *Rhabarber*).—The root of several species of *Rheum* is one of the commonest and most valuable purgatives, and is also used as a stomachic and tonic. The bulk of the commercial drug would seem to be afforded by two species, but this is a point on which botanists are not agreed. The rival species are *R. officinale* and a variety of *R. palmatum* called *R. Tanguticum*. The first is a native of S.-E. Thibet, and of various parts of W. and N.-W. China, where it is in a measure cultivated. Supplies of the drug are received from these districts, and it is claimed for this plant that it is the only source of the true drug. The second species certainly furnishes considerable quantities of the drug, but opinions differ as to its genuineness. This plant is abundant near the sources of the Tatung and Etsina rivers, in the dense mountain forests. Its root is dug up by Tangutans and Chinese, in September and October; the lateral shoots are cut off, the outer rind is removed by a knife, and the root is then cut transversely into segments, which are threaded on strings, and hung up to dry in the shade, where they are exposed to a draught, but not to the sun. The larger segments are also divided longitudinally, the pieces being known in commerce as "rounds" and "flats" respectively. The drug, locally worth about 2*s.* 2*d.* a lb., is sent to Si-ning, the chief central depôt, and is thence despatched (in winter, by land; in summer, by boat) down the Hoangho to Pekin, Tientsin, &c., where it fetches ten times the local price. The plant affects ravines with a rich loamy soil and N. aspect, and is seldom found on S. slopes, or on the bare mountain. In altitude it ascends to 10,000 ft. It is sometimes cultivated by means of seeds and young plants. Seed is sown in autumn or early spring, in a fine black mould. In the third year, the root is as thick as a man's fist; in eight to ten years, it is mature.

The drug-yielding species of the plant are very widely distributed: they extend over the four N. provinces of China, named Chihli, Shansi, Shensi, and Honan; through the N.-W. province of Kansu, reaching to the frontiers of Thibet; the Mongolian province of Tsing-hai, including Lake Koko-nor, and the regions of Tangut, Sifan, and Turfan; and the mountains of the W. province of Sechuan. The drug from the last-mentioned district is very inferior, owing, it is said, to the moist heat of the province, which interferes with the drying process, and necessitates the employment of direct heat, either from the sun, or by placing the sliced root on heated stones. The places of production, qualities, and comparative prices of the various grades of rhubarb furnished by the Chinese Empire may be thus stated:—Si-ning (Kansu province), average 80 *taels* (*tael* = 5*s.* 10*d.*) a *picul* (133⅓ lb.); Liangchow (Kansu), 75 *taels;* Mienchow (Sechuan), 55 *taels;* Kiaichow (Kansu), 40 *taels;* Kansu, and N.-W. border of Sechuan, best, 40 *taels*, common, 20 *taels;* Kuan Hien (Sechuan), best, 30 *taels*, common, 20 *taels;* Sechuan also yields some very common, value 5–8 *taels*. The Si-ning and Liangchow brands never come to Hankow, and probably go overland to Russian markets; very little even of the Mienchow quality reaches Hankow, and the demand is therefore supplied entirely from the lower grades. A different species is said to grow in the alpine region of the Kansu mountains, but is unfit for medicine; yet another is ascribed to the Ala-Shan mountains.

The very various names by which commercial rhubarb has been known at different times in this country are due solely to changes in the route by which the article, purchased from the producers by Bokharian merchants, has reached Europe. The first route lies over the steppes, by Yarkand, Kashgar, Turkestan, and the Caspian, to Russia. In 1719, Urga was the great depôt; in 1728, the trade was transferred to Kiachta and Maimatchin. The drug was subjected to special control by Russia, and officials were appointed to inspect it, and reject all spurious pieces, and to improve and protect it by trimming, paring, boring, drying, and packing it in chests, sewn up in linen, pitched, and then covered with hide. This article constituted "Russian," "Muscovite," or "Crown" rhubarb, whose uniformly good quality gave it pre-eminence. Since 1860, it has disappeared from commerce; the severity of the Russian monopolists drove it to seek another outlet. The second route is by the Indus or Persian Gulf to the Red Sea and Alexandria, or by Persia to Syria and Asia Minor. From the Levant ports of Aleppo, Tripoli, Alexandria, and Smyrna, it reached Europe, and got known as "Turkey" rhubarb. This did not long survive the competition of the Russian route; and as the imports in this direction ceased, the name was commonly and confusedly (in England only) applied to the drug brought through Russia. The third line is by way of Chinese seaports, the route now traversed by all the supplies coming to W. Europe, and only developed since about 1860, whence the drug is called "China," "Canton," or "East Indian" rhubarb, generally the first-named. It is chiefly purchased at Hankow, sent down to Shanghai, and thence shipped to Europe. The exports from Hankow, in 1878, were:—Shansi drug, 2697 *piculs* (of 133⅓ lb.), value about 32,000*l.*; Sechuan drug, 3245 *piculs*, value about 11,000*l.* Tientsin, in 1877, exported 959 *piculs*. Minor quantities are occasionally despatched from Amoy, Foochow, and Ningpo. Our imports of the drug in 1870 (since which date no return has been issued) were over 153 tons, valued at more than 60,000*l.*

Its commercial value is now about 3–4*s.* a lb., for good and fine; 6*d.*–2*s.* 6*d.* for middling and ordinary. In 1657, when it came overland, its price was 16*s.* a lb. As now imported from China, the drug consists of portions of a massive root, varying in form according to the treatment undergone, and often trimmed to resemble the old Russian drug. The pieces are commonly 3 in. long, and 2 in. wide, but sometimes much larger, usually pierced by a hole, and coated with a bright brownish-yellow powder. This last characteristic is considered much more in England than on the Continent; to imitate the Russian or Crown rhubarb, it is cut or filed, by a workman wearing leather gloves, and is then known as "Turkey trimmed"; the terminal portions of these are called "stick" rhubarb, and sold at a low price. The fracture must show no sign of decay, stain, or sponginess. The root feels gritty in the mouth, from the presence of crystals of oxalate of lime, and has a bitter, astringent, nauseous flavour; and a peculiar odour.

The cultivation of medicinal rhubarb has long been carried on, more or less persistently, in several European countries. Seeds of *R. Rhaponticum*, a native of S. Siberia and the Volga basin, were cultivated at Bodicott, near Banbury, a century ago; and in 1867, some 40 acres of the plant were flourishing in that village, the soil being rich, friable loam. The roots are taken up in the autumn on to November, generally when 3–4 years old, though they are better at 6–7 years. The clumps, weighing perhaps 60–70 lb., are freed from earth and the smaller roots; the central portion is trimmed, pared, and sliced longitudinally; the lateral roots are also trimmed, pared, and assorted. All are then dried slightly in the open air in sheds, and afterwards thoroughly in a building heated by flues, for several weeks, and are stored in a warm, dry place. The best pieces are not inferior to the Chinese drug in size and colour; but in odour, flavour, texture, and structure, they are not so good. The drug commands a low price, and is exported to the Continent and America. The same species is also grown at Austerlitz and Auspitz, in Moravia, and at Ilmitz, Kremnitz, and Frauenkirchen, in Hungary. In France, *R. palmatum*, *R. undulatum*, *R. compactum*, and *R. Rhaponticum* were largely grown half a century ago; but the cultivation is now confined to the vicinity of Avignon, and a few minor spots. The first two species were long since raised extensively for the Russian Government at Kolywan and Krasnojarsk, S. Siberia. *R. Emodi* (*australe*) yields the drug in Silesia. The cultivation of *R. palmatum*, almost the most valuable species, is attended with great difficulty, on account of the central root being very liable to decay. A Russian botanist suggests a remedy for this, in cutting away the old leaf-sheaths and withered stalks before they have had time to rot at the root, thus preventing an accumulation of water. It is further recommended to cover or stop the eye of the stalk; to plant in light, black soil, in a shady situation, not having a S. aspect; at distances of 8 ft. apart; and to water well, especially with water containing abundance of lime, as in the native haunts of the plant.

St. Ignatius' Beans (Fr., *Fèves de St. Ignace*, *Noix Isagur*; Ger., *Ignatiusbohnen*).—The seeds of *Strychnos Ignatii* (*S. Philippensis*, *Ignatiana Philippinica*) are sometimes used in the same way as Nux-vomica, but especially when cheap, for the preparation of strychnine. The shrub is a native of the Bisayan group of the Philippines, being remarkably abundant in the islands of Sámar, Bohol, and Cebu; it has also been introduced into Cochin-China. The seeds are used medicinally throughout E. Asia; they contain about 1½ per cent. of strychnine. They are occasionally abundant in the English market. The preparation of the alkaloid has been described under Alkalies—Organic (see p. 231).

Sarsaparilla (Fr., *Salsepareille*; Ger., *Sarsaparill*).—A preparation of the root of several species of *Smilax* is extensively used as an alterative and tonic. Much doubt still rests upon the origin of the drug; the plants to which it is attributed are natives of the swampy forests of tropical America, from S. and W. Mexico, southwards into the N. part of S. America. In the absence of any botanical classification of the plants yielding sarsaparilla, the varieties of the drug itself may be grouped according to their peculiarities. They are usually distinguished as "mealy" and "non-mealy," the former containing much starch, the latter but little. The chief kinds of the first class are:—(1) "Honduras"; shipped from Belize, in bales secured by hides and iron bands, and made up of rolls 30 in. long, and 2½–4 in. thick, bound with roots. It was noticed in great abundance in the district just explored by H. Fowler, Colonial Secretary. The wholesale value of this variety is about 1*s.*–1*s.* 4*d.* a lb. In 1878, Guatemala exported over 136 quintals (of nearly 2 cwt.), nearly all of which went to Belize, and 4 quintals direct to England. (2) "Guatemala"; a kind much resembling the preceding, except in having a more pronounced orange colour; it is packed in the same way. (3) "Brazilian," "Pará," or "Lisbon"; packed in tight cylindrical rolls, 3 ft. long and 6 in. thick, the ends shaved off, and the whole bound by a plant stem; formerly appreciated in England, but now seldom met with; it is probably furnished by *S. papyracea*. Of the non-mealy descriptions, the most important are:—(1) "Jamaica"; the bulk of the drug shipped under this name is collected in the Cordillera of Chiriqui, Isthmus of Panama, where the plant grows at altitudes of 4000–8000 ft.; the roots are gathered by the natives, and brought down to Boca del Toro, on the Atlantic coast, for shipment. Being 6 ft. and more long, they are doubled up in bundles 18 in. long and 4 in. thick, and tied with long rootlets of the same plant. This is the most esteemed variety in English commerce, and is worth 15–19*d.* a lb. A well-prepared form of the drug, grown in Jamaica, is much paler and more mealy than the commercial "Jamaica" sarsaparilla, and is not esteemed. The exports of this, in 1871, were 1290 lb. (2) "Guayaquil"; differs widely from the foregoing kinds, and is roughly packed in large bales. It is a coarse kind, and usually has the rhizome attached. It is collected in the valleys that open on the plain on the W. side of the Andes, especially in Alansi; it is very fertile, sometimes yielding 75 lb. of the wet drug from one plant. It is second in value to "Jamaica," and fetches about 13–16*d.* a lb. In 1878, Guayaquil exported 371 quintals (of nearly 2 cwt.), valued at 556*l.* (all to England); and, in 1877, 224 quintals, valued at 336*l.* (3) "Mexican"; shipped from Vera Cruz, in straight bundles about 3 ft. long; it is probably yielded by *S. medica*, on the E. slopes of the

Mexican Andes, where it is gathered throughout the year, and sun-dried. It is slender, without rootlets, and has the rhizome attached.

The collectors of sarsaparilla are guided in their choice of the plant by three characteristics:—(1) Many stems from a root; (2) prickles closely set; (3) leaves thin: the first is essential, a species with few stems do not yield roots worth digging for, while the others have at least three long roots, radiating horizontally. The uncovering of the roots is performed by scraping away the earth by the hand and a pointed stick; when all are laid bare, the largest are cut off near the crown, and a few slender ones are left to aid in the regeneration of the plant; the stems are cut off near the ground, and a little earth and dead leaves are heaped over the crown, which soon sends up new shoots. The yield of a 4-years' plant may be 16 lb., but a well-grown one may give 32–64 lb.; cutting may be renewed in two years, but the yield will be less, and the roots more slender and less starchy. The dried root has little odour, but emits a very perceptible one on boiling; the flavour is earthy.

INDIAN SARSAPARILLA, OR NUNNARI-ROOT.—This drug, which has no affinity to the preceding, is furnished by *Hemidesmus Indicus* (*Periploca Indica*, *Asclepias Pseudo-sarsa*), a twining shrub of India and Ceylon. The drug is said to be alterative, tonic, diuretic, and diaphoretic, but it is seldom used in England, and that which reaches here is often of very bad quality. The root has a loose, cracked bark; its odour is agreeable, recalling that of melilot.

Sassafras (FR. and GER., *Sassafras*).—The root of *Sassafras officinalis* (*Laurus Sassafras*) is accounted sudorific and stimulant, and is prescribed with sarsaparilla and guaiacum. The tree is a native of the W. hemisphere, from Canada to Missouri and Florida, attaining its greatest growth in the middle and southern states, while in the northern it is little better than a shrub. The roots are dug up by the aid of levers, and sent in great quantity to Baltimore, which is the entrepôt for a circuit of 300 miles. The drug is imported in large branching stumps, 6–12 in. thick, and often including much of the inert trunk-wood and its bark. The value is about 9–11*s.* a cwt. The wood of the root is usually rasped up for sale; the bark is a separate article of merchandise, little used in England. The root-wood yields 1–2 per cent. of volatile oil; the root-bark, twice as much (see Camphor; Oils). Among the other members of the same order, whose barks possess a sassafras odour, may be mentioned:—(1) *Mesphilodaphne Sassafras*, of Brazil; (2) An undescribed species of sassafras of India and Burmah; (3) *Atherosperma moschata*, of Australia; (4) *Doryphora Sassafras*, Australia.

Sassy, Mancona, or Casca Bark.—The bark of *Erythrophlœum Guineense* is a powerful ordeal poison used on the W. coast of Africa. It causes intense and prolonged sickness and debility, and, in large doses, death. In small doses, it strengthens and retards the action of the heart. The bark is abundant, but rarely imported, as there is no demand for it. It is thick, heavy, with a smooth inner surface, and of a reddish tint. It contains an alkaloid called erythrophlœine.

Scammony (FR., *Scammonée*; GER., *Scammonium*).—The juice which exudes from the cut surface of the roots of *Convolvulus Scammonia* is employed as an active cathartic, generally with calomel and colocynth. The plant inhabits waste spots in the E. and N. parts of the Mediterranean basin, from Syria, through Greece, to S. Russia, but is unknown in the W. regions. Commercial supplies of the drug are obtained almost exclusively from Asiatic Turkey, within the area comprised by Brussa, Boli, Angora, Macri, and Adalia, and especially from the valley of Mendereh, and the districts of Kirgagatsch and Demirdjik in the neighbourhood of Smyrna. Small quantities are produced also near Aleppo, and from the valleys and wooded hills around Mount Carmel, and the Lake of Tiberias. The plant flourishes best among juniper, arbutus, and wild valonea bushes, which afford it support and shelter. Scammony produced in hilly regions and on poor soil possesses the strongest odour; that collected on rich and marshy ground contains more water, and, when dried, becomes greyish-black and of less specific gravity. The drug is gathered by the peasants, in summer, while the plants are in flower. The soil is removed from the root to a depth of 3–4 in., the latter is then severed obliquely at about 1–1½ in. below the crown, and a mussel-shell is placed to catch the escaping juice, as shown in Fig. 582, and is protected on the windward side by a large stone. The sap flows freely at early morning and late evening; the shells are usually collected at the latter time, when the cut surface is scraped, to remove any concretions of the juice, which may have formed after the first flow. Such con-

582.

cretions are termed "cream," while the fluid drug is called "milk"; dust and dirt are carefully blown from both kinds, which are then placed in copper vessels, and the whole is thoroughly incorporated, by stirring with a knife, till its consistence enables it to form strings when run off the knife. Excessive dryness is corrected by adding water, but this may only be done in the hottest part of the day. It is then left in the sun to dry. During this process, it ferments, and becomes bubbly, and of a dark or blackish colour. The product is pure scammony. The yield of the drug varies with the age and situation of the root:—a fourth year's plant in good soil may give 2 dr. (and rarely up to 12 dr.); in some districts, the average is 1 dr. a root; in others, 100 roots produce only 10 dr. If allowed to remain in the shells, the scammony is a golden-brown, transparent, gummy-looking substance. In this state, it is used by the peasants, but never exported.

The article prepared by the Greeks is much superior to that of Turkish manufacture. The former does not exceed 7 cwt. yearly, and is sold at a high figure to a few who know its value. It is placed in a room with open windows, but excluding the sun; it is spread on sheep-skins, and turned at intervals; when nearly dry, it is broken up, left for a few days longer, and packed in cases of about 30 lb. each for export. The best samples of the dry drug occur in flat pieces, ¾–1 in. or more in thickness, and 3–6 in. in diameter, the surface covered with a greyish powder, produced by attrition; the fractured surface is shining, with numerous small air cavities, the splinters looking white at the edges, but reddish by transmitted light. This is known in English commerce as "virgin" scammony. It contains 80–90 per cent. of resin, but no starch, and should become milky when wetted by the tongue. Even virgin scammony is sometimes mixed with inferior specimens, and is therefore carefully picked over after purchase by wholesale druggists in this country, the purest pieces being sold in the entire state, and the inferior apparently used for producing the powdered scammony, since powdered scammony generally contains starch. Aleppo scammony is inferior to that of Smyrna.

The second in quality is that collected by Turkish peasants. After cutting the roots, they frequently pull them up, and subject them (sometimes with stalks and leaves) to a pounding and boiling, and this decoction, freed only from the coarsest impurities, is added to the natural exudation. The instruments used are hollowed pumpkins, skins, and earthen pots. The product is black, heavy, and impure; beyond this, it is commonly adulterated, by the addition of 10–150 per cent. of very finely powdered and sifted chalky earth, while the scammony is liquefied by water. This form of the drug is bought up by Jews and Greeks, and thrown promiscuously, in its fresh state, into cotton bags, which are then placed in drums, and sent to Smyrna. Here it often lies until it is mouldy, porous, and dull; it is turned out, and broken up to dry. This mixed article is sold in London as "akilip," or inferior scammony. It contains usually 40 per cent. of resin. This kind is chiefly exported.

Several other qualities are prepared by the dealers in Smyrna and Angora, and in the interior. One of the latter kind consists in the addition of wheat starch, wood ashes, earths, gums (arabic or tragacanth), wax, flour, rosin, roots, and leaves of scammony, &c. The adulterated compound is dried in lumps, put into drums, and covered with a layer of the nearly pure drug; it is largely exported. A kind prepared at Angora with 60–70 per cent. of starch, is sent to Constantinople, and finds a ready sale in Austria. Two kinds are prepared by Smyrna Jews for the British market in particular:—(1) "First quality prepared" is made by mixing a quantity of the country adulterated drug with about 40 per cent of the inferior Angora; the whole is pounded, and placed in warm water in a shallow iron dish, which rests in a larger dish half-filled with water and set over a charcoal fire. Amalgamation ensues in about ½ hour, when the mass is turned out on a sheep-skin, and rolled by hand till cold. It is then made into cakes, washed over with a solution of pure scammony to create a gloss, and dried in an airy room. (2) "Second quality prepared" is composed of about 60 per cent. inferior Angora, 30 per cent. fair Smyrna, and 10 per cent. gum arabic and graphite. The persistent adulteration of the drug necessitates its being sold only by analysis, which fortunately is a very simple matter. Of late years, considerable quantities of the dried root have been imported, and the resin extracted by alcohol in this country. The resin so prepared does not become milky when wetted. Since 1870, resin extracted from the root by alcohol has been exported from Brussa. The root is in large pieces, 1 ft. and more long, and 3 in. in diameter, twisted, pale-brown externally, and white and starchy internally, with resinous streaks. Probably the whole yearly production of the pure drug does not exceed 30 cwt.; it is increased by adulteration to about 75 cwt.

In 1872, Smyrna exported 185 cases, value 6100*l.* In 1873, Aleppo despatched viâ Alexandretta to England 46,500 kilo. of the root, and 900 kilo. of the resin. "Virgin" scammony is quoted at 23–25*s.* a lb.; "second and ordinary," at 8–20*s.*

Senega, or Seneka (Fr., *Polygala de Virginie;* Ger., *Senega*).—The root of *Polygala Senega* is used as a stimulating expectorant and diuretic, in bronchitis, pneumonia, asthma, and rheumatism. The plant is a native of the New World, from the River Saskatchewan to Virginia, N. Carolina, Georgia, and Texas, but not in the Rocky Mountains, frequenting rocky, open woods, and plains. It has become rare in the E. States, and the drug is now gathered chiefly in Minnesota and Iowa. It has a short, brittle fracture, peculiar rancid odour, and very acrid sourish flavour; when disturbed, it emits an irritating dust, which excites violent sneezing. The rootlets are richest in active principle. It is highly valued in America. Its price in London varies from 1*s.* 9*d.* to 3 . a lb. The roots of *Asclepias Vincetoxicum* have been found mixed with it in large quantity of late years. It has an evident pith, and more rootlets, and has not the acrid taste of senega.

Senna (Fr., *Séné;* Ger., *Sennes*).—The leaves of two species of *Cassia* are very widely used as a purgative. The species are:—(1) *C. acutifolia*, indigenous to many parts of Nubia—as Sukkot, Mahas, Dongola, and Berber—Sennar, and Kordofan, as well as Timbuctu, and Socoto; it yields "Alexandrian" senna. (2) *C. angustifolia*, abundant in S. Arabia—Yemen and Hadramaut—also in Somali-land, Sind, and the Punjab (in the two last, it is cultivated); the wild (Arabian) plant yields "Bombay" or "Mocha" senna, and the cultivated (Indian) plant, "Tinnevelly" senna. The Nubian peasants collect two crops of senna-leaves annually: the first and chief harvest takes place after the rains (September); the second, and very insignificant, during the dry season (April). The operation consists in felling the shrubs, and placing them to dry on the scorching hot rocks. When dry, the leaves are packed in bags of palm-leaf, holding about I quintal (nearly 2 cwt.), sent by camel caravans to Darao and Es-souan, and thence by water to Cairo. Some "mountain senna" (*C. acutifolia*) is said to pass viâ Massowa and Suakin to Cairo and Alexandria. "Indigenous," or "wild," senna (*C. obovata*) grows in the durra-fields; but it was never esteemed, and is only rarely imported from Tripoli. Within the last few years, some fine cultivated samples of this senna have been received from Barcelona. To return to the commercial varieties—Alexandrian senna arrives in large bales; latterly it is found in very fair condition, but formerly it was always dirty, and mixed with stems, flowers, stones, and the leaves, flowers, and fruits of *Solenostemma Argel*; the latter was, indeed, deliberately added, and found favour with some, but as the leaves occasion griping without purging, they should be avoided—the leaves are easily distinguished from senna by their minutely wrinkled surface. The value of this kind varies between 3½*d.* and 1s. 6*d.* a lb. "Bombay," "E. Indian," "Arabian," or "Mocha" senna, is collected in S. Arabia, and shipped from Red Sea ports to Bombay, and thence to Europe; it is of very low quality, chiefly on account of careless preparation, as it is not adulterated; its value is ½–2½*d.* a lb. "Tinnevelly" senna is a superior and carefully prepared drug, shipped from Tuticorin (S. India); its price is 1½*d.*–1*s.* 6*d.* a lb.

Very fine senna has been grown in Rockhampton, Australia; and it is confidently stated that the culture of the plant might be profitably undertaken in the fern-tree ranges of Victoria.

Snake-root (Virginian), or Serpentary (Fr., *Serpentaire de Virginie;* Ger., *Schlangenwurzel*).—An infusion or tincture of the root of *Aristolochia Serpentaria* is prescribed as a stimulating tonic and diaphoretic, generally with cinchona; it is not now used against snake-bite. The plant is a native of the New World, growing in shaded forests, from Indiana and Missouri to Virginia and Florida, especially in the Alleghany and Cumberland ranges. The root has a dull-brown colour, an aromatic odour, and a bitterish-aromatic flavour. It is imported in bales, casks, and bags, from Boston and New York; its value is about 10*d.*–1s. a lb. The roots of *Spigelia Marilandica* and *Cypripedium pubescens* are sometimes accidentally mixed with it.

Snake-root (Texan, or Red River).—Under this name, has been imported considerable quantities of the slightly larger root of *A. reticulata*, which takes the places of the preceding species in all districts S.-W. of the Rocky Mountains. The drug is collected in Louisiana and Arkansas. It is this kind which is principally met with in English commerce. It differs from the last in the rootlets being perfectly smooth.

Snake-root (Black), Black Cohosh, or Bugbane.—A tincture of the root of *Cimicifuga* (*Actæa*) *racemosa* is used in rheumatism, dropsy, phthisis, and bronchitis, and externally for reducing inflammation. The plant is abundant in woods in the W. hemisphere, as far S. as Florida. The drug has a blackish-brown colour, a bitter-acrid, astringent flavour, and a heavy narcotic odour. In appearance, it closely resembles black hellebore root, but is less branched, and has more marked transverse scars.

Squill (Fr., *Scille, Ognon marin;* Ger., *Meerzwiebel*).—The roots of *Urginea maritima* (*Scilla maritima, Urginea Scilla*) are commonly used as a diuretic and expectorant. The plant is distributed throughout the Mediterranean basin, e. g. S. France, Portugal, S. Spain, Italy, Sicily, Dalmatia, Greece, Asia Minor, Syria, and N. Africa, as well as in the islands generally. The bulbs are distinguished as "red" and "white," but possess no difference whatever, save in the matter of colour. The red, however, is most esteemed. They are gathered in August, when leafless, and are freed from the dry outer scales, cut across into thin slices, and sun-dried. The drug has a dull-yellowish, or roseate, colour, according to the variety; when dry, it is brittle, and easily powdered. Its value is about 1–6*d.* a lb. In Greece, attempts have been made to manufacture alcohol, by fermenting and distilling squill. The bulbs of several other plants occasionally usurp the place of squill, though not in European markets; they are chiefly:—(1) *U. altissima* (*Ornithogalum altissimum*), of S. Africa, equally effective; (2) *U.* (*Scilla*) *Indica*, of N. India, the Coromandel Coast, Abyssinia, Nubia, and Senegambia, a poor substitute; (3) *Scilla Indica* (*Ledebouria hyacinthina*), of India and Abyssinia, a superior representative; (4) *Drimia ciliaris*, of the Cape, known as "Itch-bulb," and used as emetic, diuretic, and expectorant; (5) *Crinum Asiaticum* (*toxicarium*), of India, Ceylon, Moluccas, &c., a valuable emetic. Squill is imported from Malta, packed usually in casks.

Stavesacre (Fr., *Staphisaigre*; Ger., *Stephanskörner*, *Läusesamen*).—The seeds of *Delphinium Staphisagria*, reduced to powder, or made up in an ointment, are largely used for the destruction of *pediculi* on man and animals. The herb is indigenous to Italy, Greece, and Asia Minor, affecting waste and shaded spots, and is now found generally throughout the Mediterranean basin, and in the Canaries. It is cultivated in Puglia (Italy), and near Nîmes and Montpellier (S. France); our imports are principally from, Trieste and S. France. The approximate value of the seed is 50*s.* a cwt.

Storax.—The balsam known as "Liquid storax," is an old-fashioned remedial agent, now applied externally in scabies. (See Resinous Substances.)

Stramonium, or Thorn-apple (Fr., *Stramoine*; Ger., *Stechapfel*).—The leaves of *Datura Stramonium* are smoked (like tobacco) for the relief of asthma; the seeds are used, in the form of extract or tincture, as a sedative or narcotic. The plant is now met with as a weed in almost all temperate and subtropical regions; in the neighbourhood of London, it is occasionly found in rich waste land, and is cultivated at Mitcham. For medicinal application, the whole plants are uprooted; the leaves and young shoots are stripped off, quickly dried, and broken or cut into short pieces. The odour of the dry drug is pleasant and tea-like; its flavour is bitterish saline. The closely allied species *D. Tatula*, native of America, is naturalized in S.-W. Europe, and flourishes like the preceding. It has similar properties. The seeds and leaves of *D. alba* and *D. fastuosa*, natives of India, and garden-plants in S. Europe, are officinal in India. The approximate value of the leaves is 6*d.* a lb.; of the seed, 9*d.*

Sumbul, or Musk-root (Fr., *Sumbul*; Ger., *Moschus*).—A tincture of the root of *Ferula* (*Euryangium*) *Sumbul* is prescribed as a stimulating tonic and antispasmodic. The plant is found in the Maghian mountains, near Pianjakent in N. Bokhara, and in the coast province of the Amúr. The root occurs in commerce in slices 1–5 in. wide, and 1 in. thick. The so-called "Bombay sumbul," or *Boi*, is the root of *Dorema Ammoniacum.* (See Resinous Substances—Ammoniacum).

Tamarinds.—The fruit of *Tamarindus Indica* is mildly laxative, and is a constituent of *Confectio Sennæ.* (See Fruit.)

Taraxacum, or Dandelion (Fr., *Pissenlit*; Ger., *Löwenzahn*).—The root of *Taraxacum officinale* (*T. Dens-leonis*, *Leontodon Taraxacum*) is largely used as a mild laxative and tonic, especially in liver complaints. The plant is a native of the whole of Europe, N. and Central Asia, and N. America. In England, the root is gathered for extracting in November, the juice then yielding the best and most abundant product. Bentley says, however, that it is more bitter in March, and most in July, and that these seasons should be chosen for collecting it. The drug is very subject to attacks by maggots, and should not be kept longer than 1 year. It is sometimes adulterated with roots of the common Hawkbit (*Leontodon hispidus*). The approximate market value is 72*s.* a cwt.

Valerian (Fr., *Valériane*; Ger., *Baldrian*).—The root of *Valeriana officinalis* is used as a stimulant and antispasmodic. The plant inhabits the whole of Europe, N. Asia as far as the coast of Manchuria, and several of the United States. It is grown (partly cultivated) in considerable quantities in the villages of Ashover, Woolley Moor, Morton, Stretton, Higham, Shirland, Pilsley, Wingfield, and Brackenfield, all in the neighbourhood of Chesterfield, Derbyshire, the yield from which was 6 tons in 1872. Very much larger quantities are produced around Cölleda, near Leipzig; the plant is grown to some extent also in Holland, Vermont, New Hampshire, and New York. Propagation is effected by separating the young plants, developed at the end of runners springing from the root-stock. The fresh root is inodorous, but acquires its characteristic odour by drying; its flavour is bitterish-aromatic. Of late years, a kind of valerian root has been imported from Japan, under the name of Kesso, and is believed to be the produce of *Patrinia scabiosæfolia*; it is powerfully odorous. The approximate market value of valerian is 100*s.* a cwt.

Wahoo Bark.—The bark of *Euonymus atropurpureus*, used in the United States, contains a principle termed euonymine, recently introduced into this country as a cholagogue. The root-bark is said to be more powerful than the stem-bark: the former is whitish, with a somewhat nauseous odour; the latter occurs in long quills, and is greenish when the outer surface is scraped.

Wormseed (Fr., *Semen-contra*, *Semencine*, *Barbotine*; Ger., *Wurmsamen*, *Zitwersamen*).—The flower heads of *Artemisia maritima* (*Lercheana*) are largely used for their anthelmintic properties. The plant is found in saline soils, throughout the N. half of the Old World, as in Great Britain, on the shores of the Baltic, France, and the Mediterranean, in Hungary and Podolia, in S. Russia, the Caspian, Central Siberia, and Chinese Mongolia. The variety which chiefly affords the drug is most abundant on the Don and the Lower Volga, and in the Kirghiz Steppes; in the last-named district, it is gathered very extensively, and introduced into commerce through the annual fair at Nishni-Novgorod. The best samples of the drug contain only unopened, whole flower heads, so tiny that 90 equal about 1 gr.; in inferior samples, occur fragments of stalks and leaves. In 1864, St. Petersburg imported about 11,400 cwt. of the drug, from the Kirghiz deserts, viâ Semipalatinsk and Orenburg. Barbary wormseed, which is rarely seen now in the London market, differs from the Russian drug in being minutely hairy, and largely mixed with fragments of stalks. It is not known to contain santonin. It is supposed to be the produce of *A. glomerata*. The approximate market value of wormseed is 8*d*. a lb.

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(See Alkalies—Organic; Dye-stuffs; Fruit; Narcotics; Nuts; Oils; Resinous Substances; Spices; Timber.)

DYEING AND CALICO-PRINTING (Fr., *Teinture, Impression;* Ger., *Farberei, Zeugdruckerei*).

These terms are used to signify the arts of producing at will colours upon textile fabrics, whether of animal or of vegetable origin. "Dyeing," in the strict sense of the word, is confined to those operations by which loose fibre, yarns, or woven goods, are made to assume some uniform colour. "Calico-printing," or, as it may be more properly called, "tissue-printing," is the production upon yarns or cloth of designs of two or more colours. Patterns in different colours may, however, be obtained by simple dyeing, in the case of tissues composed of more than one kind of fibre, such as wool and cotton, or silk and cotton. In virtue of certain specific properties, to which reference will be made below, animal and vegetable fibres take up colours in a very different manner, so that if a design be produced in such mixed fabrics by the art of the weaver, it will, if skilfully dyed, exhibit such a design in different colours.

The arts in question are based on the power of organic fibres to absorb colouring matters, and to retain them with a greater or less degree of persistence. This absorption is now considered to be mainly physical, rather than chemical, in its nature, and to depend on the presence, in each fibre, of innumerable pores, too small to be recognized even by the microscope, into which the colour penetrates, and where it is held by means of surface attraction. Chemical affinity plays, however, an undeniable part. Thus, if we place in a solution of magenta, or of picric acid, a piece of mixed cloth, say of wool and cotton, the woollen threads will be fully and permanently coloured, whilst the cotton threads will either remain entirely white, or at most exhibit a slight stain, which is easily removed by rinsing in cold water. The affinity of colouring matters for animal fibres—wool, silk, &c., is, with very few exceptions, much stronger than for vegetable fibres—cotton, linen, jute, hemp. Hence yarns and cloths of vegetable matter are decidedly more difficult to dye.

It has been long ago observed that certain colours combine with textile fibres very readily on mere contact. Thus the majority of the aniline colours are at once absorbed by wool and silk, and carthamine, the red colouring principle of safflower, is quite as readily taken up by cotton. Such colours are known as "substantive colours." The majority of colouring matters, however, do not thus combine with the fibre, but require the intervention of a "mordant," i. e. a body which possesses an attraction, physical or chemical, both for the fibre and for the colour, and thus enables the two to unite.

The selection and use of these mordants is, therefore, a most essential part, both of the theory and the practice of dyeing. For the most part, they consist of metallic salts, such as the sulphate, nitrate, and acetate of alumina, and its double sulphate, commonly known as alum; the proto- and per-chlorides of tin (stannous and stannic chlorides); the so-called nitrate of tin; the sulphates, nitrates, and acetates of iron, and their mixtures; the sulphate of copper (blue stone or blue vitriol), and the acetate of copper (verdigris); the nitrate and acetate of lead; the chloride and tartrate of antimony. There are also compounds extensively used as mordants, in which a metallic oxide plays the part of an acid, in combination with soda or potash. Such are the stannate, aluminate, and plumbate of soda; and, above all, the chromates of potash.

The bitartrate of potash, commonly known as tartar or argol, likewise plays an important part in mordanting woollen goods, though its action is by no means perfectly understood. The above-mentioned bodies, if mixed, in a state of solution, with e. g. the decoction of a dye-wood, precipitate the colouring matter more or less completely, leaving the liquid clear. These precipitates are called "lakes," and are supposed to be produced in the pores of the fibre, if the latter be saturated first with the mordant, and then immersed in a solution of a dye.

The above-mentioned metallic mordants do not merely mediate the absorption of the dye, but modify the shade produced, rendering it purer and brighter, as well as faster. Hence their use is often needful, even in the case of substantive colours.

Two mordants of a different class have recently been discovered, and promise to become of great practical value. The first of these is gelatinous silica, which will open out quite a new era, especially in the fixing of aniline colours upon cotton. All that is needed is to pass the yarns through a solution of silicate of soda, the so-called soluble glass, the more neutral the better, provided it retains its solubility. The yarns are steeped in a dilute acid, so as to precipitate the silica upon the fibre. After careful washing, they are plunged into the dye-beck, where they rapidly take bright, full colours, which are decidedly faster than those obtained with the various mordants previously known. The other new mordant,—also, it is believed, primarily due to Prof. Reimann, of Berlin,—is finely divided sulphur. The yarns, either woollen or cotton, are boiled in hypo-sulphite of soda, along with, or followed by, very weak sulphuric acid. Sulphur in a state of very fine division is thus deposited upon the fibre, and acts as a mordant, not merely for the aniline greens, but also for magenta, the violets, phosphine, &c.

There still remain the organic mordants. If vegetable fibres be coated with certain animal products, such as albumen (whether obtained from eggs or from blood), dissolved caseine (lactarine), gelatine, &c., they assume superficially the characters of wool or silk, and absorb a great variety of colours in the same manner as animal fibres do. These animal mordants play a more important part in calico-printing, than in dyeing. The so-called "oil-mordants" or "emulsive oils," originally introduced in Turkey-red dyeing, are found very widely applicable in fixing refractory colours upon vegetable fibre, and giving them a more permanent character. Further details concerning mordants, and instructions for their manufacture, will be found in a separate article—Mordants.

The tendency of the art of dyeing is all towards simplification. Pure colouring-matters, such as alizarine, are employed, instead of crude vegetable or animal products, and thus a great saving of time and of labour is effected.

Cotton-Dyeing.—Cotton, like all vegetable fibres, is more easily injured by acids than is wool. Consequently, neither mordants nor colours of a strongly acid character can be employed; otherwise the goods will be corroded, and the colours will fail to be duly absorbed. The solutions employed must be very feebly acid, neutral, or even alkaline. Another important feature is the temperature at which cotton is dyed. Wool almost invariably requires a boiling-heat; but cotton, in the majority of cases, is worked in the cold, or at a "hand-heat," i. e. at about 32°–38° (90°–100° F.). Cotton is most extensively dyed in the state of yarn, but a large quantity is also dyed after being woven (see Cotton Manufactures). This especially relates to the mixed fabrics, known as Bradford goods, the warps of which are cotton, and the weft worsted. The perfection of cotton-dyeing is to produce on these warps the same tone and depth of colour as are found on the worsted, so that the entire piece may appear level, and free from any checky character.

It will now be convenient to give a series of approved recipes, for producing the principal colours upon cotton, selecting such processes as may best illustrate the resources of the modern dyer, and having especial regard to the recently discovered tinctorial substances;—

Blacks: (1) *Fast Black* (for 110 lb. cotton yarn or cotton wool).—Solid extract of logwood, 8¾ lb.; catechu, 5 lb. 10 oz. Boil up together. Boil the yarn in the decoction for 1 hour, steep in the cold liquid for 24 hours; raise to a boil again; lift, and air overnight.

Dissolve in sufficient fresh water, 24⅛ oz. chromate of potash, and the same weight of blue vitriol, and work the cotton in this for ½ hour. Lift, drain, and dissolve 2¾ lb. soda ash in the cold logwood liquor. Heat to 87° (139° F.), re-enter the cotton, work for 15 minutes, and rinse. This colour bears washing and milling, and does not smear whites.

(2) *Aniline Black* (for 100 lb.).—Mix 6 lb. 9 oz. aniline oil with 8 lb. 12 oz. hydrochloric (muriatic) acid at 32° Tw. Let cool, and add solution of 4 lb. 6 oz. chlorate of potash in 66 parts water, and finally add 43¾ pints of a solution of chloride of iron at 32° Tw. Steep the bleached yarn for 8–10 hours in the liquid, which must previously be diluted with water at about 38° (100° F.); take out, and place it in a solution of soda at 23° Tw., to neutralize the excess of acid. Wash, and steep for ½ hour in a beck, made up with 66 pints of water and 7 oz. chromate of potash at about 45° (112° F.). This treatment prevents the dye from subsequently turning green. Wash, and pass the yarn through a mixture of 17¼ oz. emulsive oil (such as is used by Turkey-red dyers), 2 lb. 3 oz. potash, and 66 pints water. Dry at once.

(3) *Aniline Black for Cotton Yarns* (De Vinant's process).—The cotton yarn, well boiled out, receives 7 turns in a beck, made up with 7 oz. sulphate of copper for every 2 lb. 3 oz. of yarn, dissolved in water slightly soured with muriatic acid; it is then well wrung out. It next receives 5 turns in water at 50° (122° F.) containing 1¾ oz. sulphide of sodium per 35 fl. oz. of liquid, and is again rinsed. It then has 7 turns in a beck of 17½ pints water, 6¼ oz. of chlorate of potash, and 5⅞ oz. sal-ammoniac, all dissolved by the aid of heat, and mixed with 16½ oz. muriate of aniline. It

is then stretched out very regularly in a drying-room, and kept for 48 hours at 25° (76° F.). Lastly, it receives 4 turns in water containing 15½ gr. bichromate of potash per litre, at 30° (86° F.), and is then well washed, and dried. If the black has a foxy tone, take through 87 qts. of cold water, to which has been added 35 fl. oz. bleaching-liquor at 8° Tw. Without great care, the blacks produced by this process are cloudy.

(4) *Aniline Black with Vanadium* (Pinckney's patent).—Take muriate of aniline, 150 parts; salt of vanadium, ⅛ part; chloride of nickel, 20 parts; chlorate of potash, 100 parts; water, 2500 parts. The yarns may be steeped in a mixture of these substances, and may be died either hot or cold. In subsequent practice, the chloride of nickel has been found unnecessary, and the salt of vanadium admits of a great reduction in quantity.

(5) *Aniline Black.*—Scour well, and for each 1 lb. of cotton yarn, take 3½ oz. sulphate of copper, dissolved in water made very feebly acid with spirits of salt (muriatic acid). Give 7 turns, and wring well. Dissolve ½ lb. hydrosulphide of soda per gal. of water, at 49° (120° F.), give 5 turns, and wash well. Dye cold in chlorate of potash, 3 oz.; sal-ammoniac, 3 oz.; muriate of aniline, ½ lb.; dissolved in sufficient water. Give 7 turns quickly, wring well, and beat. Hang up evenly at 25° (77° F.) for 48 hours, and raise to 29° (84° F.). Take through either bichromate, or weak soda-lye; wash well. If reddish when dry, take through very weak chloride of lime liquor.

(6) *Fast Black* (for 60 lb. yarn).—Take through indigo vat. Then boil 5 lb. logwood extract, and 1½ lb. blue vitriol; steep yarns in this all night, and work in the morning, in 6 qts. nitrate of iron in sufficient cold water. Take through clear lime-water, and wring out. Boil 5 lb. logwood extract, ½ lb. fustic extract. Add this to sufficient hot water; work yarn in this for ½ hour; lift; add 2 lb. copperas; work again, wash off, and dry.

Blues: (1) *Methyl Blue* (30 lb. yarn).—Dissolve 4 lb. Glauber salts, 2 lb. alum, in a sufficient quantity of water. Dissolve 1½ oz. methyl blue (of Meister, Lucius, & Brüning), and add it to the dye-beck. Enter yarn at 43° (110 F.), turning rapidly, and dye to shade, raising the temperature to 49° (120° F.).

(2) *Light Blue* (50 lb. bleached yarn).—Dissolve 3 lb. alum, 3 oz. tartaric acid, and ½ oz. "water-blue 6 B" (Berlin Aktien Gesellschaft für Anilin-Farben). Enter yarns at 43° (110° F.), turn rapidly, and raise the temperature to 54° (130 F.), turning to shade. After the colour has become level, another ½ oz. of the colour, previously dissolved, should be added to the beck.

(3) *Corn Flower Blue (Pittacal).*—Prepare the cotton in a cold solution of tannin; wring, and enter into a solution of tartar-emetic. Wring, and enter into a solution of acetate of pittacal,—dissolved in acetic acid, diluted with a sufficient quantity of water, and then almost neutralized with ammonia.

(4) *Navy Blue* (11 lb.).—Boil 2 lb. 3 oz. logwood, and dissolve in the clear hot liquid 26 oz. curd-soap. Steep clear yarn in this liquor for 2 hours at 75° (167° F.). Lift; add to the beck 26 oz. copperas; re-enter the yarns, and work till the colour is even. Wash in cold water, and work in a fresh beck, with 17½ oz. curd soap, at 62° (144° F.), for 1 hour. Then make up a boiling beck with 2½ oz. of an aniline blue, soluble in spirit, and 2 lb. 3 oz. red liquor at 13° Tw. Work the yarn in this at a boil till the desired shade is obtained, and finally rinse.

(5) *Aniline Blue* (11 lb.).—Boil 2 lb. 3 oz. sumach, or 6⅓ oz. tannin, in water; filter; dissolve 17½ oz. curd-soap in the clear solution, and enter the cotton over night into the hot liquor. Wring out, and make up a beck with acetate of alumina at 3° Tw., to which a clear solution of aniline blue is added according to the shade. Enter the cotton, and dye, raising the temperature to a boil for some time.

(6) *Methylene Blue.*—This colour dyes cotton without a mordant, producing rich blues with a greenish reflection, fast against soap and light. It dissolves readily in water.

(7) *Indigo or Vat Blues.*—Indigo, being insoluble, cannot be applied to textile fibres by the ordinary dyeing processes. It requires to be reduced, to so-called "white indigo," when it becomes soluble, and is in that state deposited on the tissues of yarns, where it rapidly resumes its ordinary blue insoluble condition, and remains permanently fixed in the fibre.

In the case of cotton, the indigo vat is generally "set" in the following method. To about 2000 gal. water, are added 60 lb. indigo, ground to an impalpable powder, 180 lb. slaked lime, and 120 lb. copperas. The lime and the copperas are added from time to time. The lime is put in first, and the vat is well stirred up before adding the copperas. There must be always sufficient lime present to dissolve the white indigo as it is formed. But if too much lime be present, an insoluble compound is formed, which renders the indigo useless for dyeing.

The yarns or pieces are simply steeped in, or rinsed through, the clear liquid of the vat, and then exposed to the air, when the greenish colour which they take at first is soon converted into a blue. The dipping and airing are repeated till the shade is obtained. The goods are then taken through very weak sulphuric acid, thoroughly well washed, and dried.

The vat for dyeing cotton, or any other vegetable fibre, is always worked in the cold.

An improvement in vat dyeing was invented and patented some years ago, by Schutzenberger and

De Lalande. A solution of the bisulphite of soda, at 52°–63° Tw., is placed in a covered vessel, containing zinc-clippings, borings, &c., piled up, so as to fill the tank, without occupying more than a fourth part of its total contents. After 1 hour's contact, the liquid is drawn off into a cistern, containing milk of lime, which decomposes the zinc salts. The clear liquid is then strained off; soda or lime, sufficient to dissolve the indigo, is then added, and it is mixed with the indigo, which must be in perfectly fine powder. At once is produced a yellow solution, containing no soluble impurities, except the earthy matters which were present in the indigo itself. Access of air is avoided as much as possible during this process. In this manner, 2 lb. 3 oz. indigo can be dissolved in 7½–26 pints liquid. The vat is then filled with cold water, if for cotton, and a suitable amount of the indigo solution is added. An excess of the "hydrosulphite" is always present, whence the blue scum, which, in the common process, is formed on the surface by the action of the air on the reduced indigo solution, is almost wholly avoided, the blue indigo being reduced as quickly as formed. The dye-liquor thus resists atmospheric action far better than the ordinary copperas vat; and it is free from the inconvenience of always holding in suspension more or less peroxide of iron, carbonate of lime, &c., which must be allowed to settle before the vat can be used with advantage. By adding to the vat from time to time a little concentrated indigo solution, the strength can be maintained at any required point, and thus any given shade may be communicated by the smallest number of dips; the colours thus obtained are also brighter than those of the old process.

(8) *Prussian Blue* (10 lb.).—Take 1 pint muriate of tin, 4 qts. of nitrate of iron (so-called blue-iron), and 30 gal. of water. Run the cloths or yarns 4 times through, and wash off.

Dissolve 1½ lb. yellow prussiate of potash (potassium ferrocyanide) in 30 gal. water, and add to it ½ pint oil of vitriol (full strength sulphuric acid). Run the piece, or turn the yarns, 4 times, and then raise the colour in a beck of 30 gal. of water, ½ pint nitrate of iron, and ¼ pint oil of vitriol. Wash off, and dry.

Prussian blues are now almost entirely superseded by the coal-tar blues.

Browns: (1) *Fast Brown* (110 lb. cotton yarns).—Dissolve 22 lb. catechu, and 2 lb. 3 oz. blue vitriol (sulphate of copper) in boiling water; steep for 1 hour in the boiling hot liquid; lift, drain, and then dye at a boil in 3 lb. 4 oz. bichromate of potash in fresh water. Rinse, and dry.

(2) *Fast Red Brown* (11 lb.).—Boil 2 lb. 3 oz. good cutch in water; let it settle; dissolve in the clear liquid 3½ oz. blue vitriol. Work the yarns for 1 hour at 100° (212° F.); wring out, and make up a fresh boiling beck with 4½ oz. chromate of potash. Work for ¼ hour, and rinse. Boil 3¼ lb. sumach in water; work the yarn in the liquid for ½ hour at 88° (190° F.); lift; dissolve in the liquid 2¾ oz. tin crystals. Enter again, work for ½ hour, and wring out. Make up a fresh beck with 2 lb. 3 oz. of peachwood, and 8¾ oz. alum, and work in this for 1 hour at 37° (99° F.).

(3) *Dark Brown* (60 lb).—Boil 18 lb. cutch, and 2 lb. blue vitriol, until dissolved. Add this to a hot water; give 3 turns, and let steep all night. Give 1 turn in the morning, and wring up. Dissolve 2 lb. chrome; add this to a hot water; give 3 turns, and wring up. Boil 2 lb. fustic extract and 2 lb. logwood extract, till dissolved; add this to a hot water; give 4 turns, and lift; add 4 qts. copperas, and give 3 turns more. Wash in cold water, and dry.

(4) *Light Blonde Hair Brown*.—Boil 6 lb. cutch, and 6 oz. blue vitriol, till all is dissolved. Add this to a hot water; give the yarn 3 turns; let steep all night; give one turn more in the morning, and wring up. Add 1 lb. alum to a hot water; give three turns, and lift. Boil ½ lb. turmeric and ½ lb. extract of logwood together, and add this to the same liquor. Give four turns; wash in cold water, and dry.

(5) *Bismarck Brown* (100 lb.).—Steep the yarns overnight in a decoction of 20 lb. sumach. Wring, and pass into a boiling bath, containing the colour previously dissolved in boiling water.

For darker shades, pass the cotton from the sumach beck into a cold beck of 6 lb. copperas, and let steep for ½ hour; rinse, and return to the sumach beck for ½ hour, and dye as above.

(6) *Cinnamon Brown* (10 lb.).—Take through a catechu beck, marking 4° Tw., at a heat of about 82° (180° F.); give about 4 turns. Enter into a chrome beck at 1½° Tw.; give 3–4 turns, and wash. Enter into a water containing 30 gal. fustic liquor; give 3–4 turns, run off, and make up a fresh beck with 34 gal. sapan liquor, and ¼ lb. annatto, previously dissolved. Give 3–4 turns; lift; add to the beck 1 gal. alum solution at 8° Tw.; give 3–4 turns; lift, rinse, and dry.

(7) *Madder Brown* (for 10 pieces of 60 yds. each).—Pad the cloth in 6 gal. red liquor and 1 gal. iron liquor, to which about 6 gal. water have been added. Dry, and age for about 24 hours, when it is ready for dyeing. Run the pieces now through boiling water, in which chalk is suspended. Wash in the fly, rinse, and enter into a dye-beck of 40 lb. bark, and 20 lb. madder. Dye for 1 hour at 77° (170° F.); wash, and finish.

Yarns may be dyed in a similar manner.

(8) *Chocolate* (11 lb.).—Work the yarn for ½ hour at 75° (167° F.) in a beck of 8¾ oz. prepared catechu; lift, and take 5–7 times through a fresh beck at the same heat, made up with 1¼ oz. chromate of potash. Lift, and top in a fresh beck with $\frac{1}{10}$ oz. magenta, and 16 gr. extract of indigo.

(9) *Claret* (11 lb. yarns).—Make up a beck with 17¼ oz. prepared catechu, and work the yarns in it for 1 hour. Wring, and steep for ½ hour in a hot beck of 6¼ oz. chromate of potash; take through cold water, and wash for ½ hour in a beck of 3¼ lb. sumach at 88° (190 F.). Dye in a cold beck with 1¾ oz. magenta, lift, add to the beck 8¾ oz. alum and the decoction of 2¼ lb. logwood. Enter again, work in the cold beck; lift, and add, according to shade, from ⅓ to 1¾ oz. chromate of potash; re-enter and work to shade.

DRABS: (1) *Light Drab* (60 lb).—Boil 6 lb. solid extract of peachwood till dissolved; add the solution to a sufficient bulk of warm water; give the yarns 5 turns; lift, and add 1½ pints black liquor (acetate of iron). Give 3 turns more; wash in cold water, and dry.

For a medium shade, the process is similar; but double the quantity of black liquor is taken.

For a dark drab, boil 6 lb. cutch till dissolved; add to hot water, and work the yarns in it 5 turns. Run off the liquid, and wring out the yarns. Dissolve 1⅓ lb. peachwood extract; add this to a warm water; work 5 turns; lift, and add 1 qt. of black liquor; give 3 more turns; wash, and dry.

If a yellower shade is wanted, a little fustic is boiled along with the peachwood; if redder, a little alum is used with the peachwood; and if browner, a little Bismarck brown.

The shades produced may also be varied by topping with aniline colours in small quantities.

(2) *Silver Drab* (60 lb.).—Dissolve 2 oz. logwood extract; add the solution to a warm water; give the yarns 10 turns; lift, and add ½ pint black liquor (acetate of iron), and give 4 turns more. Wash in cold water, and dry.

GREENS: (1) *Methyl Green* (11 lb.).—Dissolve in boiling water 7$\frac{1}{10}$ oz. tannin; lay the bleached cotton overnight in the hot solution; wring out; dye in cold water with a solution of the colour according to shade. Wring out, and dry *in the dark*, without washing.

(2) Or (22 lb.).—For lighter shades, bleach well, and work in warm soap-beck, to remove chlorine. Enter into a boiling lye of curd-soap, and wash out in cold water. Make up a cold dye-beck with 3 parts colour to every 100 parts cotton; give 5–6 turns, and let steep overnight, Dry the next morning. If the shade is not full enough, take through the tannin beck, and dye again to shade. For yellower tones, dye the cotton first a yellow, with fustic and alum, and then dye cold with the green. It must be remembered that this colour is turned to a violet shade by heat.

(3) *Malachite Green*.—This can be dyed in the same manner as methyl-green; but it is not sensitive to heat, and admits, if required, of the presence of small quantities of acids.

(4) *Cæruléine*.—This colour dyes dark-green shades, though its name would lead us to expect sky-blues. For dyeing cotton, 2 lb. 3 oz. of the colour should be stirred up with twice its weight of bisulphite of soda at about 78° Tw.; the mixture may stand for some hours before it is added to the dye-beck.

The cotton-yarns to be dyed are mordanted by passing alternately through chromate of potash and bisulphite of soda. The necessary quantity of colour, according to the shade required, is then added to cold water; the yarn is entered, and the heat is gradually raised to a boil. The shades obtained bear soaping, and exposure to air, as well as do the alizarine colours.

(5) *Another Dark Green* (50 lb.).—Steep for 6 hours in a decoction of 10 lb. sumach; wring, and enter into a fresh cold beck, made up of 3 lb. alum, 9 oz. methyl-green of a bluish shade, and 2 pails fustic liquor. Turn quickly, raising the temperature to 66° (150° F.); when the dye is exhausted, dissolve 3–4 oz. copperas in the same liquor, and give 3–4 turns, to sadden.

(6) *Ordinary Greens* (100 lb. yarn).—Dissolve 10 lb. nitrate of iron, and 1 lb. tin crystals; work the yarn in this solution, cold; give 5 turns, and wring. In another beck, dissolve 6 lb. yellow prussiate; give the yarn 5 turns in the cold solution; wring, and pass back into the nitrate of iron, and thence back into the prussiate beck, to which 2 lb. alum have been added; give 3 turns in each, and rinse.

Boil 40 lb. bark for 1 hour, strain into a tub, add 1 lb. sugar of lead well dissolved; when all is well mixed, enter the yarn at 82° (180° F.), and work for ½ hour; lift, wring, and pass through another beck, containing 2 lb. alum, and 2 lb. indigo paste. Rinse, and dry.

(7) Or,—Boil 25 lb. fustic in a bag, and add to the liquor 2½ lb. verdigris, previously dissolved in vinegar and hot water; cool the dye; enter the yarn, which has been prepared overnight in a decoction of sumach; handle it well, and heat up to a boil, working for ½ hour. Cool it, and enter it into another beck, containing a decoction of 10 lb. logwood. Heat up to a boil, and work for ½ hour; take out, rinse, and dry.

If blue vitriol is used instead of verdigris, an olive-green is obtained.

(8) *Chrome Green*.—Give the yarn a blue bottom in the vat; take through dilute sulphuric acid, and wash very well. Take through sugar of lead solution at 6° Tw., then through caustic soda lye at 2°–3° Tw., and wash off. Enter into bichromate bath at 2° Tw. Each operation requires 5–6 turns. Wash off, and dry.

GREYS: (1) *Light Grey* (11 lb. yarn).—Boil 4½ oz. sumach in 87 pints water; in this, steep the yarn for 1 hour, turning frequently; lift, and add to the beck a decoction of 4½ oz. copperas; stir;

re-enter, give 5 turns, steep for 15 minutes, and give another turn; let steep again, and turn once more; lift, and take through water. Wring out, and dry.

(2) *Medium Mode Grey* (11 lb.)—Add to 44 qts. water at 38° (100° F.) a decoction of 17¼ oz. sumach, 8¾ oz. logwood, and 4¾ oz. prepared catechu. Steep for 1 hour. Add 4¾ oz. nitrate of iron at 75° Tw.; re-enter, give 10 turns, and enter into fresh water at 38° (100° F.). with 2½ oz. chromate of potash.

(3) *Light Grey on Cotton Pieces* (60 lb.).—Boil 1½ lb. solid extract of logwood, and ½ lb. extract of bark, in sufficient water. Run the pieces 6–8 times through; press; and take through a fresh beck of 5 lb. copperas; rinse; and calender out of the following mixture:—45 lb. of farina, 3 lb. wax, 6 lb. coco-nut oil, boiled to a stiff paste. Press, and dry.

(4) *Fast Grey* (22 lb.).—1st operation: 35 fl. oz. olive oil, and 2 lb. 3 oz. soda crystals. Work in this mixture at a boil for 30 minutes; wring, and dry. 2nd operation: Grind 44 lb. coal very fine; add 22 lb. soda crystals, and 17½ pints water at a boil. Mix the whole very well, and let steep for some hours. Then boil for ½ hour in 15 times the quantity of water; strain; and work the cotton in the hot liquid for ¼ hour, airing well; pass 5 times through the same liquid, and wring each time. Wash, first in luke-warm water, then in cold water; wring, and dry. 3rd operation: The dry cotton is passed into weak size, to which a little emulsive oil has been added. Wring, and dry. This grey resists soap, acids, and chloride of lime.

(5) *Grey, Stone-shade* (25 lb.).—Boil 25 lb. sumach, and 1 lb. fustic; enter the yarns into the decoction, to which a sufficient quantity of water has been added; give 5 turns; wring; and enter into a cold beck, with a solution of 1 lb. copperas (protosulphate of iron, or ferrous sulphate), and ¾ lb. blue-stone (copper sulphate). Give 5 turns, rinse, and dry.

(6) *Medium Olive* (11 lb.).—Extract 8¾ oz. sumach in boiling water; enter the yarn into the clear liquid; let steep, and make up a fresh beck, with the same weight of copperas. Wring out the yarn and enter into this second beck, working for ¼ hour. Wring, and enter into a fresh beck of red liquor at 1½° Tw. Give 12 turns; heat to 62° (144° F.); wring out; and work for ½ hour in a decoction of quercitron bark.

Oranges: (1) *Full Lead Orange* (60 lb.).—Boil 12 lb. sugar of lead in 12 gal. clear lime-water, till dissolved; add this to enough cold water. Work yarns 5 turns, and wring. Dissolve 4 lb. bichromate of potash, and add this to cold water. Work yarns 5 turns, and wring. Repeat this process twice in the cold liquors, wringing after each time. Get a clear lime-water up to the boil, and give the yarns 5 turns in it, working very quickly. It is very important that the lime-water should be boiling, to keep the yarns level. Wash off in warm water with a little soap, and dry.

This colour, like all others in which lead is an ingredient, will be darkened and spoiled, if exposed to fumes of sulphuretted hydrogen.

(2) *Annatto Orange* (60 lb.).—Boil 6 lb. concentrated annatto with 2 lb. soap, and 2 lb. common soda, till completely dissolved; add this to boiling water. Work the yarns 5 turns; wash in cold water, and dry.

This colour may be modified by topping with small quantities of magenta, &c.

(3) *Aniline Orange* (60 lb.).—Boil 3 lb. tannic acid, and add the solution to warm water. Work the yarns 5 turns, and wring. Add 3 qts. nitro-muriate of tin to enough cold water, and mordant in the mixture. Wash well in cold water, with a little soap in the last water. Dissolve 12 oz. aniline orange, and add the solution to warm water. Give 5 turns, wash, and stove-dry.

(4) *Purple* (10 lb.).—Prepare in stannate of soda at 10° Tw.; pass in dilute sulphuric acid at 2° Tw.; and give 2 washings in clear cold water. Fill up a tub with 30 gal. logwood liquor; give 4–5 turns; lift; and add 4 qts. alum solution, and ½ pint double muriate of tin; re-enter, and give 3–4 more turns. Wash off; and prepare another beck with 30 gal. logwood liquor, and 10 gal. peach- or sapan-wood liquor; re-enter, and give 3–4 turns; add ½ pint purple spirit, and 4 qts. alum-water. Give 5–6 turns; wash, and dry.

Reds: (1) *Eosine Reds.*—These shades range from a cherry-red to a true rose, and have not the violet cast of magenta.

For a more bluish shade, steep in a bath of curd-soap at 62° (144° F.); work for ½ hour; rinse; and work for the same length of time in subacetate of lead (basic sugar of lead) at 4° Tw. Rinse, and dye in a bath of eosine at 62° (144° F.). Soft-soap must be used throughout the process. If yellower tones are required, alum is added to the sugar of lead beck, more or less, according to the shade intended.

Eosine is also sometimes fixed upon cotton by mordanting in red liquor, and then passing through water in which chalk is suspended, when hydrate of alumina is deposited on the fibre.

(2) *Rose Bengale.*—This beautiful colour is fixed upon cotton as follows:—Work the yarns for 1 hour in water, to which has been added 5 per cent. of the emulsive oil used for Turkey-red dyeing. Dry; steep for 2 hours in cold red liquor at 3° Tw.; and enter into the colour-bath, which should contain ½ oz. of the dye, and ¾ oz. of the red liquor, to every 2 lb. 3 oz. of cotton. Work for an hour at 44°–60° (112°–140° F.).

The red liquor in question is made by dissolving 3½ oz. alum in 17½ oz. water, and adding 1⅞ of acetate of lime, previously dissolved in the same bulk of water. It is allowed to settle; the clear is drawn off, and set at 3° Tw.

(3) *Coralline Red* (11 lb. yarn).—Make up a hot beck with a decoction of 2 lb. 3 oz. turmeric. Work for ¼ hour; take out, and rinse in cold water; prepare another beck with 1¾ oz. soap, and 3½ oz. olive oil, the heat being 30° (86° F.); work the yarn in this for ¼ hour, and wring. Then dye in a cold solution of soluble red coralline, to which a trace of acetic acid has been added. The quantity of acid is greater or less, as a more or less yellowish shade is required.

(4) Or,—Boil in water 4½ oz. white starch, and the same weight of white glue. Enter the cotton in this at 30° (86° F.); work for ½ hour; rinse, and dye in a coralline beck at 30° (86° F.), as already described.

(5) *Coralline and Aurine* (11 lb.).—Aurine dyes shades more inclining to orange than coralline. Boil 2 lb. 3 oz. sumach, or 6⅙ oz. tannin, in water, and soak the tannin all night in the clear hot liquid. Wring out next morning, and enter into a fresh beck of 17½ oz. good glue at 50° (122° F.). Wring out, and dye to shade in a cold solution of coralline. Wring again, and dry, without rinsing, in a room where the air is impregnated with ammonia.

The cotton, if desired, may be grounded with turmeric and annatto, and merely topped with aurine.

(6) *Galleine.*—Galleine dyes deep and very solid reds. The yarns are mordanted in chrome alum, or by alternate passages through chromate of potash and bisulphite of soda. The requisite quantity of galleine is then placed in a bag, and suspended in a beck of cold water; the yarn is entered, and the heat is gradually raised to 100° (212° F.). The goods are then taken out, and the colour is developed by hot soaping.

Colours derived from resorcine, such as the eosines, phloxine, &c., may be fixed in the following manner:—The yarns are soaped hot with curd-soap for 1 hour, and wrung without rinsing. A solution is then made of 8¾ oz. alum in 35 fl. oz. water, and diluted to 17½ pints; 1¾ oz. soda crystals are then added; the whole is allowed to settle, and the clear is drawn off. The cotton is steeped in this liquid, and kept at a boil for 10–12 hours; it is then passed into a bath containing 17½ pints water, and 6¾–10½ oz. emulsive oil, such as is used in Turkey-red dyeing. Before the oil is added to the bath, it should be very well shaken up with 35 fl. oz. water. The cotton is steeped in this liquid for 1 hour; then wrung, and dried.

The dye-beck is then made up as follows:—Pure water, such as condensed steam-water, 17½ pints; red liquor at 7° Tw., 7 fl. oz.; and the needful amount of colour. The dyeing is begun at 50° (122° F.), and the beck is gradually raised to 88° (190° F.). The goods are allowed to steep till the bath is exhausted; then wrung without rinsing, and dried.

The red liquor is prepared by dissolving 4½ oz. alum in 8¾ fl. oz. boiling water, and adding a solution of 3¾ oz. sugar of lead in an equal bulk of water. The two solutions are mixed, allowed to settle, and strained; the clear liquid is set at 7° Tw.

(7) *Scarlet on Cotton* (100 lb.).—Steep overnight in a decoction of 40 lb. sumach. Lift, and wring; enter in a bath of oxy-muriate of antimony at 3° Tw. Give 3 turns quickly; steep for ¾ hour, turning occasionally. Lift, wash well, wring, and enter into a colour-beck made up with 10 oz. "extra scarlet" (of Sehlbach & Co.), and dye to shade at 43° (110° F.).

(8) *Saffranine Scarlet* (60 lb. yarn).—Boil 10 lb. sumach; enter yarns; give 6 turns; let soak for 1 hour, and wring. Enter into a fresh cold beck of nitro-muriate of tin at 2° Tw.; give 6 turns; wash, first in warm, and then in cold water; wring well, and enter into a beck of 10 lb. turmeric. Finally, make up a beck with ½ lb. saffranine; enter yarns at 10° (50° F.), and raise the temperature to 49° (120° F.), turning continually. Wring, and dry.

(9) *Pink* (50 lb. yarn).—Dissolve 5 lb. Glauber salts, and 4½ oz. "erysine" (of the Berlin Aktien Gesellschaft). Enter yarn at 54° (120° F.); give 5 turns quickly, and dye to shade, gradually raising the temperature to 60° (140° F.).

To ensure even shades, it is better to add only half the erysine at first; and the rest, previously dissolved, by degrees.

(10) *Magenta Ponceau* (10 lb.).—Boil 2 lb. turmeric, strain, and steep the cotton in the liquid for 4–5 hours. Wring, and take through cold sours, containing about 10 oz. muriatic acid, and rinse well, and handle for 10 minutes in lukewarm water, containing 10 oz. starch, which has been boiled up to a paste with 1 oz. glue. Lastly, dye to shade in a fresh magenta beck.

Magenta ponceaus and scarlets, even if the yellowest shades of the dye are taken, are never so satisfactory as those got up with eosine, saffranine, and other coal-tar colours, free from the violet tone of magenta.

(11) *Alizarine Red.*—Mordant in cold red liquor at 7° Tw. for 2 hours, with frequent turning. Lift, wring, and air for 24 hours. Enter into a fresh beck, and dye at 100° (212° F.) with a solution of artificial alizarine.

(12) *Cochineal Scarlet* (10 lb.).—Boil 1 lb. annatto in a solution of 10 oz. potash for 20 minutes;

cool a little; enter the cotton, work for 1 hour, lift, wring, and wash. Enter for ½ hour in a beck of permuriate of tin, marking 8° Tw., to which 2 oz. tin crystals have been further added; lift, wring, and dye in a decoction of 1¼ lb. cochineal, beginning at a hand-heat, and gradually raising the temperature.

(13) *Saffranine Rose* (11 lb.).—Mordant with a decoction of 2 lb. 3 oz. sumach, or a correspondingly smaller quantity of pure tannin, which is preferable. Dye in a clear solution of saffranine. If a shade verging towards a bluish-red is required, add to the sumach beck, before mordanting, 1¾–2¼ oz. tin crystals. Saffranine may also be fixed on cotton by means of red liquor, or soap.

(14) *Safflower Pink* (60 lb. bleached yarn).—Add 1½ pint carthamine (extract of safflower) to the needful quantity of water. Work the yarns for 5 hours, giving a turn every ½ hour, and keep them in the liquid till all the colour is taken up. Wash off in three cold waters, adding 1 lb. cream of tartar to the last. Then dry, preferably by means of a current of cold air in the dark.

(15) *Safflower Rose* (60 lb.).—Work as above, but use double the quantity of carthamine, and take a longer time.

(16) *Common Scarlet* (60 lb.).—Boil 6 lb. sumach, and add decoction to hot water. Work yarns 5 turns, and wring; mordant in a tin solution (red cotton spirits). Wash in two waters, and wring up. Boil 18 lb. peachwood, and 18 lb. fustic, ground, and add the decoction to hot water. Work the yarns 10 turns, and raise with 1 lb. alum. Wash in cold water, and stove.

For lighter shades, the sumach may be dispensed with, and turmeric may be used in place of fustic.

(17) *Barwood Red* (10 lb.).—Steep for 5–6 hours in a decoction of 2 lb. sumach, to which a very little sulphuric acid has been added, turning from time to time. Wring out, and work in barwood spirits at 2° Tw. Wring, and enter into a beck of water at 93° (200° F.), containing 10 lb. rasped barwood; and work to shade at a boil.

(18) *Turkey-red, with Artificial Alizarine.*—The pieces are twice treated with soda-ash, 1⅝ oz. soda-ash a piece, each time for 18 hours; wring. Pad in oil at 71° (160° F.); hang up for 4 hours at 76° (169° F.). In padding, the lower roller should be dressed, and the upper not. Pad 5 times in the same oil bath, with both rollers dressed. After each padding, hang up at 76° (169° F.). Pad in potash lye at 6° Tw. at 32° (90° F.). Pad in potash at 8° Tw., same heat. Pad in potash at 5° Tw., same heat. Pad in potash at 3° Tw., same heat. After each padding, hang up at 71° (160° F.). Pass through potash at 4° Tw., heated to 42° (107° F.).

Extract the liquor, and take care that the pieces do not touch cold water. Hang up for 4 hours at 71° (160° F.). Pass into the following beck at 50° (122° F.):—Water, 2625 pints; potash, 17¼ oz. Wash, and dry. Formerly, when the subsequent dyeing was performed with madder-root, there followed here the "galling" process,—a treatment with tannin, which is no longer required, since artificial alizarine has come into use. The pieces are passed at once to the alum-bath, which is thus made up:—To 110 lb. crystallized alum, take 33 lb. soda crystals, and mix the solutions in water, stirring diligently. The clear liquid is finally set at 6½°–7° Tw. The cotton is mordanted in this liquid for a day, and is then carefully washed, and wrung out, and is now ready for the dye-beck. To 110 lb. cotton, are taken alizarine at (10 per cent.) about 14 lb. 6 oz., and of pure tannin 17¼ oz. Raise very slowly to a boil during 2 hours, and keep up the boiling heat for another hour.

The "cleaning process" (*avivage*), a treatment with soap and tin crystals, is not required, when working with good artificial alizarine. The cotton is at once bloomed with curd-soap, and a little annatto.

It is to be remarked that, if the water contains no lime, 3½ oz. of chalk should be added to the dye-beck for the above quantity of cotton.

The oiling process is considerably simplified and abridged, by replacing the ordinary emulsive oil with the compound invented by Dr. Müller-Jacobs,—a mixture of sulpho-ricinic and sulpho-pyroterebic acids, in combination with ammonia. A single passage through this mordant supersedes the five successive oilings formerly employed. A small quantity of the compound is recommended to be added to the dye-beck.

Violets: (1) *Gentiana Violet* (11 lb.).—Boil 2 lb. 3 oz. sumach, or 6⅙ oz. tannin, in water, and steep the yarns overnight in the clear solution. Wring up next morning, and dye in a beck at 74° (165° F.), containing 9 oz. gum arabic, adding more or less of the dissolved colour according to shade. Wring, and dry.

(2) Or,—Make up a beck at 50° (122° F.) with 80 gr. tannin for each 2 lb. 3 oz. cotton, and turn well for 4–5 hours. Wring, and enter into the colour-beck at 43° (110° F.), adding 775 gr. acetic acid for 11 lb. cotton. Wring, and dry.

(3) *Medium Violet* (100 lb.).—Mordant yarns in stannate of soda at 8° Tw.; sour at 1½° Tw. with dilute sulphuric acid; wash off with cold water, and dye with ¼ lb. aniline violet according to shade. Heat up to about 71° (160° F.).

Yellows: (1) *Yellow* (11 lb.).—Dilute red liquor to 6½° Tw., and steep the clear yarns overnight in the cold. Extract 4 lb. 6 oz. quercitron bark in boiling water, let cool down to 75°

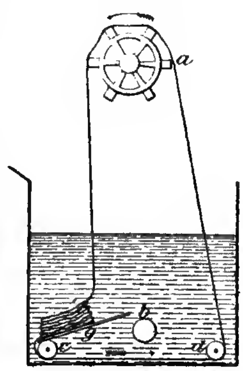
167° F.), and dye the yarns to shade. If a brighter shade is desired, add to the bark liquor 1¾ oz. tin crystals.

(2) *Fast Yellow* (60 lb.).—Boil 6 lb. brown sugar of lead in 6 gal. water till dissolved; add this solution to sufficient cold water. Work the yarns 5 turns, and wring. Dissolve 2 lb. bichromate of potash, and add it to sufficient cold water. Work yarn 5 turns, wash twice in cold water, and dry.

Mechanical Appliances.—The mechanical appliances used in dyeing vary very much, according to the class of the material and the scale of the operations. Unspun wool and rags are simply laid in the dye-becks, and turned as may be required with the dyer's pole. Yarns and woven goods on the small scale are dipped and turned in the dyeing-baths by hand, the yarns being generally supported on sticks, passed through the hank, and resting upon the tub, vat, or cistern. On the large scale, the goods are turned by machinery. In piece-dyeing, very great use is made of the padding machine, a kind of trough or cistern, fitted with rollers both above and below the surface of the liquid, over which the pieces pass with a regular speed, the dye being thus squeezed into the fibre,—an arrangement which greatly facilitates the regular deposition of the colour. These machines are especially used for mordanting cotton piece-goods, and for applying such colours as are worked in the cold. For dyes which require a high, and especially a boiling, heat, the dye-pans are fitted with winches, either fixed or movable, and generally capable of being turned by power. The piece, being rolled up on a wooden roller, is allowed to uncoil itself, and gradually descend into the liquid. When it is run out, the motion is reversed, and so on till the piece is dyed up to shade. In piece dyeing, great rapidity and regularity of motion are of the first importance, especially at the beginning of the operation; with dyes which have a strong affinity for the fibre, a slow movement allows some parts of the cloth to absorb too much of the colours, and a stoppage often leaves a line across the piece, corresponding with the surface of the liquid—the point at which action is greatest.

Fig. 583 will convey an idea of a dye-beck fitted with rollers:—*a* is a reel, having long wooden spans on its circumference, and being set in motion by a driving-shaft. Steam is admitted, if required, by the perforated pipe *b*. The pieces of cotton, stitched together at their ends, pass over the reel in the direction of the arrows, and fall on a sloping ledge *g*, on one side of the beck, whence they pass under the rollers *c d*. Its general dimensions are 6 ft. in length, 4 ft. in width, and 4 ft. in depth.

583.



The material of the pans, &c., in which dyeing is carried on, is of great importance. According to the colour used, the vessels may be of wood, iron, block-tin, slate, sandstone, &c. They must be selected so as to be incapable of yielding to the dye-bath any substance that could interfere with the process. Thus an iron pan or beck should on no account be used for dyeing any bright or light colour, especially if acid mordants or dyes are present. The most scrupulous cleanliness—one might say chemical cleanliness—is an essential in successful dyeing. Wherever it is possible, the same becks, pans, &c., should be reserved for the same class of colour.

The selection of the water used in dyeing is also of great importance. As a rule, the nearer it approaches to distilled water, the better. For many delicate aniline and grain colours, condensed steam-water, free from grease, should be employed. The woollen yarn dyers of Berlin, and the calico-printers of Alsace, are indebted to the character of the water at their command for no small part of their success. To this rule, there are two exceptions: madder and its derivatives require the presence in the dye-water of a certain quantity of lime, which is easily supplied by adding ground chalk, or acetate of lime; blacks and other sad colours may also be more economically dyed with hard waters, such as those from deep artesian wells.

The heat required in dyeing may be produced either by open fires beneath the pans, or by steam, applied either in a steam-jacket, in the form of coils of steam-pipe, or by blowing steam direct into the liquid.

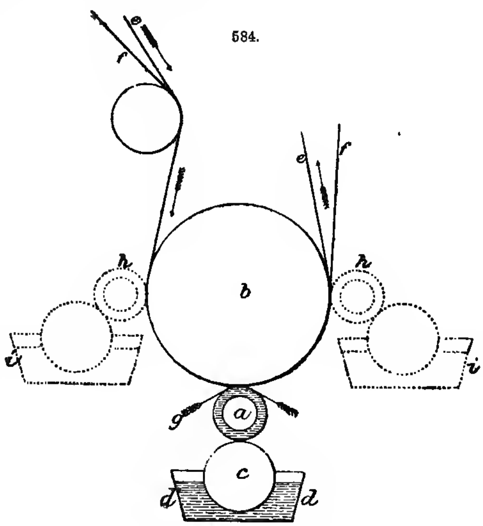
Calico-Printing.—This art differs from dyeing, both in its object and its means. The purpose of the printer being to produce upon pieces regular designs in two or more colours, he is compelled to limit the action of his materials to particular portions of the surface to be thus ornamented. Hence his colours are not liquids, but pastes, or pulps; and they are applied to those parts of the cloth, where they are to take effect, by a stamping process, performed either by hand or by machinery. These conditions involve no small difficulty; the dyer can and does "work to shade," adding, as circumstances may require, a little more of his ingredients, or prolonging the action. But the printer has no opportunity of modifying his materials after they are once brought into contact with the fibre.

The foremost peculiarity of the printer's colours, mordants, or mixtures of both, as distinguished from those of the dyer, is that they require to be thickened. For this purpose, a great variety of materials are used:—flour, starch, whether of grain or of the potato; natural gums, such as arabic, senegal, and tragacanth; and artificial gums, such as dextrine, which, in its various modifications, is known as British gum, calcined starch, leiocome, gomeline, &c. There are also mineral bodies occasionally employed for this purpose, such as China-clay, and siliceous earth. These various substances are not all equally fitted for all purposes. No small part of the art of the printer lies in the skilful selection of a right thickener. The properties of the chemicals present, the actions to which the mixture has to be exposed, the character of the design, and the manner of printing, whether by hand or by machine, have to be duly taken into account. For machine work, much smoother and finer thickeners are required than for block work, even the presence of grit in the gum or starch being a serious inconvenience. Sometimes one of the ingredients in a colour—an acid or an acid salt—is not added till the mixture has become cold, lest at a high temperature it might convert a portion of the starch into glucose, and thus greatly modify the expected reaction. The thickening power of these bodies differs greatly, 10–12 oz. gum tragacanth per gal. being as effective as 20 oz. starch, 22 oz. flour, or 8–9 lb. calcined farina. The larger the quantity of thickening employed, the lighter, generally speaking, will be the resulting colour. As a rule, the more the colours, by judicious thickening, can be kept upon the face of the cloth, and prevented from sinking in, the brighter will be the colour, the clearer the design, and the more economical the working.

In the earlier days of the art, printing was exclusively performed by hand, with wooden blocks, upon which the designs were produced in relief, by cutting away portions of the wood, and letting in slips of sheet copper. This method of printing is still found exceedingly useful for the production of particular effects, though for general work it is quite superseded by the swifter and more economical cylinder-machine.

Fig. 584 shows the general principle of the printing-machine: *a* is the roller, on which the pattern is engraved; it is mounted so as to revolve against two other cylinders *b c*. The latter is covered with woollen cloth, and, as it revolves, it dips into the trough *d*, containing the colour properly mixed. Some of the colour thus taken up is transferred to the pattern-roller *a*. The other cylinder or drum *b* is of iron, covered with several folds of woollen cloth or felt, to give an elastic surface. Round the drum, travels an endless web of blanketing *e*, in the direction of the arrows, and over this, so as to come into direct contact with the roller *a*, passes the piece to be printed *f*.

584.



To prevent *a* taking up superfluous colour, it is scraped as it revolves by a sharp plate of steel, or alloy of nickel, called the "colour-doctor," *g*; on the opposite side, is a similar plate, the "lint-doctor," to remove any loose fibres from the roller. The rollers *h* and troughs *i*, shown in dotted lines, represent the arrangements required if more than one colour has to be printed upon the cloth.

A four-colour machine is seen in end elevation in Fig. 585, and in section in Fig. 586. A is the cast-metal frame-work, bolted down by the bolts B; C is the drum, about 2 ft. in diameter, and 3–4 ft. in length, according to the kind of cloth to be printed; D are the copper pattern-rollers, of the width of the piece; E are mandrels, on which the roller is forced by a screw-press, about 4 in. in diameter where the roller is fixed, but the journals are narrower. Within the roller, is a projecting piece or "tab," extending all the width, and fitting into a slot cut in the mandrel, to prevent slipping. The bowl or pressure-cylinder C rests with its gudgeons in bearings or bushes, which can be moved up or down in slots in the side-cheeks A; these bushes are fixed by strong screws F, turning in nuts screwed to A, to counteract the pressure of the two lowest rollers. The sliding pieces G support the bearings of the mandrels, colour-boxes, and doctors, and move in arms of the frame-work, by means of screws H, working in female screws I, and forming a portion of the set of jointed levers K. They give further pressure to the rollers D. The two uppermost rollers press against the cylinder by the levers K, which are joined to the frame-work at *f*, and to the

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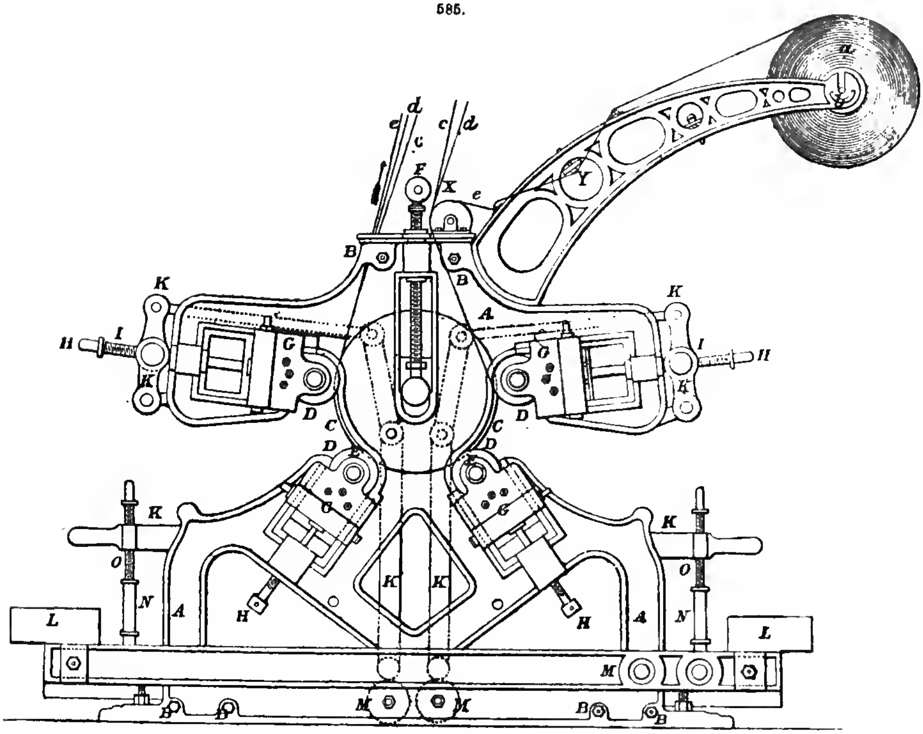
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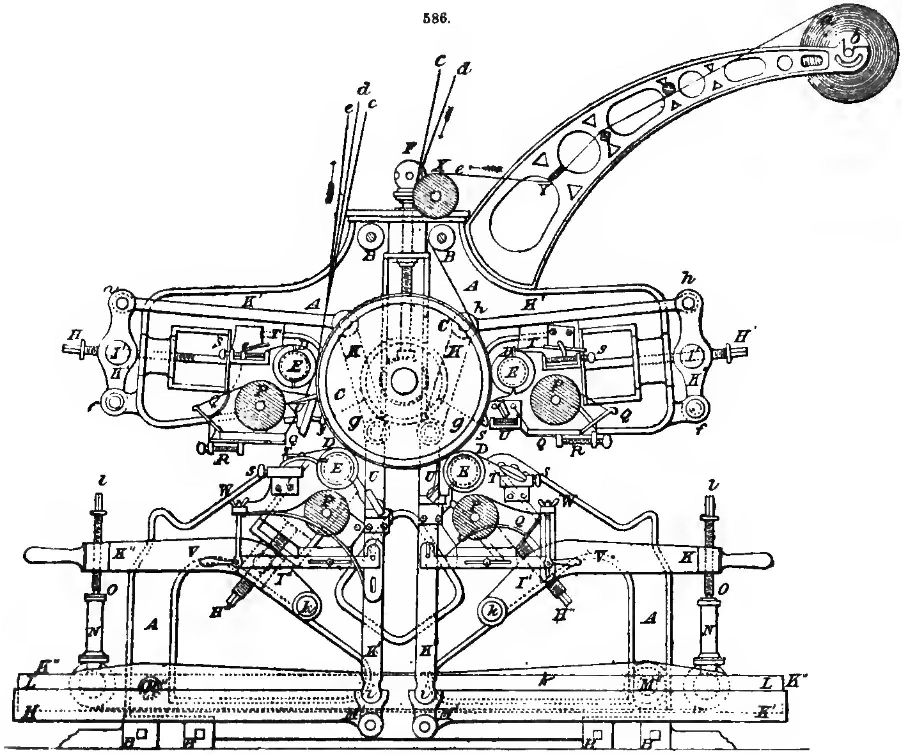
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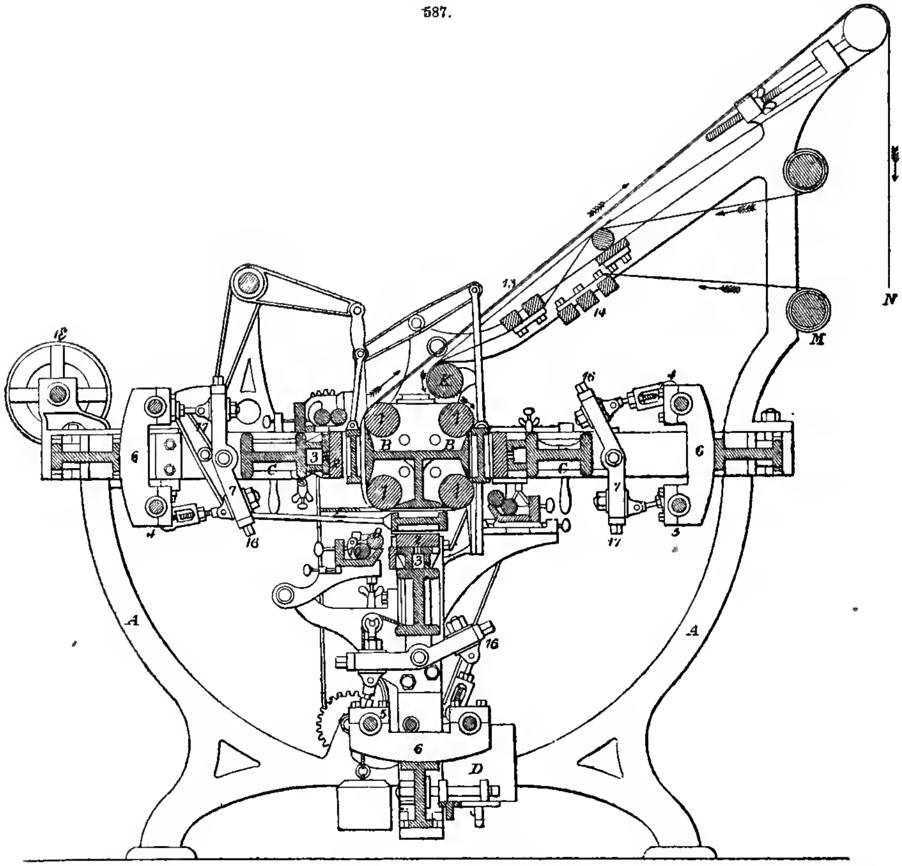
inside of the main frame g and M, as fulcrums, and are jointed together at h. The bent levers $h\ g\ i$ fit into the sockets i of the horizontal levers M K, loaded with movable weights at K. The two lower rollers are pressed against the cylinder in an analogous manner.

The perrotine may be described as a machine for doing a style of work almost the same as block printing. It works three wooden blocks, each 2–5 in. in width, and varying in length according to the width of the piece. Upon these blocks, the pattern is engraved. They can be mechanically brought down upon the front, top, and back of a four-sided iron beam, faced with cloth, over which the pieces travel. The perrotine produces effects in three colours, which could not be obtained in hand-printing, without blocking the pieces three times over. It even executes some styles of work which the cylinder-machine cannot perform without the aid of the "surface-roller."

This latter machine, which has been developed in Scotland and England to work with only a man and two boys in attendance, does as much work as 200 men and boys could complete by hand-printing, and has been constructed to perfect at once patterns of 12, and even 20, colours.

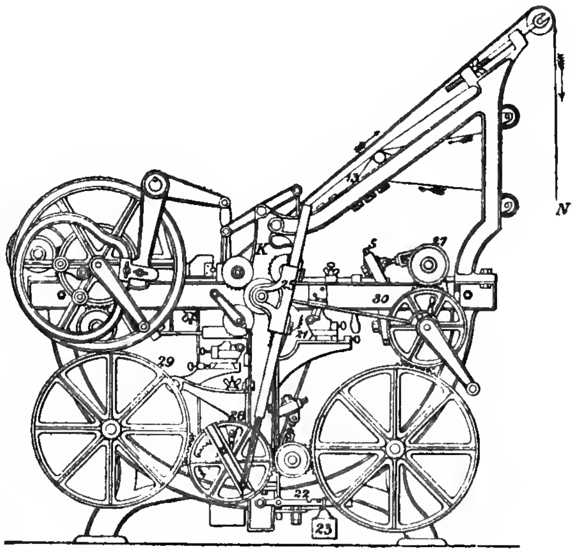
The perrotine is shown in a vertical section in Fig. 587, and in elevation in Fig. 588: A represents the cast-iron frame-work; B, cast-iron tables, planed smooth, over which revolve the

587.



blanket, the back-cloth, and the piece to be printed; C, sliding pieces, to which are screwed the block-holders 3, and causing the engraved blocks 2, to move alternately against the woollen surface where they receive the colours and the goods to be printed, by the action of the arms 4, 5, whose supports 6, rest on the frame A, and act on the beams 7, keyed to the slides c. The lower of these slides, being in a vertical position, takes by its own weight a retrograde movement, regulated by a counter-weight. E are movable colour-sieves, keyed to connecting-rods, and receiving from the power applied to the machine the kind of movement which they require. These sieves, which are flat, and covered with cloth on the surface opposite to the blocks, slide in grooves on the sides of the tables, and receive from the furnished rollers the colours which they afterwards transmit to the blocks. F are troughs, filled with colour, and each furnished with rollers 8 10, the last of which, dipping into the troughs, are charged with colour, which they communicate to the rollers 8, covered with woollen tissue, and these again transfer the colour to the sieves E, where it is spread by the fixed brushes 9. To vary at will the quantity of colour supplied, the rollers 10 are connected with levers 11, which, by means of adjusting screws, bring them into contact more or less close with the rollers 8, and thus regulate the charge of colour. The blanket, back-cloth, and pieces are made to travel thus: at the four angles formed by the three tables B, are rollers 1, fitted on their surfaces with needle-points, to prevent the pieces from slipping as they pass on, and thus to secure the regular progress of the goods, which is determined by the toothed wheels 21, fixed at the extremities of the axles of the rollers. G is a roller for stretching the endless web, resting with the ends of its axle on two cushions, forming the extremities of the screws 12, by which the roller can be pushed further out if needed, to give the required tension; H is another tension-roller, supporting the blanket and back-cloth. K is a roller which serves similar purposes for the blanket, the back-cloth, and the tissue being printed; T, the blanket, which passes over the semi-circumference of the roller G, passes over H, and behind K, to circulate around the cylinder I, and the surface of the table B; L is a cylinder, from which the back-cloth is unwound, after being stretched by H, and smoothed by bars 13, whence it joins the blanket at K; M is a roller, from which the pieces are unwound by the movement of the machine, passing over the scrimping-bars 14, and joining the blanket and back-cloth at K, which it accompanies as far as the roller G, when it passes off, in the direction of N, to the hanging-rollers, where it is dried.

588.



The manner of running a machine is in brief as follows:—The pieces, stitched end to end in lots of 40, are wound on a wooden roller, arranged for the purpose; and a few yards of common coarse cloth, kept for the purpose, are attached at the first end, upon which the printer adjusts his pattern. Behind the machine, stands a boy, who guides the cloth evenly, and removes any loose threads. The printer has his stand in front, attending to the colour-boxes, one of which supplies each roller. After every 30–40 pieces have been worked off, the machine is stopped, in order that the "doctors"—blades which press against each cylinder, and remove all superfluous colour—be examined, and their edges sharpened with a file, if needful.

589.

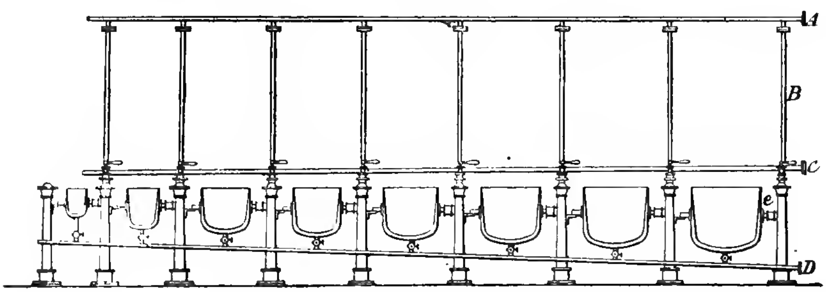
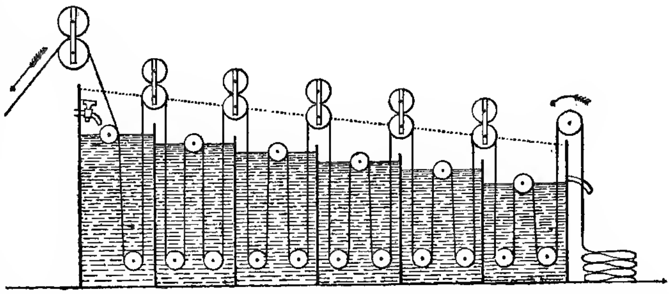


Fig. 589 shows a range of colour-pans, as made by Storey, of Manchester. The set consists of 8 cased copper pans, ranging in contents from 1 to 28 gal. Each can be turned over for emptying, as a brass stuffing-box is fixed to each pan and to the pillars; A is a copper pipe, by means of which steam can be admitted down the pillars, as far as the stuffing-boxes, and thus into the casing of each pan, and out at the condensing pipe D if needful; C is a copper pipe for the admission of cold water into any pan.

Fig. 590 shows a longitudinal section of a rinsing-machine. It consists of a wooden cistern, 20–30 ft. long, 3 ft. wide, 4 ft. high at one end, and 3 ft. at the other, and divided transversely into compartments, by water-tight partitions, which gradually decrease in height from the higher to the lower end of the cistern. The pieces of cloth are passed through in the direction of the arrows, and, on leaving each compartment, pass between a pair of squeezing-rollers, placed above, before descending into the next compartment.

590.



There are several main styles or classes into which calico-printing is conventionally divided, according to the effects aimed at, and the means taken for their production. This classification was never very accurate, and is now less trustworthy than ever, since multitudes of patterns are produced by a combination of two or more of these styles.

Madder Colours.—This style has for a long time held the first place, and will probably maintain it, though the effects are no longer obtained with madder-root, but with artificial alizarine and anthrapurpurine. On the Continent, it is generally characterized as "dyeing mordants," or "dyeing upon mordants,"—a preferable name, since the essence of the style is that merely mordants, duly thickened, are printed upon the pieces. The cloth is then worked in a dye-beck, formerly with madder,—as if the object were to produce a uniform colour. As, however, the mordants have been applied to certain parts of the surface only, the colour attaches itself to these alone, producing the design. The colours thus obtained are then cleared or brightened, and the white ground is freed from all traces of colour.

The subjoined are some of the more important of the mordants (here called by the misleading name of colours) printed on for the production of special effects in the madder style :—

Purple Fixing Liquor.—(*a*) Water, 7½ gal.; acetic acid, 1½ gal.; sal ammoniac, 9 lb.; arsenious acid, 9 lb. Boil till all the arsenic is dissolved; let stand to settle, and decant off the clear for use.

Purple Assistant Liquor.—Potato starch, 100 lb.; water, 37½ gal.; nitric acid at 60° Tw., 123 gal.; black oxide manganese, 4 oz. When the reaction is over, and the nitric acid is destroyed, add pyroligneous acid, 50 gal.

Purple Fixing Liquor.—(*b*) Water, 2 gal.; soda crystals, 25 lb.; white arsenic, 22½ lb. Boil till dissolved, and add raw acetic acid, which should first be heated to 49° (120° F.), 50 gal. Let settle for some days; decant off the clear, and add muriatic acid at 32° Tw., 3 qt.

Black (for machine work).—Black liquor at 24° Tw., 4 gal.; crude acetic acid, 4 gal.; water, 4 gal.; flour, 24 lb. Grind the flour to a smooth paste with a little of the mixed liquid, stir in the rest, boil, and stir in 1 pint of gallipoli. No clots must be allowed to remain.

It must be noted that blacks are less frequently produced by the madder style than was formerly the case, as the aniline black is more and more taking their place.

Brown Standard.—Water, 50 gal.; catechu, 200 lb. Boil 6 hours, and add acetic acid, 4½ gal. Make up to 50 gal. with water. Let stand for 2 days; decant the clear, heat to 54° (130° F.), and add sal ammoniac, 96 lb. Dissolve, and let settle for 48 hours. Decant the clear, and thicken with 4 lb. gum senegal per gallon.

Brown (for machine work).—Brown standard, as above, 8 gal.; acetate of copper, as below, 1 gal.; acetic acid, ½ gal.; gum senegal water (4 lb. a gal.), ½ gal.

To make the acetate of copper, take blue-stone, 4 lb.; sugar of lead, 4 lb.; hot water, 1 gal. Dissolve; let settle, and set the clear at 16° Tw. with water.

Madder Brown to resist heavy covers of Purple.—Catechu, ½ lb.; sal ammoniac, ¼ lb.; lime-juice at 8° Tw., 1 qt.; nitrate of copper at 80° Tw., 2½ oz.; acetate of copper, 1½ oz.; gum senegal, 1 lb.

Chocolate.—Iron liquor at 24° Tw., 3 gal.; red liquor at 18° Tw., 6 gal.; flour, 14 lb.; logwood liquor, 1 pint.

Drab.—Brown standard, 4 gal.; proto-muriate of iron (ferrous chloride) at 9° Tw., 1 gal.; acetate of copper, 3 gal.; gum substitute water, containing 4 lb., 1 gal.

Purple.—Add to the iron liquor, in proportions varying according to the shade, light British gum, 40 lb.; water, 16 gal.; purple fixing-liquor, 2 gal. Boil well together; draw off, and allow the whole to stand for 3–4 days. Of this, 8–30 gal. may be added to 1 gal. black liquor.

Padding Purple.—Make up a thickener as follows:—Water, 13½ gal.; purple fixing liquor, 2 gal.; logwood liquor, at 8° Tw., 2 qt.; flour, 18 lb. Boil, and add 2½ gal. of farina gum-water, made by boiling 6 lb. dark calcined farina in 1 gal. water.

Dark Red (for machine work).—Red liquor at 18° Tw., 6 gal.; flour, 12 lb.

Standard Red Liquor.—Alum, 20 lb.; sugar of lead 12½ lb.; boiling water, 5 gal. Stir till dissolved; let settle, and draw off the clear.

Dark Red (for resisting a chocolate cover).—Resist-red liquor (see below) at 18° Tw., 12 gal.; flour, 24 lb. Boil well, and when almost cold, add 12 lb. tin crystals.

The resist-red liquor consists of acetate of lime at 24° Tw., 90 gal.; sulphate of alumina, 272 lb.; ground chalk, 34 lb.

Red (for resisting purple covers).—Resist-red liquor at 14° Tw., 6 gal.; flour, 12 lb. Boil; when nearly cold, add 2½ lb. tin crystals.

A "cover" is a small pattern in purple, chocolate, &c., applied over the whole surface of the piece. The "resisting reds" above mentioned prevent it from becoming fixed to those portions of design where they are applied, and where, therefore, a red is produced.

White figures are obtained by printing on some mixture like the following:—Lime-juice, at 8°, 20°, or 30° Tw., 1 gal.; starch, 1 lb. Boil, and stir till dissolved. Where this so-called "acid" is printed in, covers and padded grounds subsequently printed take no effect, and the figure remains white. Upon such whites, steam colours (see below) may be afterwards blocked in, and thus a great variety of effect is obtained.

Chrome Standard.—Boiling water, 2 gal.; bichromate of potash, 8 lb. Dissolve, and add muriatic acid at 32° Tw., 1⅞ gal. Stir gradually in 3½ lb. sugar.

The pieces, before printing, are bleached in the most perfect manner. After the so-called "colours" have been printed on, the next step is "ageing." In this process, the goods were formerly hung up in single folds in enormous rooms, maintained at the proper degrees of warmth and moisture. They are now laid in bundles upon sparred floors, placed at different heights in the ageing house. The temperature is kept at 27° (80° F.), the wet-bulb thermometer marking 24½° (76° F.). For this purpose, a large iron steam-pipe runs under the flooring, and steam is allowed to enter directly into the house from a number of small jets. Double windows and doors, a double roof, and thick walls serve to guard against sudden changes of temperature; but proper ventilators are fixed, to allow the vapours of acetic acid, given off, to make their escape. The ageing process may last 2–3 days; its object is the decomposition of the acetates of alumina and iron in the mordants, so that either the bases or hydrated subsalts are left attached to the fibre.

The next step is "dunging," the purpose of which is the removal of the thickeners, which have now played their part. The process, which is known in French as *dégommage* or *bousage*, was formerly performed with cow-dung. This material has, however, been almost entirely superseded by the double phosphate of soda and lime, the arsenite and arseniate of soda, and the silicate of soda. The pieces are passed through warm but weak solutions of these substances. This operation is often performed twice, the first time being called "fly-dunging"; and the next, "second dunging."

When silicate of soda is used, the goods pass through two cisterns, heated to 50° (122° F.) or even 100° (212° F.), containing 738 gal. water and 19 gal. silicate of soda at 14° Tw., if the goods have been mordanted for brown and red, black and red, brown only, red only, and rose on a white ground. But if mordanted for black only, purple only, or purple and black, the proportion of silicate of soda is reduced to 13½ gal. at the same strength. The next step after washing is the dyeing, formerly with madder-root, or some of the extracts of madder, but now with artificial alizarine, or anthrapurpurine. The colour is now formally and permanently attached to the mordanted portions; but the whites are still stained or soiled, and the pieces are therefore submitted to the clearing process (*avivage*), which consists in successive treatments with soap-lye. A common treatment is two soapings at a boil, each time for ½ hour, with ¼–½ lb. of soap. The pieces are washed in clean water after each soaping. The quality of the soap is of great importance: it should be quite neutral, and is made, by preference, from palm-oil. Freedom from alkalinity is especially important for madder-purples.

The following process has been employed in Alsace for clearing roses and reds:—(1) Soap-bath: water, 1200 litres; white curd-soap, 4 kilo. per 900 metres; time, 1¼ hour; temperature, 50° (122° F.). (2) Washing in machine with cold water. (3) Bath of oxy-muriate of tin: water, 800 litres; solution of tin, 4·5 litres per 900 metres; time, 15–20 minutes; temperature, 56°–62° (133°–143½° F.). (4) Washing in machine. (5) Second soap-bath: water, 1200 litres; soap, 3 kilo.; time, 45 minutes; temperature, 94° (201° F.). (6) Washing again in cold water. (7) Third soap-bath: proportions as in second. (8) Washing again in cold water. (9) Boiling in closed boiler, in water, 1200 litres; soda crystals, 2½ kilo.; soap, 2½ kilo.; time, 2 hours. (10) Washing in cold water. (11) Warm bath for ½ hour in water at 50° (122° F.).

Grass-bleaching is occasionally used in the clearing process for chintzes, cretonnes, &c., as it is considered to render the shades more transparent.

The clearing process has been very much simplified in consequence of the introduction of artificial alizarine.

Plate Style.—This is a modification of the madder style. For a "plate purple," a purple is printed on, and an "acid," as above described, and the whole is covered over with a lighter purple. The pieces are then aged in the normal manner; fly-dunged at 77° (170° F.); and dunged a second time at 74° (165° F.). They are next washed and dyed, raising the temperature in two hours to 79° (175° F.), which heat is kept up for ½ hour. Wash, and soap, taking 1 lb. soap for 3 pieces of 30 yds. each, boiling for 30 minutes. Wash, and take for 5 minutes through a beck of 500 gal. water, with ½ gal. solution of chloride of lime at 8° Tw. Rinse; boil for ½ hour with 1 lb. soap per 5 pieces; wash; chlore again for 5 minutes; wring in 1 gal. bleaching-liquor at 8° Tw., in only 200 gal. water, along with 2 lb. soda-ash at 71° (160° F.).

The garancine style differed from madder-work in the employment of garancine in place of madder-root. Weaker mordants were used, and catechu was largely associated with the garancine. The patterns produced were chiefly combinations of black, red and chocolate, drab, brown, and orange. The shades were brilliant, but less fast than those obtained with madder-work; and the clearing was not so severe, the rather as the white grounds were very slightly stained in dyeing.

Reserve Style.—This is another modification of madder-work. Acid reserves, consisting of lime-juice and caustic soda, are printed on the pieces; next, the ordinary "colours" for madder reds, purples, chocolates, &c., are printed; and the goods, after the usual operations of ageing and dunging, are dyed. In the white portions reserved, steam or pigment colours may be blocked in.

Padding Style.—This is a further modification of the madder style. The pieces are padded over with red and black liquor, dried in the so-called padding-flue; the pattern is printed on in lime-juice and bisulphate of potash, thickened generally with starch, thus removing the mordant from certain parts. After ageiug, dunging, and dyeing, the design appears in white, on a claret, scarlet, or purple ground.

It is, of course, easy to convert the white design into a yellow, or to block in steam or pigment colours.

Indigo Effects.—Under this style, will be included the so-called "China blues"—designs in blue on a white ground; the kinds where reserves or resists are printed upon the cloth, which is then dyed in the vat, thus producing white, yellow, and orange designs on a blue ground; and lastly, the style named "lapis" or "lazulite."

Effects of the first kind, direct indigo blues, are now very simply produced by means of the "hydrosulphite" process of Schutzenberger and De Lalande.

Direct Indigo Blues.—(1) Put into a colour pan, 8 lb. 2 oz. indigo, finely ground in water, 4 lb. 6 oz. indigo in 26 pints liquid. Heat; and add 6 lb. 9 oz. ground gum. Dissolve; and add 11 lb. saturated hydrosulphite, 15½ oz. milk of lime, containing 7 oz. lime per 1¾ pint. Heat to 70° (158° F.) for 20 minutes; cool down to 40° (104° F.); and add 3 lb. 4 oz. saturated hydrosulphite, and 15½ oz. milk of lime. The yield is 30 lb. 12 oz. of colour.

(2) Or,—Mix 22 lb. *bleu-gommé* (explained below), 13 lb. 2 oz. gum water, 15 lb. 5 oz. saturated hydrosulphite, aud 32¾ oz. milk of lime.

These colours must always be used warm, never under 30° (80° F.), nor over 35° (95° F.). Nor must they be used too soon after they are prepared. Those colours give the best results which show a greenish hue till the next morning.

When the colours are printed, the pieces are spread out overnight in an airy place, or, if necessary, they may immediately after printing be passed through a weak lukewarm chrome beck. In either case, they must be very well rinsed, washed, and soaped, for 30–45 minutes at 50°–60° (122°–140° F.). If the whites are not good, they are taken through weak chloride of lime. If this blue is printed along with other colours, the pieces may undergo the treatment necessary for such colours, without any attention being paid to the blues. Passiug through soda, sulphuric sours, chrome baths (warm or cold), alkaline, chrome and lime baths, silicate of soda, phosphates of lime or soda, cow-dung, &c., has no effect on these blues.

The *bleu-gommé* is prepared as follows:—4 lb. 6 oz. good Bengal indigo are ground up in the ordinary manner, employing water enough to make the paste up to 35 pints. This is placed in a boiler, made up with water to 105–140 pints, along with 11½ lb. caustic soda-lye at 62° Tw. and 30¾ lb. hydrosulphite of soda. It is heated to about 70° (158° F.) for 15–20 minutes. Then 131 fl. oz. hydrochloric acid are poured in through a long-necked funnel, reaching to the bottom of the vessel. This operation should be performed under a chimney, as much sulphurous gas is given off. If the liquid has a faintly acid reaction, the decomposition is complete, and the whole is poured into a cask capable of holding 280 pints, which is filled up with water. The next morning, the liquid standing over the sediment is run off through holes in the sides of the cask, till the bottom is only covered to the depth of 9–10 in. Tho vat is then filled anew with water, to which 4 per cent. by measure of saturated hydrosulphite is again added. The next day, the water is again drawn off, and the sediment is thrown upon a filter, and washed. When completely drained, 7 lb. of a dense paste are obtained for every 2 lb. of indigo originally employed. To preserve this paste, it is suspended in gum water.

The yield, as above, is mixed with 44 lb. thick gum water, containing in each 1¾ pint 3 lb. 1 oz. gum. This mixture is the *bleu-gommé*. Gnm senegal should be used, as starch, calcined starch, and tragacanth have given bad results.

It must be remarked that this process, like all the applications of the "hydrosulphite" to dyeing and printing, is patented in the United Kingdom.

In the "lapis style," mordants with reserves are printed on. The following are specimens of these compositions.

White Lapis resist (for block and machine).—Water, 5½ pints; lime-juice at 53½° Tw., 6 lb. 9 oz.; pipe-clay, 11 lb. Mix also separately: water, 5½ pints; lime-juice at 53½° Tw., 4 lb. 6 oz.; corrosive sublimate, 3 lb. 13 oz.; calcined starch, 11 lb.; lard, 12¾ oz.; turpentine, 6½ oz.; muriate of zinc at 98° Tw., 3¼ lb. Mix and boil.

Red Lapis resist.—Red liquor, 7 pints; verdigris, 6⅜ oz.; pipe-clay, 9 lb. 13 oz.; lard, 4⅞ oz.; turpentine, 4⅞ oz. Dissolve also separately: arsenious acid, 12¾ oz.; acetate of alumina, 5⅓ pints. Mix also apart: acetate of alumina, 3½ pints; gum senegal, 3¼ lb.; muriate of zinc at 98° Tw., 17¼ oz.; extract of logwood at 6¾° Tw., 8¾ fl. oz. Mix these three parts with the aid of heat, grinding them very well, and straining before use.

The cylinders for printing should be engraved very deeply. The pieces are next aged for 48 hours, at a temperature of 35° (95° F.), with the wet-bulb thermometer at 32° (89° F.). Dry for 12 hours thoroughly at 30° (86° F.). If left damp, the pieces will not resist the vat.

Dye blue for 3–5 minutes in the cold vat. Drain, wash for ¼ hour in a current of water. Dung in folds for ½ hour in a beck at 60° (140° F.), with 4 pails of dung, and 15¼ lb. chalk, for 6 pieces of about 50 yds. Wash; and dung a second time, in the same matter, but without chalk; and wash.

Dye for 2 hours at 60°–70° (140°–158° F.), in the following beck:—Garancine (for which will now be substituted a proportionate quantity of alizarine), 8¾ lb.; sapan-wood, 6 lb. 9 oz.; sumach, 11 lb.; bark, 17½ lb.; glue in jelly, 7 pints (containing 17½ oz. dry glue).

Wash till no more colour runs off; chlore at ¾° Tw. Wash; dry; block in yellow, if needed; and age for 24 hours at 30° (86° F.), the wet-bulb thermometer standing at 27° (80° F.).

Here may be introduced a notice of the patented process of the late John Lightfoot, for combining indigo and madder effects (No. 3668, Dec. 26th, 1867).

He takes dry indigo, ground and prepared, 1¼ lb.; tin crystals, 1¼ lb.; caustic soda at 30° Tw., 1 gal. These materials are put into the colour pan, and raised to a boil in ½ hour, when 1 gal. boiling water is added. The mixture is then allowed to become quite cold, and 2 gal. cold water are added, in which ¾ lb. sugar has been previously dissolved. To this solution, are added 2½ pints muriatic acid at 32° Tw., or 1 pint ordinary oil of vitriol, previously diluted with 1 pint water, and allowed to stand till cold, or 3 qts. acetic acid at 80° Tw. The indigo blue may also be precipitated by a mixture of double muriate of tin at 120° Tw., with any of the acids above mentioned, taking ¼ pint of the tin solution to half the quantities of acid given above. But of all these precipitants, acetic acid alone is preferable. The indigotine precipitate is filtered through a deep conical filter, leaving exposed to the air as small a surface as possible. The pulp obtained from the above quantities, when filtered, should measure about 1 gal.

To make a blue colour for printing, the patentee takes 4 gal. of the above precipitated indigo, and 14 lb. gum senegal in powder, stirring till dissolved. The colour, when strained, is ready for printing.

For a green colour, he takes 4½ gal. indigotine precipitate, 18 lb. powdered gum senegal, stirring till dissolved; 11 lb. nitrate of lead, and 11 lb. white sugar of lead, both in powder. The mixture is stirred till all is dissolved, and is then strained.

Compound colours are made by mixing the blue and green colours with each other, or with ordinary mordants for dyeing. With the blue and green above described, and with the ordinary iron and alum mordants (as used in madder-work), he prints calico, and, after cooling, ages the pieces for a night. They are then fixed by passing the pieces into a solution of silicate of soda at 8° Tw., to which is added 1 oz. powdered chalk in a gal. This bath is in a cistern fitted with rollers at top and bottom, and heated to 32° (90° F.). The pieces pass through this solution at the speed of 25 yds. a minute. They are then rinsed in a tank of cold water, fitted with a reel about 4 ft. above the surface. By this process, the indigotine attached to the fibre is rendered blue. If the green mixture has been printed on, the pieces are next passed into a chrome beck at 38° (100° F.), containing 1 oz. bichromate of potash in a gal. of water. Here the pieces remain for 5 minutes, and are then washed. They are next submitted to second dunging (the passage through silicate of soda being the fly-dunging) for 15 minutes, at 38° (100° F.), in a beck of cow-dung and water. They are next washed in water, and dyed with madder, munjeet, flower of madder (alizarine), garancine, cochineal, or mixtures of garancine with sumach and bark. The grounds are then cleared in the ordinary manner, preferably with chloride of lime.

Patterns in indigo may also be produced with the vat. Either certain reserves (resists) are first printed on, and the pieces are then vatted; or the cloth is first died a uniform blue, and discharges are afterwards printed on to form the design. Examples are given of the mixtures used for both purposes.

White reserve (block).—Blue-stone, 3 lb.; water, 1 gal.; pipe-clay, 15 lb. Beat up with some of the solution; mix gradually to a smooth paste, and add thick gum senegal water, 1 gal.; and muriate of copper at 80° Tw., 1 qt.

White reserve (machine).—Blue-stone, 2½ lb.; water, 1 gal.; flour, 9 lb.; British gum (dark), 2 lb.

White resist (for lighter vat-blues).—Dark British gum, 25 lb.; water, 15 lb. Boil for 10 minutes; and add soft-soap, 7½ lb. When thoroughly incorporated, add sulphate of zinc, 20 lb. Stir in well, and add further:—Water, 7½ pints; pipe-clay, 10 lb.; nitrate of copper at 80° Tw., 7½ gal. Work all thoroughly together.

Orange reserve.—Heat 2 lb. water to a boil, and add, with constant stirring, 1 lb. sugar of lead, and ½ lb. litharge; boil for 20 minutes, and add to the liquid, to which more water must be supplied, to compensate for the loss by evaporation, 1 lb. blue-stone, 2 lb. nitrate of lead, and 1½ oz. verdigris, previously softened in acetic acid. The whole is let stand for a day, with frequent stirring; 1¼ lb. powdered gum senegal, and 1 lb. sulphate of lead, are then stirred in; and lastly, 2½ oz. powdered sal-ammoniac, and 1 oz. lard, are added. If the colour is too stiff, it is diluted with water. It is then strained, and printed on at about 50° (122° F.). Age for a day or two at 19°-25° (66°–77° F.). Dye in the cold vat; dry, and sour at ⅜° Tw. For raising the orange, take for 100 yds., 175 pints water, containing 8 lb. chromate of potash, and 16 lb. lime. Let settle; run off the clear, and heat to a boil, at which temperature the pieces are passed through at such a speed that each part may occupy 3 minutes in traversing the liquid. Rinse well.

Yellow reserve.—Blue-stone, 20 lb.; water, 2 gal.; nitrate of lead, 20 lb. Dissolve; and thicken with flour, 12 lb.; sulphate of lead pulp, 2 gal. Boil well together.

The sulphate of lead pulp here mentioned is the sediment left on making red liquor with solution of sugar of lead and alum (or sulphate of alumina), after the liquid has been run off.

To produce a pale-blue pattern on a deep-blue ground, the entire pieces are first dyed a light shade in the vat. They are then withdrawn, thoroughly washed in water, taken through vitriol sours at 2° Tw., washed again, squeezed, and dried. One of the white reserves is then printed on, and the pieces are returned to the vat, and dyed the darker shade. The reserved parts appear as a pale-blue pattern on a deep-blue ground.

To obtain a design in two blues on a white, muriate of manganese is printed on, thickened with dark British gum, and is then peroxidized by being passed through chloride of lime and soda, as in the production of "bronzes." The goods are then dried, and those parts of the pattern which are to appear white are printed with a white reserve. The goods are next limed, vatted to shade, taken out, aired to oxidize the indigo, washed, and rinsed in weak muriate sours, to which a little protochloride of tin has been added. The pattern appears then in white and dark-blue on a light-blue ground, the white being where the discharge was applied, and the dark-blue where the indigo is fixed upon a bottom of manganese brown.

If yellow or orange is to be obtained in addition, the yellow or the orange reserve (see above) is blocked in beside the muriate of manganese and the white reserve. Vitriol sours must be used here, and the yellow is then developed by a passage through bichromate of potash at 38° (100° F.) containing 2 oz. a gal. Wash in water, and pass through muriate sours at ½° Tw., with the addition of 1 oz. oxalic acid a gallon.

If a blue and green design is intended, the yellow discharge above given, or one of a similar character, is printed on, and the goods are dipped in the vat to a full blue, washed, aired, washed again, taken through vitriol sours, at 2° Tw., washed again, and passed through the bichromate beck, but without any treatment in oxalic-muriatic sours. The green is formed by the combination of the yellow and the blue.

To produce two shades of the blue with a green, the cloth is vatted to a pale-blue, a white reserve for light shades, and an orange reserve, are printed in. The usual operations are then gone through; but after the bichromate process, the pieces are taken through nitric acid, which must be very dilute, otherwise the indigo may be destroyed. The result is a dark-blue ground, with a design in pale-blue, where the white resists have been applied, and in green, where the orange has been printed.

The following are examples of compositions for producing a design by discharging a vat-blue ground.

Red and White discharges on Vat-Blues.—Give a medium blue in the vat. Steep pieces in bichromate of potash, 4⅜ oz. in 1⅝ pint water, and dry on rollers, avoiding sun-light. Print on the following discharges:—

White discharge.—Water, 7 pints; white starch, 2 lb. 7½ oz. Boil, and add while still warm, 2 lb. 3 oz. tartaric acid, and then 21¼ oz. oxalic acid, dissolved in 1⅜ pint water.

Red discharge.—Red liquor, 14 qt.; white starch, 17½ lb. Boil; let one half grow cold, and add to it 7 lb. 10 oz. oxalic acid. Then add the other half of the hot mixture to complete the solution of the acid.

Preparation of the Red Liquor.—Alum, 2 lb. 3 oz.; acetate of lead, the same weight; water, 3½ pints. Print on the white and red discharges with the perrotine, or with a two-colour cylinder machine. Do not dry too strongly. Age in hot, but not moist, air, which is an essential condition. The next morning, dung as follows:—Into a beck with rollers, put 6 lb. 9 oz. neutral arseniate of potash, 27 lb. 7 oz. chalk, and 1750 pints water. Pass the pieces slowly through at a simmer, so as to keep the chalk in suspension. After leaving this beck, the pieces are strongly compressed between two rollers covered with cloth. After the first five pieces have passed, feed the beck with 1⅝ oz. arseniate of potash, and a little chalk, per piece. After thus cleansing the pieces, dye up in alizarine, and take through boiling water.

Green and Yellow on a Deep-blue Ground.—Boil the pieces with 2 lb. 3 oz. soda-ash per 100 yds.; wash well, and take through a weak soda beck, containing per 100 yds., 8¾ oz. soda-ash at 38° (100° F.). Dry, calender, and dye a blue in the cold vat. Take through sulphuric acid at 1·4° Tw., starch slightly, dry, and calender cold. Print the following colours on the blue ground:—

(1) *Green Discharge.*—26¼ lb. pipe-clay, 6 lb. 9 oz. gum arabic, the same weight of blue-stone, and of verdigris, 13 lb. 2 oz. nitrate of lead, and 6 lb. 9 oz. sugar of lead. The verdigris is dissolved in acetic acid, and the gum in water; the two solutions are stirred together, and the pipe-clay, previously softened in water, is added. The other ingredients are powdered, and stirred in by degrees. Water is added, enough to make the mixture fit for printing; when it is boiled, the water lost by evaporation is replaced, and the colour is then ready.

(2) *Yellow Discharge.*—Pipe-clay 19 lb. 11 oz.; verdigris, 2⅝ lb.; blue-stone, 2 lb. 7½ oz.; nitrate of copper, 3⅝ lb.; the same weight of gum arabic, 15½ pints water, 6⅝ lb. nitrate of lead, the same weight of sugar of lead, and 4 lb. 6 oz. nitric acid, at 143° Tw. Make up the colour without the nitric acid, stir all well together, and stir in the nitric acid just before using.

Print on first the green and then the yellow. Age in the cold, till the discharge becomes visible on the back of the pieces. Take them through a weak vat to wet them, and then dye up to shade in a fresh vat. Sour without drying, wash off the colours, rinse, take through weak lime-water to remove the acid, and then through a beck of chromate of potash, containing 3¼ lb. chromate per 87 qts. water. The pieces are caused to move very slowly, so that the dyeing process may go on satisfactorily. Rinse, dry, stiffen, and calender.

Discharge Style.—By a "discharge" (*enlevage*), is understood a mixture which, if printed upon cloth previously dyed some uniform colour, e.g. Turkey-red, vat-blue, aniline-black, &c., destroys such ground colour, leaving a design which may be white, black, yellow, green, &c. The term "discharge style" is more especially applied to patterns of this nature obtained upon a Turkey-red. The following colours will serve as examples of these discharges:—

White (for cylinder work).—Tartaric acid, 6 lb.; water, 1 gal.; starch, 1½ lb.

White (for block work).—Tartaric acid, 10 lb.; China-clay, 7½ lb.; perchloride of tin, 1½ lb.; gum water, 1 pint; water, 1 gal.

Black.—Logwood liquor at 4° Tw., 1 gal.; yellow prussiate, 2 lb.; thick gum tragacanth water, 1 qt.; flour, 2 lb. Boil, and add black liquor at 30° Tw., 2 qt. When quite cold, add nitrate of iron at 80° Tw., 1 gill.

Blue.—Tartaric acid, 5 lb.; water, 1 gal.; tin pulp, 1 gal.; double muriate of tin at 120° Tw., 2 gal.; gum tragacanth water, 2 gal.

Yellow (block).—Lime-juice at 50° Tw., 1 gal.; tartaric acid, 4 lb.; nitrate of lead, 4 lb. When dissolved, add China-clay, 6 lb.; gum senegal, 3 lb.

Yellow (cylinder).—Thicken the former with 1½ lb. starch, instead of gum and China-clay.

After any of these discharges is printed on, the pieces, when dry, are passed through the "decolouring vat," which is made up of 1000 gal. water and 1000 lb. chloride of lime, well raked up, and freed from lumps. A double set of wooden rollers at top and bottom is placed in the vat, and the liquid is kept constantly stirred up, so as to be perfectly uniform. The pieces are now allowed to run through the liquor at the rate of 28 yds. in 3 minutes. On leaving the vat, they are run between squeezing-rollers into water, and are then rinsed for 10 minutes in solution of bichromate of potash at 4° Tw. Wash in pure water, then in water soured with muriatic acid, and lastly in pure water; after this, dry. Except where the discharge was printed on, the Turkey-red is unaffected; but there, it is removed, and the ground is either left white, or a mineral colour takes its place.

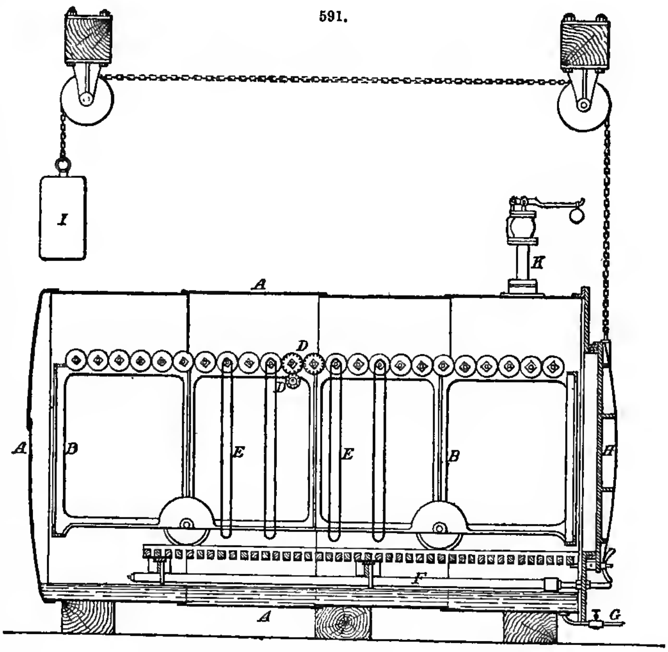
Steam Colours.—This style has latterly undergone a very great development. It includes the processes by which the aniline colours in the majority of cases are fixed upon cotton goods, and, in addition, the topical application of the colours formerly obtained from madder, but now produced artificially. Printing upon woollen, worsted, and silk tissues, as well as upon mixed fabrics, such as delaines, coburgs, &c., is included in this style.

The aim of steaming is to get a moist heat, both the temperature, and the degree of moisture, being carefully regulated, according to the class of the goods, the nature of the colours, &c. In some cases, the pieces after printing are exposed to the air, at common temperatures, for 12–24 hours before steaming; whilst in others, they are steamed immediately. Sometimes, the goods are steamed for a time, taken out to air, and steamed again; whilst on other occasions, the steaming is conducted for the necessary time without interruption. The temperature, the pressure, and the degree of moisture, vary greatly, some printers using very dry, and others very moist, steam.

The apparatus in which the steaming is performed is called the "steam-chest," an iron chamber, generally about 9 ft. high, 6 ft. wide, and 12 ft. long. At one end, are well-fitting folding doors, capable of being closed tightly, and held in place by bars and screws. The chest has a double bottom, the upper layer of which is on a level with the floor of the room, and is perforated with a great number of holes. Underneath this false-bottom, runs a steam-pipe, extending round three sides of the chest, and also perforated with holes, through which the steam escapes, and is further distributed by means of the holes in the false-bottom. A tramway is fixed upon the false-bottom, parallel with the sides of the steam-chest, and extending out into the room. Upon these rails, runs a carriage consisting of wooden rods, fixed in an oblong frame, as wide as the chest will allow, and as high as where the slope of the roof begins.

Fig. 591 shows a longitudinal section of Mather & Platt's steam-chest:—A is the body of the structure, of wrought-iron plates, in a cylindrical form; B is the carriage, and wheeled frame, fitted with square wooden rollers, all geared together by spur-wheels, worked by a handle passing through a stuffing-box to the outside of the chest; D represents the handles and wheels; E, pieces hanging on the rollers; F, perforated pipe for introducing steam; G, escape pipe and tap for condensed water; H, movable door, hung with balance-weight; K, pressure-gauge and safety-valve.

591.



When the goods are ready for steaming, the carriage is drawn out into the room, and filled with the pieces, which are one after another wound upon an open reel, the selvages being kept parallel. They are then drawn off the reel, and flattened, and a string is drawn through the selvages on one side, and looped. Through the loops, are thrust wooden rods, resting on the sides of the frame-work. The carriage is run back into the chest, which is closed, and made steam-tight, the pressure being regulated by a safety-valve. After the lapse of the requisite time, which ranges from 20 minutes to 1 hour, the chest is opened, and the pieces are taken out, unrolled, and folded loosely, so as to be ready for rinsing. They are stitched together end to end, and taken first through a cistern of water, next through a very weak solution of bichromate of potash; then washed, and drained in the centrifugal, ready for finishing.

Before the colours are printed on, the calicoes are generally "prepared" by the following process:—The pieces are padded in a solution of stannate of soda, commonly known as "alkaline preparing salts," at 10° Tw., in a machine fitted with wooden rollers. The padding is generally done twice, and, in the meantime, the pieces are allowed to remain wet for about 1 hour; next they pass through sours, i. e. dilute sulphuric acid at 1½°–3° Tw., then into pure water, and are washed, so that no free sulphuric acid may remain upon them, but the washing must not be so severe as to remove the oxide of tin, which has been deposited upon the fibre. The pieces are then drained in the centrifugal machine, carefully dried at a gentle steam-heat, and are ready for printing.

For heavy shades, the strength of the solution of stannate may be raised to 24° Tw.; the pieces are left to lie wet for 2 hours, and are then taken through sours at 6° Tw., washed, and drained in the centrifugal. All these operations are then repeated once more in the same order, and the goods are then dried. Care must of course be taken to keep the sours up to the same point of acidity. Without attention to this point, they become rapidly weakened, and the fixation of the tin being thus rendered irregular, the colour subsequently produced will be uneven.

If preparation with stannate of soda is useful for calico, it is in general absolutely necessary for worsted stuffs, and mixed goods.

The following are examples of steam colours:—

Amber.—Gum substitute, 15 lb.; olive oil, neutral, ⅜ pint; bark liquor at 12° Tw., 3 gal.; sapan liquor at 8° Tw., 2¼ pints; red liquor at 16° Tw., 3 qt. Half boil, and add 6 oz. tin crystals, previously dissolved in 2 pints of the red liquor. Mix, and add $\frac{3}{16}$ pint oxy-muriate of tin at 120° Tw. Mix well, and strain as fine as possible.

Blacks: (1) Machine work.—Logwood liquor at 6° Tw., 1 gal.; starch, 1¼ lb.; boil, and add, whilst still hot, copperas, 5 oz.; stir thoroughly, and, when the mixture has grown almost cold, add gallipoli oil, 2 oz.; and nitrate of iron, well neutralized, 10 oz.

(2) Another black.—Logwood liquor, 12° Tw., 1 gal.; gall liquor, 9° Tw., 1 qt.; mordant, 1 qt.; flour, 2 lb.; starch, 6 oz.

For the mordant, mix acetic acid, 1 qt.; acetate of copper, 1½ qt.; black liquor, 24° Tw., 1½ qt.; red liquor, 20° Tw., 1 qt.

(3) Black for Calico.—Dissolve in water 5 lb. 7¼ oz. solid extract of logwood, and allow the liquor to settle. Dissolve separately in water 17¼ oz. gum tragacanth. Mix the two solutions, and boil. Boil out 2 lb. 3 oz. gall-nuts in water, and add the decoction to the above, making up to 17½ pints. Let cool, and stir in 2 lb. 3 oz. nitrate of iron at 30½° Tw., and the same weight of black liquor at 26¾° Tw. Print, and hang up for 2 days, or preferably for a few hours; steam well, and wash.

(4) Black for printing Cotton Yarns.—Dissolve in water 5 lb. 7 oz. solid French extract of logwood, and 17¼ oz. gum tragacanth. Make up the mixed solution to 21 pints, in which dissolve 4½ oz. extract of bark. Let cool, and stir into the mixture 2 lb. 3 oz. black liquor at 30½° Tw., and 17 oz. nitrate of iron at 98° Tw. Print, hang up for 2 days, steam, and wash. If a very blue tone is required, the nitrate of iron is left out.

Blues: (1) Dark, for cylinder work.—Water, 7 gal.; starch, 14 lb.; sal ammoniac, 2¾ lb.; boil, and add, while hot, yellow prussiate, ground, 12 lb.; red prussiate, 6 lb.; tartaric acid, 6 lb. When nearly cold, add sulphuric acid at full strength, 1 lb.; oxalic acid (previously dissolved in 2 lb. hot water), 2 lb.; tin pulp (see below), 6 gal.

Tin pulp is prepared as follows:—The strongest double muriate of tin, a saturated solution of the protochloride of tin (stannous chloride), is mixed with as much solution of yellow prussiate as will throw down all the tin as a ferrocyanide. Wash in water by decantation, and drain on a filter till it becomes a stiff paste.

(2) Aniline Blue.—Red liquor at 20¼° Tw., 35 fl. oz.; bisulphite of soda at 39½° Tw., 35 fl. oz.; strong gum water, 3½ pints; aniline blue (Schlumberger, Brussels), 3½ oz. The colour, when ready, is printed at once. The calico may either be printed without any preparation, or it may be padded in a soap-lye containing 1 oz. curd-soap per pint, and dried. After printing, steam for 1½ hour. Wash, take through lukewarm soap-lye, and sour in weak muriatic acid. Wash, and dry.

(3) Prussian Blue for Shawls, &c.—Boil up 10 oz. starch to a uniform paste with 7 pints water; stir into it 2½ lb. yellow prussiate, 1½ lb. red prussiate, 7 lb. tin pulp, 4 lb. tartaric acid, ¼ lb. oxalic acid, 5½ pints water, and 1 oz. sulphuric acid.

Browns: (1) Catechu Brown.—Boil 4 lb. catechu in water; let settle, and strain off the clear. The liquor thus obtained is mixed with 1 lb. red liquor at 8¼° Tw., and thickened with ¾ lb. gum tragacanth.

(2) Dark Brown.—Gum starch, 6 lb.; satin gum, 9 lb.; olive oil, 2 pints; red liquor at 17° Tw., 16½ qt.; acetic acid at 7° Tw., 6 pints; catechu liquor, 4 gal.; sal ammoniac, 4 lb.; sapan liquor at 8° Tw., 4 qt.; logwood liquor at 10° Tw., 4 qt.; acetate of copper, 1 qt.; nitrate of copper at 86° Tw., 1 qt. Boil well, and strain.

(3) Bimas Brown.—Extract of Bimas at 5½° Tw., 3360 parts; acetic acid at 11¼° Tw., 560 parts; cubic catechu, 560 parts; sal ammoniac, 140 parts; verdigris, 105 parts. Thicken with gum arabic, 2000 parts.

(4) Berry Brown.—Berry liquor at 20° Tw., 1½ gal.; Brazil wood liquor at 8° Tw., 1½ gal.

alum, 3 lb.; lavender liquor, ¾ gal.; gum senegal water, at 6 lb. to the gal., 1½ gal.; nitrate of copper at 100° Tw., 1½ lb.

(5) Brown Standard.—Bark liquor, 12° Tw., 3½ gal.; sapan liquor, 12° Tw., 3½ qt.; logwood liquor, 12° Tw., 1½ qt.; gum substitute water, 8 lb. to the gal., 3 gal.; alum, 3½ lb.; chloride of potash, 2 oz.; red prussiate, 5 oz.

Light browns are obtained by letting this standard down with gum water.

(6) Another Brown.—Bark liquor, 12° Tw., 3 gal.; berry liquor, 12° Tw., 3 gal.; logwood liquor, 12° Tw., 2 gal.; sapan liquor, 10° Tw., 2 gal.; British gum, 48 lb. Boil, and add alum, 3 lb.; sal ammoniac, 2 lb.; sulphate of copper (blue-stone), 2 lb.; nitrate of copper, 8° Tw., 2 pints; lilac standard, as below, 3 gal.

To prepare the lilac standard, take gum senegal, 4 lb.; red prussiate of potash, 8 oz.; alum, 12 oz.; oxalic acid, 1 oz.; binoxalate of potash (salt of sorrel), 2 oz. Dissolve in logwood liquor, 20° Tw., 1 gal., previously heated to 79° (173° F.).

(7) Another Brown.—Berry liquor, 3° Tw., 1 gal.; logwood liquor, 8° Tw., ¼ pint; peachwood liquor, 8° Tw., ½ gal.; solid nitrate of copper, 24 oz.; alum, the same weight. Thicken according to shade with gum senegal water.

Buff.—Bark liquor, 10° Tw., 1 gal.; madder liquor, 3 gal.; red liquor, 14° Tw., ½ gal.; starch, 7 lb. Boil, and add crystals of tin, 2 oz.

Chocolates: (1) Cylinder work.—Sapan liquor, 12° Tw., 2 gal.; logwood liquor, 12° Tw., 3 gal.; bark liquor, 12° Tw., ½ gal.; nitrate of alumina, 1 gal.; water, 4 gal.; starch, 17 lb. Boil, and add red prussiate of potash, 2½ lb.; chloride of potash, 8 oz.

To prepare the nitrate of alumina, take boiling water, 4 gal.; crystal nitrate of lead, 12 lb.; alum, 12 lb.; carbonate of soda crystals, 2½ lb. Stir till perfectly dissolved, let settle, and decant the clear.

(2) Alizarine Chocolate.—Alizarine paste, 15 per cent., 2 lb.; thickening, 2½ gal.; nitrate of alumina, 26¾° Tw., 1⅘ lb.; acetate of alumina, 18¾° Tw., ⅘ lb.; red prussiate of potash in hot water, ⅘ lb.; acetate of lime, 26¾° Tw., 1 lb.

In order to obtain a yellowish chocolate, add, for each quart, 1 oz. extract of bark at 30½° Tw.

This chocolate may also be prepared from stale red colours by adding to them, for each quart, ⅘–1 oz. red prussiate of potash dissolved in hot water.

(3) Chromium Chocolate.—Take 70 fl. oz. Pernod's extract of madder in paste; the same measure of acetic acid at 9½° Tw., and 105 fl. oz. acetate of chromium at 25¼° Tw. Mix well, print, and steam.

In place of Pernod's extract, a proportionally smaller quantity of alizarine will now be used.

(4) Chocolate.—Sapan liquor at 9° Tw., 12 qt.; nitrate of alumina, 3 qt.; logwood liquor at 12° Tw., 6 qt.; yellow prussiate, 6 oz.; red prussiate, 6 oz.; chlorate of potash, 9 lb.

Cinnamon.—Cochineal liquor at 8° Tw., 1 qt.; logwood liquor at 8° Tw., 1 qt.; berry liquor at 10° Tw., 1 qt.; alum, 6 oz.; alum 4 oz.; cream of tartar, 4 oz.; starch, ½ lb. Boil, and, while still warm, add tin crystals, 3 oz.

Dark Drab.—Berry liquor at 12° Tw., 4 qt.; gum substitute, 7 lb. Boil, cool, and add alum, 24 oz.; copperas, 16 oz.; logwood liquor at 2° Tw., 1 qt.; cochineal liquor at 3° Tw., 1 qt.

Drab.—Lavender liquor, 2 gal.; blue standard, 2 gal.; bark liquor 8° Tw., 2 qt.; gum water, 20–35 gal.

To make the blue standard, take water 2 gal.; yellow prussiate, 4 lb.; alum, ¾ lb.; sulphuric acid, 170° Tw., 1½ lb.

Greens: (1) Berry liquor at 11¼° Tw., 7 pints; red liquor at 11¼° Tw., 1¾ pint; blue mixture, as below, 7 pints. When cold, add solution of chloride of tin at 113½° Tw., 8¾ oz.; white starch, 20 oz. Steam twice for 20 minutes each time; wash, dry, and finish with 350 pints cold water, 88 lb. white starch, and 4 lb. 6 oz. stearine.

To make the blue mixture, dissolve 22 lb. yellow prussiate, 3 lb. 4 oz. tartaric acid, and the same weight of oxalic acid in 87½ pints boiling water.

(2) Cæruleine Green.—Gum water, 17½ qt.; cæruleine, 7 qt.; bisulphite of soda, 1¾ pint. To be added on using, acetate of chrome at 26¾° Tw., 3½ pints.

(3) Bark Green.—2¼ lb. starch, 1½ gal. bark liquor at 16° Tw. Boil, and add 9 oz. alum, 1½ oz. oxalic acid, 8 oz. tin crystals. When half cold, add 1 lb. 14 oz. tartaric acid, 3 lb. 6 oz. yellow prussiate, 1½ pint tin pulp, ⅜ pint olive oil. After steaming, pass through chrome liquor at 4½° Tw. Wash in clear water, and dry.

(4) Aloes Green.—Chrysammide (the product of chrysammic acid on treatment with ammonia), thickened according to shade with gum water.

After steaming, this colour comes up a rich moss green, which is not affected by boiling water, nor by the madder baths, and is capable consequently of a variety of useful applications. Thus an aloes green ground may be obtained; iron and alum mordants may be printed on, and the piece may be dyed with alizarine, giving red, purple, chocolate, and black figures, on a green ground.

(5) Green for Blotch Grounds.—Bark liquor at 10° Tw., 4 gal., boiled up with 6 lb. starch. Add alum, 2¼ lb.; tartaric acid, 3 lb.; yellow prussiate of potash, 6 lb.; oxalic acid, 12 oz.; and tin pulp, ¾ gal. After printing, take through a weak bath of bichromate of potash, to raise the colour.

(6) Green for Block Work.—Yellow prussiate, 14 lb., dissolved in very hot water, 3 gal. Mix meantime, in another vessel, water, 1 gal.; double muriate of tin at 120° Tw., ½ gal.; and gum senegal water, at 6 lb. per gal., 5 gal. Now mix these two liquids by pouring them repeatedly backwards and forwards, and stirring thoroughly. When perfectly mixed, add berry liquor at 10° Tw., 6 gal.; tartaric acid, 5 lb.; oxalic acid, 1¼ lb., previously dissolved in 2½ gal. water; acetic acid, 1½ qt.; extract of indigo, $\frac{9}{16}$ pint.

Greys: (1) Aniline Grey for Calico.—Dissolve 21⅝ oz. chlorate of potash in 6 pints boiling water. When cold, add 11¾ pints gum water, 10⅞ oz. sal ammoniac, 3¼ lb. chromo-tartrate of potash at 49° Tw., 6⅞ oz. aniline, and 2 lb. 8½ oz. tartaric acid. Print on, age for 48 hours at 32° (89° F.), and wash for 1 hour. Lighter shades are produced by increasing the gum. This grey gives a fine ground, and can be submitted to all the operations necessary for alizarine reds, except passing through a salt of tin.

To prepare the chromo-tartrate of potash, 33⅛ oz. bichrome are dissolved in 5⅛ pints boiling water. When it has cooled down to 43° (110° F.), add gradually 3 lb. 2⅛ oz. tartaric acid in fine powder, avoiding a rise of the temperature.

(2) Uranium Madder Grey.—Add together 70 fl. oz. extract of madder in paste, the same measure of acetic acid at 9⅓° Tw., and 105 fl. oz. acetate of uranium at 14° Tw.

Lavender.—Lavender liquor, 4 gal.; blue standard, 4 gal.; gum water, 24–48 gal.

The lavender liquor is prepared by mixing 2 gal. red liquor at 18° Tw. with 6 lb. ground logwood. Steep for 48 hours, and strain off the clear. A stronger quality is made from 10 lb. logwood with the same quantity of red liquor.

For blue standard, take 1 gal. water, ¾ lb. oxalic acid, 4½ oz. yellow prussiate, 28 oz. gum substitute, water 1 gal.

Lilac.—Pink standard, 6 gal.; purple standard, 2 gal.; gum substitute, 20 lb.

For pink standard, mix cochineal liquor at 6° Tw., 4 gal.; alum, 2 lb.; cream of tartar, 2 lb.; oxalic acid, ½ lb.

For purple standard, logwood liquor at 12° Tw., 2 gal.; alum, 12 oz.; red prussiate, 8 oz.; and oxalic acid, 4 oz.

Orange.—Mix Saturn red (Baden Aniline and Soda Co.), 9 lb. 13 oz.; glycerine-arsenic, 7 fl. oz.; water, 44 fl. oz.; blood-albumen thickening, 10½ pints; gum water, 3½ pints.

The gum water is made by dissolving 21¾ oz. gum senegal in 1¾ pint water.

For the glycerine-arsenic, dissolve 2 lb. 8¾ oz. arsenious acid in 17½ pints glycerine at 36° Tw., and concentrate to 100° Tw.

To make the blood-albumen thickening, dissolve 13 lb. 2 oz. blood-albumen at a gentle heat in 16 pints of water, 7 fl. oz. caustic ammonia at 10 per cent., and 8½ fl. oz. oil of turpentine. Print, dry, steam, and wash.

Pinks: (1) Sapan-wood Pink.—Sapan liquor at 3° Tw., 1 gal.; pink salt, 1 lb.; sal ammoniac, ⅛ lb.; oxalic acid, 1 oz.; blue-stone, 1 oz.; thick gum water, 1 gal.

(2) Pink Standard (Cochineal).—Cochineal liquor at 6° Tw., 4 gal.; alum, 2 lb; bitartrate of potash (cream of tartar), 2 lb.; oxalic acid, ½ lb.; thick gum senegal water, 4 gal.

(3) Mixed Pink.—Sapan liquor at 8° Tw., 5 gal.; cochineal liquor at 8° Tw., 1 gal.; nitrate of alumina, ½ lb.; alum, 3 lb.; oxalic acid, 2 oz.; chlorate of potash, 8 oz. When these ingredients are perfectly mixed up, add 12 gal. gum water.

(4) Cochineal Pink.—Cochineal liquor, 8° Tw., 1 gal.; starch, 20 oz. Boil a little, and add 3 oz. oxalic acid. Dissolve, strain, print, steam for 40 minutes at 3 lb. pressure; let lie for a night, and run through very weak alum-water.

Purples: (1) Alizarine Purple.—Alizarine paste, 15 per cent., 1⅘ lb.; thickening for purple, 2½ gal.; pyrolignite of iron, 17° Tw., ⅜ lb.; acetate of lime, 23½° Tw., ¾ lb. After printing, the pieces are steamed for 1–2 hours at a pressure of ½ atmos., and then aged for 24–36 hours. The steam should be very moist. The pieces are gathered on rollers, and rinsed for 1–1½ hour through the following baths, heated to 50°–60° (122°–140° F.):—Water, 250 gal.; chalk, 40 lb.; arseniate of soda, 10 lb. Wash, soap for ½ hour in a bath containing 3 lb. soap to 10 pieces of 50 yds. each, heated to 60°–71° (140°–160° F.). Wash; dry; if needful, give another light soaping. The best results are obtained by steaming perfectly dry pieces with wet steam.

The thickening for purples, above mentioned, consists of wheat starch, 12 lb.; water, 4½ gal.; tragacanth mucilage, 2¼ gal.; acetic acid, 11·2° Tw., 3 qt.; olive oil, 2 lb.

It is to be remarked that alizarine shades, when obtained by dyeing upon mordants previously printed upon the fibre, are more beautiful, more transparent, faster, and more economical than when fixed by steaming. Hence alizarine colours ought not to be applied by steaming, except when it is absolutely necessary, i. e. when blues, greens, yellows, oranges, catechu browns, greys, mauves, &c., have to be associated with alizarine reds and purples.

(2) Logwood Purple.—Logwood liquor at 16° Tw., 1½ gal.; red liquor at 20° Tw., 1½ gal.; carbonate of soda, 1 oz.; crystal soda, 5 oz.; red prussiate, 5 oz.; oxalic acid, ¾ lb.; gum senegal, 10 lb. Boil, cool, and strain.

Reds or Roses: (1) Magenta Red.—Magenta crystals, ¼ oz.; acetic acid, 6½ oz.; water, 3 oz. Dissolve at a boil. Meantime mix for thickening 17½ fl. oz. red liquor at 21¾° Tw.; the same measure of water, and 12 oz. dextrine. Boil, cool, and mix with 4½ oz. thick gum water.

(2) Or,—½–¾ oz. magenta crystals, ¼ lb. alcohol, 10 oz. boiling water. Dissolve, and add ¼ oz. oxalid acid. Thickening:—17½ oz. thick gum water, 18 oz. decoction of galls at 11¼° Tw., 9 oz. acetic acid. Mix, and add to the red; and stir in further 17½ oz. thin gum water.

(3) Or,—1¾ pint red liquor at 14° Tw., 2¾ oz. arsenite of soda, and ⅝ oz. magenta. Steam for 1 hour, soap, and wash in pure water.

This process is applicable also to other aniline colours.

(4) Aniline Rose.—Water, 35 oz.; starch, 6 oz.; red liquor, 35 fl. oz. Dissolve, and stir in 7½ oz. roseino carmine (Baden Aniline Works).

(5) Saffranine Red for Calico.—Mix ½ pint saffranine paste with 10 pints of the subjoined thickening:—1 gal. acetate of alumina (red liquor) standard, 1 gal. of water, and 2 lb. starch. Boil, cool, and add 1 pint arsenic and glycerine standard.

The acetate of alumina standard is made with 1 gal. boiling water, and 2½ lb. alum. Dissolve, and add 3 lb. white acetate of lead. Dissolve, let settle, and use the clear.

The arsenic-glycerine standard is composed of 1 gal. white glycerine, 4 lb. arsenious acid; boil till dissolved, and filter.

Print the colour on, and steam for ½ hour.

(6) Or,—Dissolve ¼ oz. saffranine in 3½ oz. hot water. Make prepared thickening: 2 lb. 3 oz. acetate of alumina at 21¾° Tw., 17½ oz. arsenite of soda at 98° Tw., 1 lb. 10 oz. acetic acid. Mix; dissolve separately 2 lb. 3 oz. soda, and the same weight of white arsenic in 2⅝ pints of water. Mix all together, and add 3 lb. 4 oz. gum water at 2 lb. 3 oz. per 1¾ pint.

Take 5 lb. 7½ oz. of the thickening, and 1 lb. 1½ oz. solution of saffranine. Steam as in the former process.

This colour is applicable for mixed goods.

(7) Eosine Red.—Print with a thickened solution of eosine; steam, and pass into a bath of acetate of lead.

(8) Or,—Animalize with albumen, and dye in solution of eosine.

(9) Or,—Thicken a solution of eosine with white starch, or gum tragacanth; add arsenite of alumina (i. e. mixture of arsenite of soda and red liquor as given under saffranine). Print upon cloth prepared with tin; steam, and wash.

(10) Or,—Mix a solution of eosine with acetate of lead, acetate of tin, or red liquor thickened. Print upon calico prepared with tin, or oiled. Steam, and wash. Upon oiled calico, the shades are bluish.

(11) Or,—Prepare the calico with solution of glue; print on a mixture of eosine with three times its weight of tannin; steam, and wash.

(12) Grain Ponceau.—Boil 17½ oz. cochineal in 10½ pints water. Boil out the residue again in water; mix the decoctions, and evaporate down to 10½ pints; let cool, and settle. In the clear liquid, dissolve 6¼ oz. oxalic acid, 3½ oz. white starch, and 4⅜ oz. white glue. Print, steam at 88° (190° F.), and rinse.

(13) Grain Red for Mixed Silk and Cotton Goods.—Mix 1 oz. extract of cochineal at 6·8° Tw. (for heavy shades this may be doubled), with the same quantity of berry liquor at the same strength. Thicken with 17¼ oz. gum tragacanth; boil, stir till cold; dissolve in the liquid, 8⅝ oz. oxalic acid, and 3⅛ oz. tin crystals. Make up to 17½ pints. Print, dry, hang up for 24 hours, steam for 1 hour at 100° (212° F.), and rinse.

(14) Alizarine Red for Grounds.—Alizarine paste, 15 per cent., 1⅗ lb. (if 10 per cent., 2 lb.); acetic acid at 8·2° Tw., 1 qt.; water, 2 qt.; olive oil, ⅖ lb.; acetate of lime, 14° Tw., ⅗ lb.; wheat starch, 1 lb. Boil the whole, stir well till cold, and add acetate of alumina, ⅗ lb.

(15) Ditto for Mille Fleurs.—Alizarine paste, 15 per cent., 5⅕ lb.; thickening for reds, 10 qt.; nitrate of alumina, 21¾° Tw., ⅗ lb.; acetate of alumina, 17° Tw., 1⅕ lb.; acetate of lime, 23½° Tw., ⅘ lb.

(16) Ditto for very deep Reds.—Alizarine paste, 15 per cent., 6⅗ lb.; thickening for reds, 10 qt.; nitrate of alumina, 21¾° Tw., ⅘ lb.; acetate of alumina, 17° Tw., 1⅕ lb.; acetate of lime, 23½° Tw., 1 lb.

(17) Red without Olive Oil.—Alizarine paste, 15 per cent., 5⅗ lb.; acetic acid, 11·2° Tw., 9⅗ lb.; flour, 3⅗ lb.; water, ⅘ lb. Boil to a paste, stir till cold, and then add acetate of lime, 23½° Tw., 5½ oz.; nitrate of alumina, 21¾° Tw., 2 lb.; hyposulphite of lime, 12·6° Tw., 3 lb.

Red and Pink.—Alizarine paste, 15 per cent., 3½ lb.; thickening for red, 8 qt.; acetate of alumina, 17° Tw., 1 lb.; acetate of lime, 23½° Tw., ½ lb. For pink, add 2–3 times its weight of thickening for red.

If a dark-red design is to be covered by a lighter red, the dark-red is first steamed for 1 hour. After printing the second colour, it is again steamed for 1 hour, and hung up for 24 hours.

The pieces are then taken through either of the two following baths:—(A) Water, 250 gal.; chalk, 60 lb.; tin crystals, 3 lb. (B) Water, 250 gal.; chalk, 40 lb.; arseniate of soda, 10 lb.

The baths are heated to 50°–62° (122°–143° F.), and the passage lasts for 1–1½ minute. Wash and rinse in the following soap becks, each warmer than the former, and prepared as follows (for ten pieces of about 50 yards each):—First beck: Soap, 3 lb.; tin crystals, ¼ lb.; heat, 50° (122° F.); time ½ hour. Second beck: soap, 3 lb.; heat, 75° (167° F.); time ½ hour. Third beck: soap, 3 lb.; heat, 75°–80° (167°–177° F.); time, ½ hour. After each soap bath, the pieces are well washed.

The thickenings and mordants here mentioned, are prepared as follows:—Thickening for reds, No. 1.—Wheat starch, 12 lb.; water, 5 gal.; acetic acid, 8·2° Tw., 1 gal.; tragacanth solution (2 oz. per qt.), 2½ gal.; olive oil, which must be thoroughly incorporated with the mass, 3 lb. Stir till perfectly cold.

Thickening for red, No. 2.—Wheat starch, 12 lb.; water, 4½ gal.; acetic acid, 8·2° Tw., 4½ gal.; olive oil, 3 lb.

Nitrate of Alumina Mordant.—Nitrate of lead, 20 lb.; alum, 20 lb.; boiling water, 5 gal. Let the sulphate of lead settle, and draw off the clear. If the nitrate of alumina is used instead of the acetate, it causes the red to turn more to a scarlet; but it requires the use of a little more acetate of lime than acetate of alumina.

Acetate of Alumina Mordants.—Dissolve first 68 lb. alum in 100 gal. water, and precipitate by adding a solution of 62 lb. soda crystals in 150 gal. water. This precipitate, which is a basic sulphate of alumina, is washed three times by decantation. It is then thrown on a filter, let drain, and pressed. Of the paste thus obtained, 30 lb. are placed in 6 qt. acetic acid at 11·2° Tw., and heated to 32° (90° F.), till complete solution has taken place. It is then filtered, and diluted with water to the strength required.

As a general rule, 100 parts alizarine paste at 15 per cent. require 30 parts acetate alumina at 17° Tw.

Acetate of Lime Mordant.—The solution of acetate of lime at 23½° Tw. contains about 25 per cent. of the salt. For a neutral well-washed paste, at 15 per cent., about 15 per cent. of its weight of acetate of lime is used.

Alizarine reds produced by printing, are never quite so beautiful as the corresponding shades obtained by dyeing upon mordants according to the madder style.

Violets: (1) Galleine Violet.—Paste Galleine, 35 qt.; gum water, 17½ qt.; acetate of chrome at 26⅔° Tw., 1⅔ qt. Print and steam.

(2) Hofmann's Violet.—Mix the dissolved and filtered colour with red liquor, and with a solution of arsenious acid in glycerine. Thicken with gum and starch. Steam for 1 hour, and soap gently.

(3) Aniline Violets.—½ oz. Hofmann's or Perkin's violet, 13½ oz. hot alcohol. (There are now violets perfectly soluble in water). Dissolve, filter, and add immediately 1½ oz. tannin, ¼ oz. oxalic acid. Let cool, and meantime mix 2½ lb. thick gum water, 18 oz. water, 18 oz. acetic acid. Stir up well, and add to the above solution of colour. Print and steam.

(4) Or,—17½ oz. pure tannin are dissolved in 15⅔ pints gum water, and an amount of aniline violet is added according to the required shade. Print, steam, enter the pieces at 57°–82° (135°–180° F.) into a bath of tartar emetic, containing ½ oz. of this salt per 1¾ pint; wash and dry. Or the pattern may be printed on with a thickened solution of tannin, ranging from ¾ oz. per 1¾ pint for pale, to 4½ oz. for full shades, steamed, and passed into a bath of tartar emetic. They are then well washed and dyed in the bath of aniline violet, raising the temperature gradually to a boil, which is kept up for 20 minutes. Wash, and soap slightly.

This process is applicable to various other aniline colours.

Yellow.—Berry liquor at 12° Tw., 4 gal.; alum, 1½ lb.

Spirit Colour Style, or Application Colours.—This style differs from the steam style, because the colours employed contain so large a proportion of acid mordants, chiefly the chlorides of tin (or, as they are technically called, "spirits"), that steaming would be impracticable. After printing, the goods are carefully dried, aged for a few hours, rinsed, washed with cold water, and are then ready for drying off. The colours are bright, but, as a rule, not enduring; and the cloth is often weakened by the action of the strong mordants. The colours, as will be seen, bear a considerable resemblance to those employed in the steam style. The following are examples:—

Block Blue.—Water, 1 gal.; yellow prussiate, 1 lb.; alum, 6 oz.; starch, 20 oz. Boil, and after letting cool down to 43° (110° F.), add nitrate of iron at 80° Tw., 15 oz.; and oxymuriate of tin at 120° Tw., the same quantity.

Brown.—Berry liquor at 80° Tw., 1 gal.; light British gum, 2 lb. Boil, and add tin crystals, 1 lb., and of the pink colour and the purple colour given below, 2 qt. each.

Chocolate.—Sapan liquor at 8° Tw., 3 qt.; logwood liquor at 10° Tw., 2 qt.; bark liquor at 13° Tw., 1 qt.; starch, 3 lb. Boil; when cooled down to 43° (110° F.), add further oxymuriate of tin at 100° Tw., 1 pint; nitrate of copper at 80° Tw., ½ pint; and olive oil, 1 pint.

Green.—Mix the blue and the yellow colours here given, according to shade.

Pink.—Sapan liquor at 14° Tw., 1 gal.; sal ammoniac, ½ lb.; gum water, at 6 lb. per gal., 1 gal.; oxymuriate of tin at 120° Tw., 1 pint.

Special Pink (for blocking in madder-work).—Sapan liquor at 10° Tw., 4½ gal.; pink salt (i. e. double chloride of tin and ammonium), 9 lb.; sal ammoniac, 3 lb.; blue-stone, 2 lb.; oxalic acid, 5¼ oz.; water, 1 pint; gum senegal water (6 lb. per gal.), 4½ gal.; oxymuriate of tin at 120° Tw., 1⅛ qt.

Purple.—Logwood liquor at 8° Tw., 1 gal.; water, 1 gal.; copperas, 10 oz.; starch, 2 lb. Boil, and add protochloride of iron at 80° Tw., 1 pint; oxymuriate of tin at 120° Tw., 1 pint.

Red.—Sapan liquor at 4° Tw., 3 gal.; sal ammoniac, 1 lb.; verdigris, 1 lb.; starch, 4½ lb. Boil, and add when cold, pink salt, 5 lb.; oxalic acid, 1 lb.

Yellow.—Berry liquor at 10° Tw., 1 gal.; alum, 8 oz.; starch, 1 lb. Boil, and add double muriate of tin at 120° Tw., 1 pint.

Such of the coal-tar colours as can bear the presence of acids, e. g. acid rubine, may, if desired, be applied in spirit styles.

MANGANESE BRONZE STYLE.—This style of calico-printing is in much less demand than was formerly the case. A brown ground is produced over the entire surface by padding in solutions of a salt of manganese, drying and padding in soda lye, first at 24° Tw., and then at 12° Tw., rinsing in water, and taking through bleaching lime at 2° Tw., washing again in water, and drying. By these processes, manganese peroxide is uniformly deposited over the fibre. Various colours are then printed upon this ground, so made up as to discharge it, and become fixed in its place, the result being designs in white, black, red, green, blue, yellow, &c., on a brown ground. After printing, the pieces are hung up for a few hours, rinsed in a flow of water, again in chalk water, and then again in pure water, and, in case of chrome yellow-greens, in a solution of bichromate of potash at about 40° Tw. Lastly, the goods are washed and dried.

As specimens of the discharge colours printed on, the following are given:—

White.—Water, 2 gal.; light British gum, 8 lb. Boil, and add tartaric acid, 8 lb.; double muriate of tin at 120° Tw., 1 gal.

Pink.—Brazil-wood liquor at 12° Tw., 1 gal.; blue-stone, 2 oz.; sal ammoniac, the same weight; starch, 2 lb. Boil, and add oxymuriate of tin at 120° Tw., 8 fl. oz. Mix 2 qt. of the above colour with 1 qt. double muriate of tin at 120° Tw.

PIGMENT STYLE.—The colours employed in this style are not soluble dyes, but insoluble colours or pigments, which are fixed upon the fibre by various mediums. This style has of late been much improved, and offers the advantages of solidity and permanence, combined with a lightness and brilliance equalling, in many cases, those of colours formed in the fibre.

The pigments chiefly employed in this style are ultramarine of various shades, from greenish-blue to a full blue, violet-blue, and even a reddish-violet; vermilion; several ochres; zinc-white; certain chrome colours, such as chrome-yellow, chrome-green, Guignet's green, Wilner's green, lamp-black; sienna; umber, &c.

The vehicles or mediums employed for attaching these pigments to the fabric are albumen, caseine, or, as it is often called, lacterine. Blood-albumen may be used for all save the lightest and brightest colours. The pigments are ground up in albumen, thickened often with gum tragacanth, printed and steamed. The albumen is thus coagulated, and the colour is permanently attached to the fibre.

Pigment printing is chiefly confined to such parts of designs as consist of small dots, stars, and flowers; more rarely to broad stripes, large foliage, &c. It affords the means of producing many pleasing effects which would not otherwise be practicable.

Pigment colours, and other colours fixed by means of albumen, may be discharged by printing in the juice of the papaw-tree (*Carica papaya*), thickened with gum.

Aniline Black.—Aniline black seems to form a distinct style, but is capable of being combined with a great variety of colours, produced according to the styles already described.

Aniline Blacks for Yarn Printing.—Gum tragacanth water, 1¾ pint; water, 2⅝ pints; sublimed aniline muriate, 9¾ oz.; chlorate of potash, 2¾ oz. Immediately before use, work in 2¾ oz. sulphide of copper. The colour thus made is printed; the pieces are dried, and aged for 48 hours at 30° (86° F.) in a moist atmosphere. As soon as the colour appears of a blackish-green, the yarns are washed, taken through weak bichromate of potash, then through a solution of soda, washed, and dried.

Aniline Black for Machine Work.—Chlorate of potash, 159 parts; sal ammoniac, the same weight;

moist sulphide of copper, 150 parts; white starch, 360 parts; calcined starch, 180 parts; water, 2300 parts. Boil, stir till cold, and add 317 parts sublimed aniline salt, previously dissolved in 9000 parts cold water.

Prussiate Aniline Black.—Chlorate of aniline, 34 parts; prussiate of aniline, 12 parts; water, 34 parts; gum tragacanth water (containing $4\frac{3}{8}$ oz. per $1\frac{3}{4}$ pint), 12 parts. This mixture may also be thickened with starch paste, both for block and machine work.

The chlorate of aniline is prepared by dissolving 5 parts tartaric acid in 10 parts boiling water, and, separately, 4 parts chlorate of potash in 12 parts boiling water. These two hot liquids are mixed together, 20 parts cold water and 3 parts aniline being added. After this addition, the liquid takes a faint yellowish tinge, and stands at $9\frac{1}{2}$° Tw.

To obtain a prussiate of aniline, treat 7 parts yellow prussiate with 3 parts sulphuric acid, previously diluted with 14 parts water. After some days, the yellow colour disappears, and a deposit of sulphate of potash is formed. To 100 parts of the solution thus obtained, are added 128 parts of water and 20 of aniline.

White Discharge upon Aniline Blacks.—Thicken an acid solution of the permanganate of potash with finely-ground siliceous earth and China-clay, and block on. Take through oxalic acid, when dry. No organic matter must be used for thickening the permanganate.

Aniline Black, with Design in White, Madder Red, and Chrome Orange.—This process illustrates the manners in which aniline black may be combined with other colours.

For the madder red, is used a mordant of red liquor at 12° Tw., thickened with $2\frac{1}{4}$ lb. flour per gal. Cool, and add, per gal., 4 oz. tin crystals.

For the orange, dissolve nitrate of lead, $4\frac{1}{2}$ lb.; white sugar of lead, $4\frac{1}{2}$ lb.; in $\frac{1}{3}$ gal. water. Add $\frac{2}{3}$ gal. gum Barbary water (6 lb. to the gal.).

For the black, mix 1 gal. of the colour below, just before printing, with $\frac{1}{2}$ pint sulphide of copper paste. To make the colour, thicken 6 gal. clear chlorate of ammonia with 36 lb. British gum. Heat to 66° (150° F.), let stand till cold, and add aniline oil, 4 qt.; best muriatic acid at 34° Tw., 3 qt. Mix well together.

To make the chlorate of ammonia, dissolve $7\frac{1}{2}$ lb. tartaric acid in 6 gal. boiling water. When dissolved, add gradually 3 lb. 2 oz. sesquicarbonate of ammonia. Now add 8 lb. chlorate of potash, and stir till dissolved. Let stand till cold, and filter. Wash the precipitated tartar (potassium bitartrate) with 6 qt. cold water. This should yield 6 gal. clear chlorate of ammonia solution.

For the sulphide of copper, take flowers of sulphur 2 lb. 2 oz.; caustic soda lye (70° Tw.), $11\frac{1}{2}$ lb. Stir well till dissolved, without heat; add it to 10 lb. blue-stone, dissolved in 20 gal. boiling water. Wash till neutral to test-paper, and filter till the bulk of the paste is reduced to 1 gal.

Print the above black, red, and orange colours, and hang in a room at 21° (70° F.) with about 8°–9° F. difference between the wet and dry-bulb thermometers. Age till black, and pass through ammonia gas. Hang in a cool room for a few hours, and pass through the following solution at 71° (160° F.):—Sulphate of soda, 2 lb.; phosphate of soda, 1 oz.; water, 1 gal. Wash, and give a second dunging for 25 minutes at 54° (130° F.) in water, 100 gal.; sulphate of soda, 2 lb.; phosphate of soda, 1 oz.; and solid cow-dung, 4 qt. Wash, and dye with 13 lb. madder, or a proportionate quantity of alizarine, per piece. Wash, pass through chloride of lime at 1° Tw., then steam, and wash. Dry, and steam for $\frac{1}{2}$ hour at 2 lb. pressure. Wet out, soap-wash, and pass through weak sours (1 part oil of vitriol at 170° Tw., to 1000 water) at 15° (60° F.) for 6 minutes. Wash, and pass through chloride of lime, as before. Wash, dry, and raise orange in the usual way, first in bichromate alone, and then in bichromate and lime at 100° (212° F.). Wash well, and pass through chloride of lime, as before. Wash and dry.

Another Aniline Black.—Dissolve $\frac{7}{8}$–$1\frac{1}{4}$ oz. chlorate of soda in 17 fl. oz. water, and thicken as usual. In another vessel, thicken 17 fl. oz. water, and stir in $2\frac{3}{4}$ oz. muriate of aniline, with $1\frac{1}{2}$ gr. chloride of vanadium.

Equal measures of these two solutions are mixed, and printed at once. Age at a low temperature, as long as chlorine is given off, and raise the temperature till perfectly dry. Lastly, pass through a solution of bichromate of potash, wash, and dry.

The cerium aniline black, of Jerens, is obtained by mixing 75 gr. bisulphate of cerous oxide with $2\frac{3}{4}$ oz. muriate of aniline, thickened as usual. The shade, after printing, appears a light-green, but after ageing for 24 hours at 25° (77° F.)—20° (68° F.) by the wet-bulb thermometer—it turns to a dark-green, and, after soaping, and taking through an alkaline beck, it comes up a fine black.

General Considerations.—In this brief sketch of the art of calico-printing, one vital point must not be overlooked—the influence exerted upon colours by their juxtaposition to others. It is nothing uncommon to find, both in printed tissues and in goods where many-coloured patterns are produced by means of the Jacquard loom, shades which, if viewed singly, would to a practical eye appear very ordinary in character; but, by being arranged in accordance with the optico-physiological laws, which have been so ably expounded by Chevreul and Von Bezold, these indifferent colours enhance and support each other, and the general effect is admirable. Conversely, too often are found designs where each individual colour is splendid, but where the arrangement is so deplorable that each is impaired by being wrongly associated with others.

Among the happy associations of colours where each is beautified by the association, may be mentioned the pairs formerly known as "complementary"—an assumption only approximately true—such as magenta and green, carmine and bluish-green, vermilion and turquoise-blue, orange and ultramarine, yellow and bluish-violet, yellowish-green and crimson-violet.

Among triple combinations, the following groups produce good effects:—Magenta, yellow, and turquoise-blue; carmine, yellowish-green, and ultramarine; vermilion, green, and blue-violet; orange, bluish-green, and reddish-violet. Each of these groups may be further enriched by the addition of black and white.

Combinations of four colours each—black and white being, strictly speaking, not regarded as colours—are very difficult to arrange. Beautiful effects have indeed been produced with magenta, or a red verging towards violet, green, scarlet bordering upon carmine, and turquoise-blue. But in such combinations, care has been taken that the magenta and the scarlet, and respectively the green and turquoise-blue, should not lie side by side, but should be separated by black or white.

As examples of inharmonious pairs, mention may be made of vermilion and yellow, yellow and green, green and turquoise-blue, turquoise-blue and blue-violet, magenta and vermilion. Such colours should never be placed alongside each other in a design, especially if in broad masses. If they are both introduced, they should be separated, for instance, by black.

Professor Von Bezold very justly remarks that such combinations are rendered much worse if the brighter of the two is applied in the heavier shade. Light blue stripes or spots on a dark green ground are much worse than dark blue on a light green; and, in the same manner, light magenta on a dark vermilion is more intolerable than the converse arrangement. The brighter are any ill-matched colours, the worse is the effect produced—a law from which may be drawn the practical conclusion that the bright and pure colours now at the disposal of the printer and the dyer require much more judgment and skill to make them harmonize than did the comparatively dull colours which were known a century ago. It may even be said that the general ignorance of, and indifference to, the laws of colour have greatly restricted the use of the coal-tar dyes.

It will thus appear that the utmost skill on the part of the colour maker and the colour mixer is rendered of little avail if the designer is not equal to the resources placed in his hands.

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(See Albumen; Alum; Alumina; Coal-tar Products; Dye-stuffs; Mordants.)

DYE-STUFFS (Fr., *Matières tinctoriales;* Ger., *Färbematerialien*).

The term "dye-stuffs" is commercially employed to designate collectively the plants, flowers, lichens, woods, roots, exudations, and other products yielded by the vegetable kingdom, which are used in dyeing, printing, staining, and colouring.

Until within very recent times, these substances formed one of the most considerable items of our import trade, and were essential to the existence of our textile industries; but the modern introduction of compounds derived from coal-tar—containing the same colouring principles in an artificial form, or replacing them by others, equally, and often more, brilliant and permanent,—and the cheapness and abundant supply of these manufactured substitutes, have had a most disastrous and lasting effect upon a once flourishing and important branch of commerce. The deleterious nature of some of the coal-tar colours is at present confining their use within comparatively narrow limits, and this may yet continue for a few years; but it seems impossible to doubt that the old-fashioned dye-stuffs will, in the near future, be almost entirely replaced by the cheaper chemical preparations, at least in those countries where the latter are largely produced.

Alkanet (Fr., *Orcanète;* Ger., *Orkanet*).—The root of *Anchusa* (*Alkanna*) *tinctoria* contains a dark blood-red resinous principle termed "Anchusin," $C_{35}H_{20}O_8$, or "Alkanna red," obtained by exhausting the root with alcohol, evaporating, and shaking up with ether. The resin is insoluble in water, but readily soluble in alcohol, and better still in ether, oils, and bisulphide of carbon, to all of which it communicates a purple-red colour; in concentrated sulphuric acid, it gives amethyst; in alkalies, blue; from the last, it is precipitated by acids, in brown-red flocks. It is used chiefly in pharmacy, to colour medicines; in perfumery, to colour oils and greases; to colour lime-wash, for application to walls; and with oils, to stain woods in imitation of rosewood. In China, it is used chiefly for colouring candles, and medicinally. The plant grows in sandy places in the Mediterranean basin, and is occasionally cultivated in Languedoc, and the Levant. Small quantities are met with in commerce, and valued at about 30*s*. a cwt.

Aloes (see Drugs).—From aloes, has been produced a yellow dye, termed "chrysammic acid." It is prepared by heating in a water-bath 8 parts nitric acid with 1 part aloes; when violent action has ceased, a second part of the latter is added; heating is continued till no more hyponitric fumes are evolved. The mass is then poured slowly into abundance of water; chrysammic acid flakes settle at the bottom of the vessel; they are washed with water, till the latter assumes a fine purple colour. The acid occurs as small golden-yellow scales, soluble in alcohol and ether, sparingly in cold water, readily in boiling water. The acid is a pure polychrome, changing its colour according to circumstances. It has long been known as giving a beautiful purple to silk, black to wool, and pink to linen. A French firm have recently used it to produce a fine brown, named "vegetable brown," which consists in applying the acid in conjunction with sulphuric acid—say 45 parts of the former to 6–8 parts of the latter. The dye is bright; it resists the strongest alkaline milling; it combines with most of the aniline and other dyes, economizing them, and rendering them thoroughly fast; and it is not expensive.

Annatto, or Arnotto (Fr., *Arnotto, Rocou;* Ger., *Arnotto, Orlean*).—The seeds of *Bixa orellana* are enveloped by a soft resinous pulp, of vermilion colour, and unpleasant odour, known in the French Colonies as *rocou*, and in other parts of S. America as *achiote*. The plant grows in Africa, the E. and W. Indies, and S. America; it is cultivated chiefly in Guadaloupe, Cayenne, and Martinique, sparingly in Mexico and Brazil. There are several ways of preparing the dye:—(1) The pulp and seeds are treated with hot water, left to macerate in the presence of an antiseptic, and separated by pounding with a wooden pestle; the seeds are strained off, the pulp is left to settle, the water is decanted, and the colouring matter, in a pasty condition, is exposed in shallow vessels to dry gradually in the shade. When sufficiently consistent, it is made into rolls or balls of 2–3 oz., and dried in an airy place. (2) The entire ripe fruit is coarsely crushed, treated with hot water, and soaked for several days; the seeds are then strained off, and the pulp is left to ferment for about a week; the water is poured off, and the dye-stuff is dried in the shade till it can be made up in cakes of 3–20 lb., and covered with banana leaves. This is known as "flag annatto"; it is inferior to (3), owing to the fermentation. The fresh article contains about 5½ per cent. of colouring matter and over 70 per cent. of water. (3) The Indians adopt a laborious process:—they rub the fruit with oiled hands, till the pulp is separated, and reduced to a clear paste; this is scraped off the hands, and laid on leaves to dry in the shade. The product is very superior. The three French Colonies of Cayenne, Guadaloupe, and Martinique have about 6000 acres of land under culture with annatto, and produce yearly about 3 million lb. The supply now exceeds the demand. In dyeing and printing, it is now largely superseded by rosolic acid (see p. 680), though still retained for low-class cotton yarns, and for modifying the shades of other dyes. The tablets prepared by the first process are used in Dutch, American, and English dairies, for colouring butter and cheese. Our annual imports of "roll" annatto are about 1000 cwt.; and of "flag," 3000 cwt. The former is worth about 2*d*.–9*d*. a lb.; the latter, 5*d*.–1*s*. 6*d*.

Barwood (Fr., *Bois du Santal, Santal rouge d'Afrique;* Ger., *Sandelholz*).—This dyewood is derived from *Pterocarpus Angolensis*, a tall tree of W. Africa. The colouring principle, termed Santalin, $C_{30}H_{14}O_{10}$, is common to several other members of the same genus (see Camwood, Sanders-wood), and is developed only with age, being absent from young branches, but abundant in the trunk. In the African markets, the dye-stuff occurs in a ground state, made up into balls; the wood is imported in square logs deprived of the bark. Its value is 3*l*.–3*l*. 10*s*. a ton. It is chiefly used to produce orange-reds, called "mock Turkey reds," on cotton yarns.

Berberin, $C_{40}H_{17}NO_8 + 9HO$.—This golden-yellow colouring matter appears to be very widely distributed; it has been recognized in the barks of *Geoffroya inermis, Xanthoxylum Clava*

Herculis, and in the root-bark of *Berberis vulgaris*; also in the flowers of the last named, in the bark of *Xylopia polycarpa*, in the root of *Jateorhiza Columbo*, in the wood of *Coscinium fenestratum*, and in *Jeffersonia diphylla*, *Leontice thalictroides*, *Podophyllum peltatum*, *Coptis Teeta*, *C. trifolia*, *Hydrastis Canadensis*, and *Xanthorrhiza apiifolia*. The only plants whence the dye seems to be commercially obtained are the several species of *Berberis*. *B. vulgaris* is found in abundance throughout Europe; in the Savoy Alps and in Poland, a decoction of the bark and roots is used for dyeing leather and woven fabrics, and in Nuremberg for colouring toys. In India and China, several species yield a yellow dye, and as the watery extract is well known to the natives, large quantities might be prepared in that way.

Brazil-wood (Fr., *Bois de Fernambouc;* Ger., *Fernambukholz*, *Brasilienholz*).—Several species of *Cesalpinia* yield a colouring principle known as Brasilin, $C_{44}H_{20}O_{14}$. Brazil-wood proper, derived from *C. Braziliensis*, is now seldom met with, owing to the destruction of all the trees within reach of a port; its best substitute is obtained from *C. Christa*, a native of the province of Pernambuco, and of Jamaica, and worth 13*l*.-45*l*. a ton. A second variety, termed "peach-wood," is imported from Nicaragua; a third, of inferior quality, from Peru, is known as "Lima-wood," and valued at 11*l*.-11*l*. 10*s*. a ton. The same principle exists in Sapan-wood (q. v.). An extract is prepared from these woods in the following way:—They are finely ground, and left to ferment and oxidize in the air; treated with water, the decoction is concentrated by evaporation as rapidly as possible. By adding 4 lb. of gelatine, dissolved in water, to every cubic yard of ground wood, and leaving the whole to ferment for several days, a much richer and stronger extract is obtained. The brilliancy is much increased by adding a little chlorate of potash to the hot extract. The extracts are used principally to produce pinks and reds in steam styles; and with quercitron, in the production of cheap garancine styles. Decoctions of the woods yield beautiful pink lakes, used by paper-stainers; common red ink is prepared by adding a little alum and acid to their aqueous solutions. The exports of Brazil-wood from Bahia, in 1878, were 821 kilos., almost entirely to the United States.

Broom (Fr., *Genêt;* Ger., *Färberginster*, *Gilb-kraut*, *Geniste*).—The "Dyers' broom" (*Genista scoparia*) is very abundant in the Alps, and is still occasionally used by the Italians for dyeing skins.

Camwood (Fr., *Bois de Cam;* Ger., *Camholz*).—This appears to be identical in origin with Barwood (q. v.), its commercial difference depending upon the selection of the wood for the development of its colour. It is worth 15*l*.-23*l*. a ton.

Cauline.—Colouring matter, to which this name has been given, is derived from the red cabbage, in the following way:—The cabbage is cut into small pieces, and placed in boiling water, in the proportion of about 3 lb. of the former to 5 pints of the latter; the infusion is left to macerate for twenty-four hours; the leaves are taken out and pressed, and the expressed liquid is added to the infusion. The dye has a violet-blue colour, and forms the base of a series of derivatives. It is prepared dry, and in the form of a syrupy extract.

Chay (Fr., *Chayaver*, *Chavayer;* Ger., *Sayawer*).—A very popular red colour is obtained from the root of *Oldenlandia* (*Hedyotis*) *umbellata*, known also as "Indian madder." The plant flourishes in the sandy soils of the Coromandel coast; besides being found abundantly in the wild state, it is very extensively cultivated. The roots are found in commerce in little bundles, 6 in. long, and 1½–2 in. in circumference. The dye is in great repute in India, but is said to deteriorate rapidly in any dark place, and parcels of it exported have therefore been regarded unfavourably.

Chinese Green.—This colour was first met with as a sediment left after dyeing cotton cloths with the barks of *Rhamnus chlorophorus* and *R. utilis*, and known in China as *Lo-Kao*. The sediment is spread on blotting-paper, and dried, forming thin scales. It was highly valued, as affording a pure green even in artificial light. Its value in the London market, in 1861, was placed at 7*s*. 6*d*. an oz. In 1853, it was largely imported into France, for silk-dyeing. In 1864, Charvin obtained the same colouring matter from *R. catharticus*, a weed indigenous to Europe, and was able to sell it at 37*s*. a lb. These beautiful dye-stuffs are now completely driven from the market by the aniline dyes. (See p. 668.)

Cochineal (Fr., *Cochenille;* Ger., *Cochenille*).—The colouring matter known as "cochineal" is the product of an insect called *Coccus cacti*, which lives on several species of cactus, but especially *Cactus Nopal* (*Opunta coccinilifera*). The plant and insect are natives of Mexico and Guatemala, but have been successfully introduced into the Canary Islands, as well as Algeria, Java, and Australia. The production is almost confined to Guatemala and the Canaries.

In the former country, gardens of the nopal plant extend in every direction. Each is surrounded by a mud fence, on which is built a thatched roof, forming a shed, which is open on the sunny side. Here the insects are preserved and bred; the young are placed in little leaf boxes or bags, attached to the spikes on the leaves of the plant. Rain is fatal to the insect, especially during the first ten days of its existence. According to Boddam-Whetham, in some districts, the female is left on the leaf long enough to produce a second crop in the same year; this is much heavier than the first, and much more profitable. The gathered insects are spread on flat trays, covered with thin cloths, and placed in ovens. When dry, they are sifted, packed in bales, and sent to market.

The average yield of an acre of nopal is said to be about 1800 lb. of the insects in the two crops. In Mexico, the plant and insect occur both wild and cultivated: the product from the cultivated plant is much superior, and is known as *mestique;* that from the wild plant is called *sylvestra.* In May, in the plains, and in November, in the hills, the Indians remove the young female insects to growing plants; after about three months, the myriads of young insects borne by the female are brushed off the leaves into tin dishes. They are then thrown into hot water, and dried in the sun or in stoves, producing *zacatilla*, or "black cochineal"; or they are bagged or stoved at once, which process leaves them with a peculiar lustrous look, whence they are termed *blanco*, or "silver cochineal." The values of the New World brands distinguished in the London market are approximately as follow:—Honduras, black, 2*s.*–2*s.* 5*d.* a lb.; silver, 2*s.*–2*s.* 3*d.*; Mexican, black, 2*s.* 1*d.*; silver, 1*s.* 10*d.*–1*s.* 11*d.* The exports (in quintals of 101½ lb.) from Guatemala, in 1878, were:—to California, 155; England, 133; New York, 70; S. America, 54. The total value was about 4500*l.*; in 1877, it was 36,000*l.* Less than twenty years ago, the exports amounted to 600–750 tons yearly.

The cultivation in the Canaries is carried on as follows:—The insects are reared in the winter, so as to be ready for "planting," or putting out on the cactus plants, in the latter end of May to late July or early August. The plants are robbed of their fruit as fast as the buds appear, otherwise they become too weak for rearing the cochineal insects. About a table-spoonful of pregnant females are put into little gauze bags, 8–9 in. long, and hung upon the cactus leaves. The young escape as fast as they are born, and spread over the surface of the leaf, great care being required to proportion the number of insects to the size of the leaf. In August and September, the moment the insects exhibit signs of spawning, they are rapidly collected. The method of gathering them varies much, but, as a rule, the leaves holding bags are severed sharply by a knife, close to the branches, and the cochineal is swept off into closely-woven, broad baskets. The leaves are afterwards cut up, and dug in between the rows, as manure. Other hands carefully scrape off any insects which may have passed into the branches or stem of the plant, as these would otherwise spawn, and weaken the plant, to the injury of future crops. Immediately the insects are gathered, they should be turned out of the baskets, and spread in a layer not exceeding 2–3 in. in depth, either on trays, or on a sheet on the ground. Here the cochineal remains during the day. Towards evening, it is placed in an oven, heated to about 65° (150° F.), for four to five hours; the oven is then allowed to cool gradually till the morning. When taken out, the insects will be found still moist; they are then exposed to the sun for a few days to complete the drying, suffering much less loss of weight in this way than if they were thoroughly dried in the oven. A few growers use special means to effect the drying:—(1) A little wood ashes is scattered over the cochineal; the latter dies in an hour or two; the dust is sifted off, and the cochineal is dried in the sun. (2) Moderate quantities of the insects are placed in a sack, which is violently shaken; this produces a brilliant polish, which enhances the price of the article sufficiently to atone for the slight loss of weight incurred. The oven is, however, most universally employed. The "grain," as the dry cochineal is called, is sifted, to remove an adherent white powder, and is picked over, to free it from fragments of the plant. When clean, it is packed in bags of about 150 lb. each, for export. The produce is estimated at 250 lb. dry cochineal from an acre. Hot winds from the Sahara, and heavy rain, are fatal to the crop. Compared with the American article, the London prices of Teneriffe cochineal are about as follow:—Black, 2*s.*–2*s.* 10*d.* a lb.; silver, 2*s.*–2*s.* 1*d.*

Cochineal is very frequently adulterated. A common fraud consists in extracting part of the colour by soaking it in water, then drying it, and selling it as black cochineal, or shaking it up with ground talc or sulphate of lead, to resemble silver cochineal. The fraud is easily detected by throwing some of the ground article into water. The chief use of cochineal has been for dyeing wool; in calico-printing, to produce pinks and reds; an ammoniacal preparation for dyeing silk, and to produce violets and mauves on wool; and for the manufacture of carmine lakes (see Pigments). Though it has suffered much from competition with coal-tar dyes, our imports, in 1878, were 30,827 cwt., valued at 359,836*l.* The chief contributors were:—Canary Islands, 26,740 cwt.; Mexico, 1549; W. Coast Africa (foreign), 1330; other countries, 1208. In 1879, the figures were reduced to—Canaries, 24,720 cwt.; Mexico, 1931; other countries, 1301.

Cudbear.—(See Orchella.)

Ericine.—This is a new colour, derived from the wood of the common heath (*Erica vulgaris*), and different kinds of poplar. The stems of the former, or new branches and twigs of the latter, are cut up, crushed, pulverized, and boiled in an alum solution—10 lb. wood with 1 lb. alum in 3 gal. water; the whole is boiled for twenty to thirty minutes, and filtered. The filtrate becomes turbid on cooling, and deposits a greenish-yellow resin. When free from resin, the liquor is refiltered, and left for three to five days exposed to light and air; it thus acquires a golden-yellow colour, and may be worked into an extract, or precipitated as a lake. The extract surpasses most yellows in brightness; the lake can be used in paper-staining, artificial flower making, calico-printing, &c.

Fustic (Fr., *Fustique;* Ger., *Visetholz*).—The dye-stuff known as "Old Fustic" is the produce of *Morus tinctoria*, a native of Brazil, Mexico, and several of the West Indies. It arrives in logs of various sizes, the best being dense, of a fine orange-yellow colour inside, and not worm-eaten. Cuba fustic is valued at 8*l*.–8*l*. 10*s*. a ton, while Jamaica, Mexican, and Honduras fetch only 5*l*.–5*l*. 10*s*. The article is used chiefly for wool dyeing, and is but little employed by calico-printers. Extracts, both liquid and solid, are largely imported from America and France; the West Indian colonists do not seem as yet to have availed themselves of this method of reducing cost of transport. The exports from San Domingo, in 1878, were 948,000 lb.; of this, 718,000 lb. went to the United States, and only 16,000 lb. came to Great Britain. The so-called "Young Fustic" is a distinct product. (See Tannin.)

Gardine.—This yellow dye-stuff, consisting of the fruits of a species of *Gardenia*, is extensively used in China, under the name of *Hoang-tchi*. It has been introduced into Germany, Holland, and England, but without attracting much notice. The extract gives orange on wool, fiery-yellow on silk, and yellow on cotton, and is said to resist soap and most acids.

Godari, or Dhauri.—The flowers and leaves of *Grislea tomentosa* are much used in some parts of India, for giving a red colour to skins for native slippers. The plant grows abundantly in the Northern Circars.

Henna.—This popular Eastern dye is derived from the leaves of *Lawsonia alba* (*spinosa, inermis; Alcanna spinosa*). This plant is common from Egypt to India; it is very generally cultivated in Indian gardens, and on a much more extensive scale for commercial purposes in some districts, e. g. at Touat, in Arabia, and near Bombay. The best henna grown in all Asia is said to come from Yezd, in Persia; a very superior quality is produced also near Mecca. It forms an important article of commerce in every Eastern bazaar. The shrub is propagated by cuttings, planted in shaded situations, and grows rapidly. It is cultivated both for the sake of the dye, and for the delicious perfume of the flowers. In the former case, the shoots are cut when 3 ft. long, and are stripped of their leaves, which are sun-dried, and finally ground in a mill. Two or even three crops are obtained in a year. If the flowers are required, the shoots are allowed to reach 5–6 ft. before cutting. The dye is applied to the finger-nails of men and women, and to the manes, tails, and hoofs of horses, to produce a brownish-yellow tint. Applied to human hair, it produces a beautiful black by a second dyeing with indigo. The flowers are used in perfumery and embalming. Medicinal virtues also are ascribed to the plant. Egypt is said to produce 6½ million lb. yearly; Morocco, in 1873, exported 2216 cwt., valued at 3545*l*.

Indian Mulberry.—The root-bark of the Indian mulberry (*Morinda citrifolia*) produces a scarlet dye, largely used by the natives of India, for colouring turbans, handkerchiefs, &c. The tree is cultivated in Kandeish, Berar, and the Deccan; in a wild state, it is common in most parts of India. The roots are partially dug up in the second year, and are in perfection in the third. The small best pieces are worth 4–5 rupees a *maund*. Large quantities of the bark are exported from Malabar to Guzerat and North India. *M. tinctoria* appears to be the same species, wild. *M. tomentosa*, of Travancore, yields a dye from the interior of the wood in old trees. *M. umbellata*, of Travancore, Malabar, and Cochin China, contains a permanent yellow colouring matter in its roots; added to sapan-wood, it produces brilliant and permanent reds, rivalling madder.

Indigo (Fr. and Ger., *Indigo*).—The well-known blue colouring matter termed "indigo" is produced by a great number and variety of plants, distributed throughout all the tropical countries of the globe. Commercially, it is obtained chiefly from species of *Indigofera*, as *I. tinctoria*, the cultivated species of India, furnishing the chief article of commerce, found also in Madagascar, St. Domingo, &c.; and *I. Anil*, in the Punjab, W. Indies, and on the Gambia river. Some is also obtained from *I. argentea*, in Africa and America; *I. Caroliniana; I. disperma*, the cultivated plant of Spain, America, and some of the E. Indies; *I. cœrulea*, the "black indigo" of India; *I. glauca*, in Egypt and Arabia; *I. pseudo-tinctoria*, cultivated in some parts of the E. Indies, and said to yield the best dye; *I. cinerea, I. erecta, I. hirsuta*, and *I. glabra*, in Guinea. Considerable local supplies are obtained from the following plants:—*Isatis tinctoria*, in Europe and China (see Woad); *I. indigotica*, cultivated in some parts of China; *Amorpha fruticosa*, in Carolina; *Baptisia tinctoria*, wild, in the United States; *Gymnemia* (*Asclepias*) *tingens*, in Burmah; *Polygala tinctoria*, in Arabia; *Polygonum Chinense, P. tinctorium, P. perfoliatum, P. barbatum, P. aviculare*, in China and Japan, and introduced into Belgium; *Ruellia indigotica*, largely cultivated in Assam, as well as in India, and at Che-king, in China; *Tephrosia tinctoria*, and *T. apollinea*, in India and Egypt; *Wrightia tinctoria* (*Nerium tinctorium*), the Palas indigo of the Carnatic.

The cultivation of indigo (chiefly *Indigofera tinctoria*) is very extensively carried on in India, especially in the district included between 20° and 30° N. lat. The soil best suited for the culture is a rich loam, with a subsoil which is neither too sandy nor too stiff; alluvial soils give the best returns, but good crops are sometimes raised on higher grounds. The land is ploughed in October–November, after the rains; the seed, about 12 lb. to the acre, is sown in February–April. Too rapid growth diminishes the yield of dye. In July–September, the plants are in full blossom, and the harvest takes place. The preparations of the dye-stuff may be performed in either of two ways, which are distinguished as the "dry-leaf," and the "green-leaf" process. The latter is considered the better, and is the more general; it is conducted as follows:—The flowering plants are cut down at about 6 in. from the ground, and immediately taken to the steeping vats, within which they are spread out, and pressed down by beams fitted to the side posts of the tanks. Enough water is then admitted to cover the plants; if this be delayed, fermentation may set in and spoil the product. The duration of the steeping is liable to considerable modification, and needs much judgment and experience; with a temperature of 35½° (96° F.) in the shade, 11–12 hours may suffice; in cooler weather, 15–16 hours may be necessary. Moreover, very ripe plants require less time than young and unripe ones. The following general conditions indicate the time for suspending the maceration:—(1) The sinking of the water in the vat; (2) the immediate bursting of the bubbles that arise; (3) an orange tint mingling with the green, when the surface water is disturbed; (4) the emission of a sweetish, pungent odour, quite distinct from the raw odour of the unripe liquor. At this point, men enter the vat, and stir up its contents, either by hand or by a wooden paddle. The agitation is at first gentle, but increases as the fecula begins to separate; this is known by the disappearance of the froth, and by the colour of the liquor changing from green to blue. The "beating," as it is called, is continued for 1¾–3 hours, the following conditions being a guide as to its sufficiency:—(1) The ready precipitation of the fecula from a sample of the liquor, and the Madeira-wine colour of the latter; (2) a brownish colour observed on dipping a cloth into the liquor, and wringing it out; (3) the appearance of a glassy surface on the liquor, and the subsidence of the froth with sparkling and effervescence.

Next, a little pure cold water, or weak lime-water, is sprinkled over the surface of the liquor, to hasten the settlement of the fecula, which occupies 3–4 hours. After this, the water is drained away from the top, by means of plug-holes in the side of the vat. The precipitated fecula is then removed to a boiler. Here it is made to boil as promptly as possible, and is kept boiling for 5–6 hours; it is constantly stirred, and skimmed with a perforated ladle. After boiling, it is run off to a straining table, where it stays for 12–15 hours to drain; next it is pressed for about 12 hours, and then cut, stamped, and placed to dry. The ordinary dimensions of a steeping-vat are 16 ft., by 14 ft., by 4½ ft. deep; this will contain about 100 *maunds* (8200 lb.) of plants, which may yield from 40 lb. downwards of indigo. The beating-vat is less deep.

Such are the methods of cultivation and manufacture most generally in use throughout India. In limited districts, however, some modifications are in vogue. On land subject to inundation, the plants last only one year. South of the Ganges, the seed is sown at the beginning of the rains, and the plants remain on the ground for two years, thus giving a double crop, the second of which is the larger and better. In very strong land, a third crop is sometimes secured. Occasionally, sesame is sown on the same ground, and harvested before the indigo is cut. Small quantities of indigo are grown on poppy lands, and irrigated. The seed is sown in March–April, and the crop is gathered at the end of the rains, in time for an opium crop to be taken off the land. Indigo is sometimes manufactured by collecting the fecula, and dropping it in cakes to harden in the sun; this is "gaud" indigo, of very inferior quality. The fecula is improved by boiling it in coppers, and pressing it into boxes. The production of the indigo blue is a result of the decomposition of the colouring principle of the plant, which exists as a glucoside. Plants grown on poor soils, and in dry climates, yield almost the whole of this glucoside to the ordinary process of steeping and beating, described above; but plants raised on rich alluvial soil, and in damp heat, contain an amount of glucoside which cannot be utilized by the ordinary process. In order to prevent this waste, which causes the richest plants to give the least return, it is necessary either to prolong the fermentation, and raise the heat to 35°–38° (95°–100° F.), or to add a solution of sugar or glucose to the vat-liquor. Olphert adopts the use of steam, to raise the temperature of the vat to 44° (111° F.), and thus obtains 25 per cent. more colouring matter.

The exports of indigo from British India, in 1878, were 120,605 cwt. About one-half of the total production comes from Behar and Bengal, especially from the districts of Tirhoot, Chumparun, and Sarun; the best comes from Kishnagur, Jessore, Moorshedabad, and Tirhoot. It is one of the most precarious of Indian crops, being very liable to the attacks of insects, and governed in a great measure by the seasons. The relative values of the various Indian brands in the London market are about as follows:—Bengal, fine violet, 8*s.* 6*d.*–8*s.* 9*d.* a lb.; good red violet, 8*s.* 4*d.*–8*s.* 6*d.*; mid. and ord. violet, 7*s.* 6*d.*–8*s.* 3*d.*; mid. to good violet and copper, 7*s.* 3*d.*–7*s.* 10*d.*; mid. to fine, 6*s.* 10*d.*–7*s.* 9*d.*; low and ord., 3*s.* 6*d.*–6*s.* 9*d.*; Kurpah, good to fine, 5*s.* 6*d.*–7*s.*; low to mid., 2*s.*–5*s.* 5*d.*; Oude, plantation, 4*s.* 6*d.*–6*s.* 6*d.*; native, 2*s.* 6*d.*–4*s.* 6*d.*; Madras, Vellore, 4*s.*–5*s.* 10*d.*; native, 1*s.* 9*d.*–4*s.* 4*d.*

Indigo culture extends very widely beyond India. In Cochin China, the plant is cultivated on light alluvial soils, of upper Tertiary age, where floods are of very rare occurrence. The native mode of preparing the dye is very rude; but several Frenchmen possess factories for the purpose, at Saigon and Cambodia. Small quantities of indigo are produced in Siam. Various plants (mentioned above) are cultivated extensively in all the provinces of China, for the production of the valuable dye; Canton exported 547 *piculs* (of 133⅓ lb.) in 1878. Japan possesses several large factories for preparing indigo from the native *Polygonum tinctorium.* The plants, 2–3 ft. high, are cut into three parts, the uppermost being the most valuable. The best dye is made from the leaves alone, which, after a few hours' exposure to air and sun, are placed in straw bags. They are afterwards removed from the bags, and moistened with water, which must be proportioned with the greatest exactitude. They are then spread upon, and covered by, mats, for a few days, after which the sprinkling is repeated. The process continues for about 80 days, the moistening being renewed about 25 times for the best leaves, and 9 for the inferior. After this fermentation, the leaves are pounded in wooden mortars for two consecutive days, by which they are reduced to a pulp; this is then formed into balls of dark-blue colour. The central provinces of Java yield large quantities of indigo, which are exported to Holland, and thence widely distributed. The indigo prepared by the natives is of an indifferent quality, in a semi-fluid state, and contains much quicklime; but that prepared by Europeans is of a very superior quality. An inferior variety, haviug smaller seeds, and being of quicker growth, is usually planted as a second crop on land where one rice crop has been raised. In these situations, the plant rises to the height of about 3½ ft. It is then cut, and the cuttings are repeated three, or even four, times, till the ground is again required for the annual rice crop. But the superior plant, when cultivated on a naturally rich soil, not impoverished by a previous heavy crop, attains a height of 5 ft., and grows with the greatest luxuriance. The plants intended for seed are raised in favoured spots, on the ridges of rice-fields in the neighbourhood of the villages, and the seed of one district is frequently exchanged for that of another. That of the rich mountainous districts, being esteemed of best quality, is occasionally introduced into the lowlands, and is thought necessary to prevent that degeneration which would be the consequence of cultivating for a long time the same plant upon the same soil. The climate, soil, and state of society of Java seem to offer peculiar advantages for the extensive cultivation of this plant. The periodical droughts and inundations of the Bengal provinces are unknown in Java, where the plant, in favoured situations, may be cultivated nearly throughout the whole year, and where it would be secure of a prolonged period of that kind of weather, necessary for the cutting. The dye is prepared in a liquid state by the natives, by infusing the leaves with a quantity of lime; in this state, it forms by far the principal dye-stuff of the country. The indigos prepared in Java by Sayers' process are of unusually high and constant quality. They contain an average of 70½ per ceut. of indigotine, and a minimum of 65–66 per cent.; and an average of 2·77 per cent. of ash. Ordinary commercial indigos seldom attain 65–66 per cent. of indigotine; and their ash averages about 16¼ per cent. The exports from Java, in 1878, were to Holland, 867,973 lb.; Italy, 19,496 lb.; Port Said for orders, 26,957 lb.; Singapore, 107,594 lb. The Philippines produce considerable quantities of indigo, the best coming from Luzon. The plants suffer from locusts and storms, but the cultivation is very profitable. The yield of indigotine is large, but the preparation is conducted in such a primitive manner that the value of the product is much deteriorated. The exports from Manilla, in 1878, were 151,500 lb., valued at 10,605*l.*; in 1877, 395,000 lb. were shipped. In many parts of Africa, as Sierra Leone, Liberia, Abeokuta, the Niger valley, Natal, Cape Colony, Tunis, and the Soudan, species of indigo plants are found in a wild state, and from them the natives prepare an inferior dye-stuff. In some of the S. States of America, notably S. Carolina, indigo culture has been attended with more or less success. The method of preparation pursued here varies but very slightly from the ordinary Indian process, almost the only important modification being the addition of a little oil to the liquor in the beating vat, when the fermentation becomes too violent. The precipitated fecula is placed in coarse linen bags, and hung up to drain. The drying is finished by turning it out of the bags upon a floor of porous timber, and working it up. It is frequently exposed to the sun for short periods at morning and evening, and is then placed in boxes or frames, to cure till it is fit for the market. Several of the Central American States have figured conspicuously as indigo producers. The dye is precipitated in the beating vat by the sap contained in the bark of Tihuilate (*Yonidium*), Platanillo (*Myrosma Indica*), or Cuaja tinta. The fecula is left during the night; and, on the following day, is boiled, filtered, pressed, and sun-dried. The London market values of the different grades, known here as "Guatemala," are as follows:—Flores, 7*s.* 2*d.*–7*s.* 3*d.* a lb.; Sobres, 5*s.* 9*d.*–7*s.* 1*d.*; Cortes, 5*s.* 8*d.*–6*s.* 8*d.*; low and lean, 4*s.* 1*d.*–5*s.* 6*d.* In most districts, the cultivation is declining, partly owing to the carelessness exhibited in the preparation of the dye.

Indigo is judged commercially by its lightness, by a copper gloss on the surface, and by exhibiting no foreign ingredients when broken. There are several ways of testing it chemically, to ascertain the exact proportion of indigotine present; one method is as follows:—Finely pulverized indigo, 1 part; green copperas, 2 parts; and water containing 10 per cent. of caustic soda, 200 parts; are well boiled in a flask, and left to cool. The clear liquor is exposed in shallow vessels to the air, when the soluble indigo is oxidized, and precipitated as pure indigotine. The residue in the flask is thus treated three times; the whole of the indigotine is then collected on a filter, dried, and weighed. The consumption of indigo is still very large; our imports, in 1878, were as follows:—From Bengal and Burmah, 45,798 cwt.; Madras, 9674; Central America, 7272; Bombay and Scindo, 675; France, 462; Holland, 280; Germany, 228; other countries, 1114. In 1879 the figures were:—Bengal and Burmah, 38,652; Madras, 27,654; Central America, 6635; Bombay and Scinde, 2963; France, 1241; Holland, 409; Germany, 354; and other countries, 2188. Artificial indigo has not, as yet, been manufactured on a commercial scale, nor at a commercial price; but it has been produced, in the laboratory, from coal-tar derivatives, and further experiment may reveal a process for preparing the article at a sufficiently low price to compete with the natural dye-stuff.

Several preparations of indigo are in use:—(1) Sulpho-purpuric acid, phenicine, or indigo-purple, is made by mixing 1 part of indigo with 4 parts of sulphuric acid (sp. gr. 1·845), and heating for ½–1 hour; the acid mass is thrown into 40–50 parts of water, when the purple falls down; it is collected on a filter, and washed with dilute hydrochloric acid; (2) Sulphindigotic acid is prepared by mixing indigotine, 1 part, with sulphuric acid (sp. gr. 1·845) 6 parts; the operation must be performed in a leaden vessel, cooled outside, and the indigo must be added by degrees, to avoid heating; the mixture is then left for 8 days, when the conversion will be complete. Fuming or anhydrous acid may be used, in less proportion, but the reaction is more difficult to manage. Weaker acid will require a longer period, say a month for "brown acid" (145° Tw.); (3) The sulph-indigotic acids are transformed into neutral paste, or "carmine," by neutralizing with carbonate of soda, and washing the paste, on a woollen filter, with a solution of chloride of sodium.

Kamala.—The fruits of *Rottlera tinctoria* (*Mallotus*, *Croton*, *Echinus Philippinensis*) are closely beset with ruby-like glands, which, when removed, constitute the powder known by the above name. It forms one of the minor products of the Government forests in Madras Presidency, and is also collected in many other parts of India. The berries are gathered in large quantities, and thrown into baskets, where they are rolled and shaken about, to thoroughly divest them of the powder, which, escaping through the wickerwork, is caught on a cloth spread beneath. In the N.-W. Provinces, the harvest commences in early March, and lasts for about a month. A little adulteration is practised by means of powdered leaves and stalks, and earthy matters. The product is in great repute as an anthelminthic, but is used chiefly as a dye. S. Arabia produces a similar powder, which is exported to Bombay and the Persian Gulf. A very peculiar form of the substance has been imported (viâ Aden) from Harár, in Somali-land, under the name of *Wars*, or *Wurrus*, a term properly confined to saffron. Its origin is uncertain; it is largely used, on the Muscat and Hadramaut coasts, in medicine and as a dye; Aden exported about 43,000 lb. of it in 1875–6. Fine Kamala is often adulterated largely with earthy matters; a large quantity in a very impure state was offered in London in 1878, for cleaning polished metal. The tree flourishes throughout India, up to 5000 ft.; in Ceylon, the whole Eastern Archipelago, E. China, N. Australia, Queensland, and New South Wales, and in Abyssinia and S. Arabia.

Kermes (Fr., *Kermès*; Ger., *Kermes*).—This colouring matter is furnished by several species of *Coccus*, named after the plants which they inhabit; it is identical in character with that afforded by cochineal. The most common variety of the insect is *C. ilicis*, found as a parasite on a dwarf species of oak, *Quercus coccifera*, a native of the whole Mediterranean basin. In England, this dye-stuff has been displaced by cochineal; but in S. France, Spain, Morocco, and Turkey, it is largely used for dyeing leather and woollens, and in Milan, Rome, and Florence, for colouring beverages. The female insect deposits some 1800–2000 eggs on the leaves and branches of the oak, the amount of the crop depending upon the mildness of the preceding winter. These eggs form excrescences, which are bodily removed just before hatching would take place, usually from mid-May to mid-June. The collecting is performed at early morning, while the dew lasts; experienced hands may pick 2 lb. in a day. The kermes are immediately exposed to the fumes of heated vinegar; this destroys their fecundity, and develops a dull reddish-brown colour. The quality and price deteriorate as the season advances. The Spanish product seems to be most esteemed. The Algerian product is chiefly consumed locally, but the exports reach about 4000 lb. yearly. France imports about 6000 lb. annually, for cosmetic and pharmaceutical preparations. The colour is scarcely so brilliant as that of cochineal; but it is unchanged by soap or dilute alkalies. Other descriptions of kermes are afforded by *C. Polonicus*, found on the roots of *Polygonum cocciferum*, and other plants, in the sandy soils of Poland, and S.-W. Russia; by *C. fragariel*, on roots of the common strawberry, in Siberia; and by *C. uva-ursi*, in Russia.

Lac (Fr., *Laque des Indes*; Ger., *Lackfarbe*).—This long-known dye-stuff is extracted from gum-lac (see Resinous Substances) by the following process:—The crude lac is coarsely ground, and immersed for 16 hours in a cistern of water; it is then trodden by men for about 4 hours, or until the colouring matter seems to be thoroughly extracted. The whole is then strained through cloths, while boiling alum-water is added; the coloured water is run through two or three settling tanks, remaining for about a day in each, by which the colouring matter is deposited. This is taken up, and placed on a canvas strainer till free from water (2–3 days); it is then pressed, to extract the remaining moisture, and, at the same time, formed into square cakes bearing the maker's name. Such is the general mode of preparation. An improved plan, adopted by Elliott Angelo, at Cossipore, is as follows:—The crude lac is placed in a horizontal disintegrator, supplied internally with water; the material is then broken very small, and the dye is extracted; should the water contain no lime, a little is added, to facilitate the precipitation of the colouring matter. The whole is left to soak for 24 hours in a large vat; the liquid is then drawn off through a series of settling tanks, each at a lower level; the clear water is drawn off at the top, and the sediment is collected, passed through strainers, left to consolidate, and pressed into cakes, which are dried in the sun. The exports of the dye-stuff from Bengal, in 1875–6, were:—to the United Kingdom, 9655 cwt.; America, 680 cwt.; France, 256 cwt.; other countries, 5 cwt. British Burmah, in the same year, exported 72 cwt. to England. The competition of coal-tar dyes has thoroughly crippled a once flourishing industry; the value of this dye-stuff in the Calcutta market has gradually fallen from 85 *rupees* a *maund* (of 82 lb.) in 1869, to 15 *rupees* in 1876, for finest quality; while inferior qualities, formerly worth 25–53 *rupees*, are now unsaleable. The London market prices are approximately as follows:—D T, 10*d.* a lb.; B Mirzapore, 9–10*d.*; J E & G Mirzapore, 2½–3¼*d.*; other good and fine, 5–10*d.*; ordinary and native, 1½–5*d.*

Lan.—This is a Chinese product, very common in the provinces of Kouang-Toung, Fokien, and Tche-Kiang It is derived from the fresh leaves of an acanthaceous plant, and yields a light blue on cottons.

Laureline.—This name has been given to some new colouring matters, which Dr. W. H. Gregg, of New York, is engaged in extracting from camphor. The main production hitherto has been yellow, in a variety of shades, and peculiarly brilliant and fast. It promises also to be cheap, and easily manipulated.

Litmus (Fr., *Tournesol;* Ger., *Lackmus*).—The colouring principle of orchella (q. v.) receives this name, when it is prepared in the following manner:—Lime and carbonate of potash are added to the ground lichen and urine; in 3–4 weeks, a blue colour is developed; this is mixed with gypsum or chalk, and dried. It is used in Holland for colouring cheese; by dyers, to produce crimsons; and in the staining of chemical test-papers.

Logwood (Fr., *Bois d'Inde, Bois sanglant;* Ger., *Blauholz*).—This well-known dye-stuff is the heart-wood of *Hæmatoxylon Campechianum*, a tree of moderate height, growing abundantly in Honduras and Mexico (as a native), and in most of the W. Indies (naturalized). The trees may be felled when about 10 years old; the bark, and the *alburnum* or white sap-wood, is chopped off, and the red heart-wood is cut into logs of about 3 ft. in length. The wood is dense and tough, but splits easily; it is very little affected by exposure, remaining brownish-red internally but acquiring a blackish-red tint externally. The felling, barking, and shipping of the wood constitute an important industry in the districts where it grows. Our imports in 1878 were contributed as follows:—British W. Indies, 19,621 tons; British Honduras, 11,147; Hayti and St. Domingo, 4541; Mexico, 1826; other countries, 1176. In 1879, they were respectively:—23,641, 10,680, 4964, 3205, and 2063 tons. Four kinds are distinguished in the London market:—"Campeachy," 7*l.* 15*s.*–8*l.* 10*s.* a ton; "Honduras," 7*l.* 10*s.*–7*l.* 15*s.*; "St. Domingo," 6*l.* 10*s.*–6*l.* 15*s.*; "Jamaica," 6*l.*–6*l.* 15*s.* Hamburg imports about 20,000 tons yearly. Logwood chips are used medicinally, for the astringent principle (see Drugs). For dyeing purposes, the logs are reduced to a coarse powder, by means of machinery; the powder is moistened, and laid in beds, 15–20 ft. long, 10–12 ft. wide, and about 3 ft. thick; fermentation ensues, by which the colouring principle, Hæmatein, $C_{32}H_{12}O_{12}$, is liberated. Large quantities of extract also are prepared. For this purpose, the wood must not be too highly oxidized; the solution obtained from it by repeated lixiviation is slowly concentrated at a temperature not exceeding 65½° (150° F.). This extract is much employed in calico-printing. Both the wood and the extract are extensively employed to produce cheap blacks on mixed fabrics. The exports from St. Domingo, in 1878, were about 1122 tons, half of which went to the United States, partly for re-shipment to Europe. Havre consumes large quantities. The exports from British Honduras, in 1878, were 13,704 tons. Under existing circumstances, this colony could easily keep up an export of 8000–10,000 tons annually; and a few seeds scattered, or a few trees planted, in any swampy ground, suffice to ensure a regular crop of the dyewood every 8–10 years.

Madder (Fr., *Garance;* Ger., *Krapp*).—The useful dye-plant, *Rubia tinctoria*, is very widely distributed, from S. Europe to E. Asia. In Central and S. Europe, it is still extensively cultivated though the development of the artificial manufacture of alizarine (see p. 683) is gradually driving the plant from Western markets. It is hardy, and withstands frost and drought; during the first winter, care must be taken, in very cold situations, that the heaving of the ground shall not expose the roots. It is propagated by sets or shoots; the best soil is a deep rich loam, containing abundance of lime salts. Planting is effected in small furrows, 3 in. deep, and 8–10 ft. apart, with a space of about 1 ft. between the roots. The ground is hoed to keep down weeds; and when the plants are 12–15 in. high, their tops are bent down to the ground, and covered with earth, except at the ends. In France and Holland, this last operation takes place in November; the practice is of questionable value, unless when sets are required for next year's planting, as it encourages "runners," which are valueless for dyeing purposes. A better plan is to cut off the herbage, which forms excellent fodder. The roots may be gathered in the 3rd year; in Turkey and the East, they are often left till the 5th–7th year, that the colouring matter may be more thoroughly developed by the oxidizing influence of the air. The benefit of this plan is, however, often counteracted by the attacks of fungi. The roots are removed singly from the ground, in August–September, and are thoroughly washed, dried, and stacked away. The drying is variously performed by sun-heat, in the shade, and by stove-heat. Fresh roots yield about 24 per cent. of commercial madder. The dried roots are selected according to quality, and ground to a fine powder, a process which is rendered very easy by the extreme brittleness of the root. The powder is stored in casks, and is said to improve by keeping for 2–3 years, but to deteriorate greatly beyond that time. The colouring matter resides almost entirely in the cortical part of the root. The best samples are grown on calcareous soils.

A preparation of the colouring matter of madder, known as *Fleurs de Garance*, is made in the following way:—The madder is mixed with 8–10 parts of water, and left for 3–4 days, at a temperature of 24°–27° (75°–80° F.), when fermentation ensues, transforming the sugar of the root into alcohol. The latter may be collected, and used for technical purposes, the yield being about 15 gal. from a ton of madder. The purified colouring matter amounts to about 55–60 per cent. of the madder. A more concentrated preparation is "garancine," prepared by treatment with sulphuric acid, which destroys much of the woody fibre, and affords about 25 per cent. of a fine light-brown colour. The pure colouring principles, alizarine and purpurine, are separated by the following method:—Madder, 600 lb., is macerated for 12–15 hours with 800 gal. of a weak solution of sulphurous acid, combined with 0·001 part of hydrochloric acid, to neutralize earthy carbonates present in the root. The operation is repeated three times; to the liquors, is added 3 per cent. sulphuric acid, and the whole is heated up to 60° (140° F.); red flakes are deposited; these, washed and dried, are commercial purpurine. The liquor is then boiled for 2 hours, and left to cool; a dark-green powder is precipitated; washed and dried, it forms alizarine verte. The product of purpurine is $\frac{1}{2}$–$\frac{3}{4}$ per cent.; and of alizarine, 3–4 per cent. Extracts of madder are produced by treating the roots with boiling water, collecting the precipitates separated on cooling, mixing them with gum or starch, and adding acetate alumina or iron. This forms a ready mordanted dye, which may be directly used in calico-printing.

The consumption of this once all-important red dye is now on the wane in England. Our imports, in 1878, were as follows:—*Madder:* from Holland, 16,750 cwt.; France, 4508; other countries, 601; *Madder root:* Turkey, 4224 cwt.; Holland, 3354; other countries, 3339; *Garancine:* France, 1762 cwt.; other countries, 820. In 1879, they were respectively:—10,822, 2862, 28, 0, 5819, 1932, 1071, and 418 cwt. Turkey madder root, which is considered the best, is now worth about 13–14*s.* a cwt.; in 1868, the prices were:—French madder, 45*s.*; Turkey roots, 50*s.*; garancine, 150*s.* The cultivation of madder in England has never been attended with success, from climatic causes; moreover, it could not be made remunerative except where land is very cheap, and where coal-tar dyes are not produced. These conditions are fulfilled in many of our Colonies; several of the Australian *Droseræ* yield an identical (or nearly so) colouring matter, and may repay cultivation. The production in France, where formerly the plant was very extensively grown, especially in the department of Vaucluse, whose principal town, Avignon, was renowned for this article, fell, in 1878, to about 14,000 cwt., the yield of about 1000 acres. In 1871, nearly 30,000 acres gave over 263,000 cwt. Here the plant is generally raised from seed, sown in the spring. Holland was estimated to produce annually about 14$\frac{1}{2}$ million lb. of madder roots a few years since. The best were grown in the islands of Schowen and Duiveland, and in the district comprised between the mouths of the West Escourt and the Belgian border. The cultivation in Italy has been entirely abandoned, yet, in 1878, some 24,000 cwt. of roots were still on hand in Naples.

The plant grows wild throughout a large portion of Central Asia and S. Russia. It is also cultivated more or less in many districts, notably about Kouban in Baku, and around Derbend. The best is said to be produced in Astrakhan, Derbend, and Trans-Caucasia, the last being known as "Persian"; the qualities of the growths of Kokhand, Bokhara, and Khiva, are in the order given. The best Persian madder comes from Yezd.

Successful attempts have been made to cultivate madder in some of the United States, as at Columbus and Birmingham, in Ohio; at Montague, Franklin Co., Massachusetts; and on the Connecticut River.

Mexican Blue.—The colouring matter of *Sericographis Mohiti*, a native of Mexico, serves the indigenous inhabitants as a blue dye for textiles, which are simply plunged into a hot decoction of the plant itself. The colouring principle bears much resemblance to litmus, being reddened by acids, and then rendered violet by alkalies.

Munjeet (Fr., *Garance des Indes;* Ger., *Munjeet*).—A product much resembling madder, and very generally replacing it in Eastern industry, is afforded by the plant known as *munjeet*, an Indian name, applied not only to *Rubia Munjista* (*cordifolia*), but also, it would seem, to *R. tinctoria*, or true madder. The plant is cultivated in many parts of India, as Assam, Nepal, and Bombay. The dried root has occasionally reached this country, but was unable to compete with European madder, as its colours were neither so bright nor so fast. It is, however, a very important article of export over the Himálayas to Thibet, where great quantities are consumed in dyeing the garments of the Lhamas. Our imports, in 1878, were 285 cwt. The London market value is about 20*s.*–25*s.* a cwt.

Nag-kassar.—The flower-buds of *Mesua ferrea* (see Perfumes) are used in India for dyeing silk; they have once been introduced into the London market, under the name "Nag-kassar," a corruption of the Bengalee *Nag-kushur.*

Orchella (Fr., *Orseille*, *Tournesol;* Ger., *Orseille*).—Three colouring matters, known respectively as Orchil, Cudbear, and Litmus, are obtained from two species of lichen, *Rocella tinctoria*, and *R. fuciformis*, found growing in the Canary Isles, the Cape Verds, Sardinia, Madagascar, Zanzibar, and Angola, but commercially obtained chiefly from Central America. From recent studies of *R. fuciformis*, it is concluded that the lichen contains two colouring matters already formed, while a third (red) is developed by reagents. The lichen is treated with hot water, to extract the green principle; then with alkaline carbonate (preferably soda), to remove the red element; and finally with alcohol, to obtain a solution of the yellow colouring matter. The consumption of orchil in this country is now almost entirely superseded by the aniline dyes, though it is occasionally employed for "topping" cheap indigo blues on cotton goods. The exports of this article in 1878 were, from Mogador, 60 cwt., value 90*l.*; from Guayaquil, 738 quintals (of nearly 2 cwt.), value 1107*l.*; all to Great Britain. The London market values are approximately as follow:—Ceylon and other E. Indian, 20–45*s.* a cwt.; Zanzibar and Mozambique, 28–40*s.*; Guayaquil, 30–35*s.*; Californian, 24–25*s.*

Osage Orange.—The wood of the hedge-plant, known as the Osage orange (*Maclura aurantica*), when boiled in water, yields a yellow extract, which, in Texas, is employed as a handsome dye.

Panama Crimson.—The leaves of a vine called *china*, which grows abundantly in the hilly regions of the Isthmus of Panama, and sheds its leaves annually, are used by some of the natives for dyeing their straw hats of a beautiful crimson tint. Commercially this dye-stuff has been quite ignored, yet it possesses the valuable properties of withstanding sun and rain, without deteriorating in the least.

Persian, or Yellow Berries.—Bright yellows and greens are produced from a decoction of the berries of *Rhamnus tinctorius*, *R. infectorius*, *R. saxatilis*, *R. amygdalinus*, *R. oleoides*, which, among dyers, are known indiscriminately as "Persian berries," while among dealers, they are named from the place whence they are imported, as "Avignon grains," Spanish berries," "Turkish berries," "Persian berries." The different species or varieties of the plant grow well in France and Spain; throughout Asia Minor and the E. Taurus, figuring largely among the exports of Alexandretta and Smyrna; and are much cultivated in Persia, especially in the neighbourhood of Kaswin. The berries should be gathered just before they arrive at maturity, otherwise good results cannot be obtained with them. After keeping for a year or two, they yield much less brilliant colours. The yellower they appear, the lower is their market value. The berries are used by dyers of woollens and mixed fabrics, by calico-printers, paper-stainers, and leather-dressers. Their decoction also yields a lake (see Pigments). The London market value of Yellow berries is about 45–65*s.* a cwt.

Poppy (Fr., *Coquelicot;* Ger., *Klatschrosen*).—A fine red colouring matter is furnished by the petals of the common red poppy, or corn rose (*Papaver Rhœas*), an annual herb, found abundantly in fields throughout all Europe. The plant is a common accompaniment of cereal crops, and is plentiful in England and Ireland, but less common in Scotland. It seems to be strictly a native of Sicily, Greece, Dalmatia, and, perhaps, the Caucasus; it is very common in Central and S. Europe, and in Asia Minor, whence it reaches to Abyssinia, Palestine, and the banks of the Euphrates; but it is absent from India and N. America. The colouring principle of the petals is still very imperfectly known; it is readily taken up by water, and by spirit of wine, but not by ether. The petals, preferably in a fresh state, are employed in pharmacy, for their fine colouring matter. They contain no medicinal principle.

Pupli.—The root-bark of the *pupli* (*Ventilago Maderaspatana*) is in common use in India, to produce orange, chocolate (with chay-root), and black (with galls) dyes. The roots are gathered by Yanadis, a rude tribe living in the jungles of the Nellore district, and subsisting by the collection of natural products.

Quercitron (Fr., *Quercitron;* Ger., *Quercitron*).—Fine yellow colouring matter is obtained from the bark (deprived of epidermis) of a species of oak, called *Quercus nigra* (*tinctoria*). The tree is a native of N. America, and is found especially in the forests of Pennsylvania, Georgia, and the Carolinas. The most esteemed qualities are imported from Philadelphia, New York, and Baltimore. The bark is removed from the tree, dried, and ground between mill-stones. The value of the powder is in direct proportion to its fineness, as the woody fibre of the bark, containing but little colouring matter, is not readily reduced. The bark is now seldom or never used directly by dyers, having been replaced by the preparation known as "flavine," the colouring principle of the bark in a commercial form. Flavine is made by two different processes:—(1) About 10 cwt. quercitron bark is boiled with 63 lb. soda crystals in about 2000 gal. water; after boiling for about 15 minutes 250 lb. concentrated (sp. gr. 1·845) sulphuric acid is added; the whole is then kept boiling for 2 hours, when it is run on to woollen filters, washed till free from acid, pressed, and dried. (2) A better method, perhaps, is as follows:—About 100 parts quercitron bark, 300 parts water, and 15 parts sulphuric acid (as before) are boiled together for 2 hours; the mass is then washed, pressed, and dried, as in the first process. The yield from 100 parts quercitron bark should be 85 parts flavine, with a dyeing power equal to 250 parts of the bark. Quercitron bark gives a fine yellow on woollens, but the colour reddens by exposure, and its use is on the decline. Flavine is employed in calico-printing, less as a yellow dye, than to communicate browns and oranges to madder reds.

Safflower (Fr., *Carthame, Safran bâtard;* Ger., *Saflor, Falsche Safran*).—The dye-stuff known as "safflower" is the bloom of a species of thistle, *Carthamus tinctorius*, cultivated in France, Spain, Italy, Egypt, and India. The European method of preparing the dye is as follows:—The florets forming the compound flowers are picked by hand in dry weather as fast as they begin to open, for by waiting for the expansion of the whole flower, the colour commences to fade. The gathered florets are at once carefully dried, either in the shade, or under pressure in a kiln. The next object is the separation of the true colouring principle, termed carthamic acid, $C_{14}H_{16}O_{14}$, from a secondary yellowish colouring matter, affording only dull shades of no value, and from impurities. This separation is rendered very easy by the solubility in water of the useless principle. The florets are tied in a sack, and laid in a trough, through which gently flows a constant stream of water; the sacks are then trodden, to help the expulsion of the yellow matter; this is continued till the effluent water exhibits no yellow tint. If the safflower is not required for immediate use, it is simply removed, dried, and pressed into cakes, when it is commercially known as "stripped safflower." To extract the red colouring matter, a further process is necessary:—the florets are again placed in water, to which is added crystallized carbonate of soda, to the amount of about 15 per cent. of the weight of safflower; the mass is left to macerate for about two hours, and the liquor, holding carthamate of soda in solution, is run off from the exhausted flowers. This liquor may be used directly as a dye, by adding citric acid, to liberate the carthamic acid; or the carthamate of soda may be decomposed by tartaric acid, when the carthamic acid is precipitated as a brilliant red amorphous powder. This powder, mixed with a little water, is sold as "safflower extract." Both it and stripped safflower are used, principally in and around Lyons, for giving red, bright orange, cherry, rose, and flesh tints to silks and satins. Safflower extract, dried, and mixed with ground talc, forms the popular cosmetic known as *rouge;* the extract is also occasionally used for colouring confectionery, but possesses purgative qualities. Safflower was for a long time the only dye used on red tape, and large quantities were consumed in Lancashire for the production of peculiar pinks for the Eastern markets. It is, however, declining before the coal-tar colours. A special preparation used in dyeing contains the carthamic acid in a condition that renders it soluble in water.

In India, safflower is extensively grown; in Bengal, it has received the attention of the local government. It is cultivated chiefly in the district between the Ganges and the Dhulleseray; 6 *seers* (say 12½ lb.) of seeds are required to sow 1 *beegah* (3025 sq. yd.) of land, and should yield about 10 *seers* (say 20½ lb.) of flowers. Land subject to periodical inundation is the best; the crop is exhaustive, and the returns will not be good for more than about 3 years in succession. The land is ploughed, and the seed is then sown broadcast, or dibbled in with the finger. Weeding must be attended to. Rain, when the plant is 1 ft. high, is beneficial; but after the appearance of the flower, it is injurious, and washes out the colour. The sowing season is October-November; harvesting takes place in March-April, when the petals assume an orange hue. The petals are plucked as they mature, at intervals of 2–3 days, and the operation has generally to be performed 4–5 times. The first harvest yields many undeveloped flowers, deficient in dyeing qualities; the last contains also many inferior flowers, as the plant is then old and withering, and the colours are fading. Skill and attention are required of the gatherers, who must be in sufficient number, as the least delay after the florets have matured causes the colour to deteriorate, and may eventually destroy it. As fast as the petals are picked, they are placed in mat baskets, in the shade, and trodden for about an hour; they are then left during the night, without any water having been applied to them. Next morning, they are placed on a mat, arranged to permit the free escape of the water, which is constantly poured on, while the mass is kneaded. River water is preferable to tank water; when filtering is impossible, the water must be allowed to stand for at least 24 hours before use, as the presence of muddy matters would spoil the colour. After being worked up in this way for two hours, the mass is replaced in baskets, and moistened with water; in the afternoon, it is again kneaded for about two hours, and abundance of clean water is poured over it. This kneading process should be repeated at morning and evening for 3 days, the mass never being allowed to become dry. To ascertain whether the pulp is fit for use, a sample is put into clean water; if the least tint is communicated to the water, kneading and washing must be resumed.

The purified pulp is squeezed between the hands, so as to form little cakes, about $1\frac{1}{2}$ in. wide, and $\frac{1}{8}$–$\frac{3}{16}$ in. thick in the middle, tapering to the edges. Large cakes are liable to be broken up, and are less in favour with merchants. The cakes are laid on mats to dry in the sun for 3–4 days; during this time, wet weather is destructive of the colouring matter, and retards the process. The dried cakes should be kept in dry covered receptacles. After the flower crop has been harvested, the plants are left for about 3 weeks, for the seed to ripen; they are then cut down, or pulled up, and spread to dry in the sun, after which, the seeds are beaten out with flails. The seeds in excess of the requirements for the next season's sowing are pressed, and yield an oil (see Oils), useful for culinary, illuminating, and medicinal purposes; the leaves and stems are used as fuel, and the ash they afford contains so much potash as to be a good substitute for soap. In Assam, Dacca, and Rajpootana, safflower is cultivated for export; that from Bombay is least esteemed. The dye is largely used in India, despite its fugitive nature. Its value in Western markets has been much depreciated by adulteration. The production of Indian safflower is now estimated at about 12,000 cwt. annually. In 1868, we imported over 32,000 cwt. from British India; in 1878, the total imported from Bengal and Burmah was only 3263 cwt., valued at 14,773*l.*; in 1879, our imports were:—from Bengal and Burmah, 926 cwt.; other countries, 222 cwt.

China has always been known as producing very superior safflower. The plant is extensively cultivated for dyeing purposes in the provinces of Sechuan, Yunnan, Honan, Kiang-si, and Chenai. The flowers are plucked, and placed in cloth bags; here they are strongly pressed, and are then dipped in a succession of baths of water; the bags are wrung several times, in order to extract all the yellow principle; and the flowers, containing only the red colouring matter, are damped with an aqueous solution of the ashes of rice-straw (for the sake of the alkali present), covered with green herbs, left for one day, and then formed into cakes. Safflower is an article of considerable importance in local Chinese trade. The exports of the article, in 1878, were:—from Hankow, 6544 *piculs* (of $133\frac{1}{3}$ lb.), valued at above 121,000*l.*; and from Ichang, $405\frac{1}{2}$ *piculs*, valued at 6342*l.*

Besides the safflower imported from India, in 1878, we received 196 cwt. from other countries, not specified in the returns. The relative market values of the different commercial brands are about as follows:—Bengal, good to fine, 8*l.*–10*l.* a cwt.; ord. to mid., 7*l.* 15*s.*–8*l.* 17*s.* 6*d.*; Persian, 1*l.*–5*l.*

Saffron (Fr., *Crocine;* Ger., *Safran*).—The saffron crocus (*Crocus sativus*) bears a great resemblance to the common garden crocus, but flowers in the autumn. It is supposed to be a native of Greece, Asia Minor, and probably Persia, but long ages of cultivation have rendered its home doubtful; by some, it is considered a hybrid. In the early part of the last century, it was largely cultivated in an area of 10 miles lying between Cambridge and Saffron Walden, and though the culture almost ceased to exist towards the end of the century, small parcels of the blossoms continued till a much later date to be brought to the London market. This branch of agriculture now flourishes chiefly in Spain,—in Lower Arragon, near Alicante, in N. Murcia (Albacete), in La Mancha, near Huelva, and in the island of Mallorca (near Palma). In France, the cultivation survives in the district of Pithiviers-en-Gâtinais (Loiret). In Italy, it was, till lately, very general, the most celebrated localities being Castelnuovo, Catania (Sicily), Aquila (Capitanata), St. Gavino (Sardinia), Bibbiena, and Montalcino (Tuscany). In Austria, small quantities of excellent saffron are produced at Maissan, north-east of Krems. Ghayo, an elevated region on the borders of Persia and Afghanistan, affords large contributions; and a little is collected at Pampur, in Kashmír. The cultivation is carried on in some parts of China; and in the United States, the collection of the flowers occasionally occupies the German inhabitants of Lancaster Co., Pennsylvania.

In France, where the cultivation is carried on by small peasant proprietors, a saffron-field is not in full bearing till the end of the second year; at the end of three years, the land is so exhausted that this crop cannot be repeated for 15–16 years. The plant requires a very peculiar soil, and land suitable for it brings double the ordinary price. An analysis of a very favourable soil gave:—Quartzose sand, 26·8; silica and alumina, 27·9; oxide of iron, 2·0; carbonate of lime, 37·0; water, and organic matters, 6·3 per cent. An acre should yield 600,000–700,000 bulbs, each producing 2 or 3 flowers; about 150,000 flowers will give 1 lb. of fresh pistils—the only valuable portion—which are reduced to about $\frac{1}{5}$ by drying; the average return of dry pistils in the second and third years is 9–27 lb. an acre. The flowers are gathered in September–October. The separation of the pistils from the flowers entails enormous labour, and costs 10*d.*–4*s.* a lb., according to the labour market. The extracted pistils are carefully dried, in lots of about 1 lb., by suspending them for $\frac{1}{2}$ hour in a horse-hair sieve over a gentle charcoal fire. The dried pistils are then bought up by commercial travellers, at about 30*s.*–40*s.* a lb.—8*l.* a lb. has been given,—chiefly for export to Germany. Despite its high price, saffron does not always repay cultivation, on account of the risk of damage from the weather, and the attacks of fungi.

In Sicily, and some of the provinces of S. Germany, the plant is grown in gardens, with great care, and yields a superior product, though small in quantity. The flowers are plucked in the autumn at early morning, and the pistils are dried very gradually in special stoves. The neighbourhood of the town of Tastus, in Tunis, produces a small quantity of excellent saffron. An important centre of cultivation is Safranbóli, in the vilayet of Kastamouny, Asia Minor. The bulbs are there transplanted in April; and, in the autumn of the third year, yield an abundant crop, valued at about 50s. a lb. In Kashmír, the cultivation is carried on in nearly every part of the pergunnah of Pampur, the local soil alone being found suitable. It appears to consist of a light ferruginous clay, which is excavated near the Djilam, and carried to the fields at great expenditure of labour. The bulbs are planted out in small square beds in June, weeded, and freely irrigated, and the crop is gathered in October. Its value varies from 5s. a lb. downwards, according to the extent of adulteration.

Commercial saffron, or "Hay saffron," as it is called, consists of a mass of crooked threads, often united in threes; their colour varies from deep orange-red to whitish; they have an aromatic, sharp odour, a pungent, balsam-like flavour, and are unctuous, tough, and flexible. Spanish saffron is quoted wholesale at 20–44s. a lb.

As a dye-stuff, saffron is now replaced by much cheaper substitutes; it is, however, still retained for colouring medicines and confectionery, and is largely used as a condiment, on the Continent and in India. In the latter, it is also employed in religious rites; and medicinally, though it is quite inert as a drug. It is sparingly used in Italy, for staining skins. The colouring matter amounts to about 42 per cent., and is so powerful that a single grain will distinctly tinge 10 gal. of water.

The high price of saffron has always been a great incentive to adulteration, which is practised in a number of ways. Sometimes *Calendula* flowers dyed with logwood, or safflower blossoms, or saffron stamens, or marigolds, or slices of pomegranate petals, are added. Another system consists in coating the genuine saffron with powdered carbonate of lime, previously coloured orange-red; barytes and emery powder are similarly used, and rendered adherent by honey. The weight is sometimes increased by the addition of oil or water. A curious fraud perpetrated in Italy is the substitution of shreds of fibrous beef, previously boiled to remove the soluble matters, then stained with solution of saffron, and dried. The presence of almost any adulterant can be detected by throwing a little of the sample into a glass of warm water: inorganic matters will create a turbidity; organic substitutes can be recognized by their shape, and change of colour.

Sanders-wood (Fr., *Santal rouge*; Ger., *Rothes Sandelholz*).—The wood of *Pterocarpus santalinus* (perhaps also of *Pt. Marsupium*), which is very commonly confounded with Sandal-wood (see Perfumes), contains the same colouring principle as Barwood and Camwood (*q. v. ante*). The tree is a native of S. India, as Canara, Mysore, Travancore, and the Coromandel Coast; it is also found in Mindanao, in the Philippines; and the discovery of a large forest of the trees in the Fiji Islands has recently been announced. Our supplies are drawn from the S. Indian forests, where the tree is now systematically cultivated (see Timber). The portions of the tree used in dyeing are the base of the stem and the thickest roots. It is imported from Madras, in heavy logs, 3–5 ft. long, without bark or sap-wood. For use, it is rasped into small chips. It is employed chiefly on the Continent, for giving a "bottom" to cloth which is to be afterwards dyed with indigo; it is also used as a colouring ingredient in pharmacy. It value is 6s. 3d.–6s. 6d. a cwt.

Sapan-wood (Fr., *Bois de Sapan*; Ger., *Sapanholz*).—The wood of *Cæsalpinia Sapan* may be considered the log-wood of the East. The tree grows in Malabar; abundantly in Siam and the Tenasserim Provinces; and in the Philippines. In Paulghât, Madras, it is regularly cultivated. In the N. provinces of Siam, and along the hills dividing that country from Tenasserim, the tree grows wild. Great quantities are annually sent from Soupan and Bang-chang, and from the W. coast of the Gulf of Siam, viâ Bangkok to Singapore, and to Dacca. Large forests of it are said still to exist about the head-waters of the Hlion Bwai and Dagyne rivers, and it is distributed more or less throughout the whole of the Tenasserim Provinces. The Philippines contribute largely to the commerce in Sapan-wood, most of the product being consumed in China, where it affords the common brownish-red dye of the poorer Chinese clothes. The exports from Manilla, in 1878, were 6019 tons, of which 5167 tons went to Hong Kong, and 545 tons to Great Britain; the estimated value was 20,485*l.* The exports from Cebu, in the same year, were 781 *piculs* (of 139⅓ lb.); and from Yloilo, 32,232 *piculs* were sent to Hong Kong, and 3522 *piculs* to the United States. The principal localities of production in Yloilo are the villages of Guimbal and Tigbanan, in the south of the island; also the neighbouring island of Guimaras. The wholesale London prices are approximately:—Siam, 7*l.* 10*s.* a ton; Manilla, 6*l.* 5*s.*–9*l.*; other kinds, 6*l.* 10*s.*–12*l.* 7*s.* 6*d.* Both the trunk-wood and root-wood are employed. It is much used in Pegu, for giving a red tint to silk; and in Madras, for dyeing straw-plait for hat-making.

Tisso, or Teesoo.—The flowers of *Butea frondosa* (see Fibrous Substances), and probably also of *B. superba*, are employed in India and China, for giving yellow and orange tints to cotton goods. They were once imported into Liverpool, as "Kessaree flowers," but are not now known in Western commerce.

Tokio-purple.—The root of *Lithospermum erythrorhizon*, a native of Japan, contains a red colouring principle, which is used with mordants, to dye a purple shade known as "Tokio-purple." The roots occur in commerce as thick lumps, purple without, and yellowish-white within. It would appear to be useful rather for colouring oils, than for dyeing textile fabrics.

Turmeric (Fr., *Curcuma;* Ger., *Kurkuma, Gelbwurzel*).—The root of *Curcuma longa* affords a yellow colouring matter. The plant is indigenous to S. Asia, both continental and insular, where it is largely cultivated. The rhizomes are of two kinds: the central ones are round, seldom less than ⅝ in. thick, often cut and scalded, to destroy their vitality and facilitate drying; the lateral ones are long. Both are very hard and firm, with a dull waxy resinous fracture, of orange, or orange-brown colour; they possess a peculiar aromatic odour and flavour. Five descriptions of turmeric are now distinguished in the English market, according to the locality of production, but possessing too feebly marked characters to admit of verbal definition. These are:—(1) China, largely shipped from Takow (Formosa) to Chinese ports; it is rare in the European market, and is much esteemed, its price being about 15–21*s.* a cwt. (2) Madras, a fine variety, occurring in pieces termed "fingers," and valued at 13–25*s.* a cwt. (3) Bengal, possessing a deeper colour than any other sort, and therefore preferred by dyers; value, 13*s.* 9*d.*–14*s.* a cwt. (4) Java, distinguished chiefly by being dusted with its own powder, and showing a dull fracture; worth 10–11*s.* a cwt. (5) Malabar, in "bulbs," 8*s.* 9*d.*–10*s.* a cwt. A sixth variety, termed Cochin, not quoted in London lists, appears to belong to another species of the plant (see Starch). *C. longa* grows wild in many parts of India, and is a general object of cultivation. It prefers rich, light soils; and is easily propagated by off-sets from the roots. An acre should yield 2000 lb. of fresh roots. The roots are dried and ground, for use. Very fine turmeric is said to grow in the Isthmus of Panama, and to await commercial development. On the slopes of all the hills bordering the plains of the Beni, in Bolivia, the plant is found in large quantities, and the roots will probably soon become an article of export. The so-called "African turmeric" is yielded by a species of *Canna*, which is cultivated by the inhabitants of Sierra Leone, for the rich yellow dye afforded by its rhizomes. The tubers attain maturity in December–January, and are then dug up, and sun-dried, before being taken to market. The price is nominal, and depends upon the demand. The value of turmeric in Western commerce depends solely upon its yield of colouring matter, Curcumin, $C_{10}H_{10}O_3$; its employment in dyeing textiles is limited and declining, and one of its principal uses is for giving a yellow tint to chemical test-papers. In the East, it is used less as a dye than as a condiment; it is also a common ingredient of curry-powders (see Spices).

Walnut-husks.—The green outer husks of walnuts contain a yellow-brown colouring matter, which dyes remarkably permanent shades on woollen and cotton goods, and might be used for staining wood. No mordant is required for wool, and the dyeing is cheap and simple. The husks may be kept dry till used, or packed moist in tubs, which latter increases their colouring power.

Weld (Fr., *Gaude, Vaude;* Ger., *Wau*).—The pods of the non-aromatic variety of mignonette, named Weld (*Reseda luteola*), afford a yellow colouring matter, which has been called Luteoline, $C_{24}H_8O_{10}$. The plant is either annual or perennial, growing to a height of 2–3 ft.; it flourishes best in light calcareous soils. The seed should be drilled in during early autumn, on land that has been well tilled. About 10 lb. of seed suffice for an acre. Inflorescence commences in the following July, when the crop may be harvested; or the ripening of the seed may be awaited, the latter being then thrashed out, and pressed, yielding 25–35 per cent. of oil. The plants are pulled up by the roots, and left lying for a few days on the ground; they are then tied together in small sheaves, and set up to dry, after which they are ready for transport to market. An average crop will be 30–40 cwt. an acre. The plant is very liable to attacks of mildew, which much reduces the value of the return. The permanence of the dye, and its suitability for both animal and vegetable tissues, led to its being largely cultivated in England, and on the Continent; but the competition first of quercitron and flavin, and then of aniline dyes, has caused it to be almost, or quite, abandoned.

Woad (Fr., *Guède, Vouède;* Ger., *Waid*).—The leaves of *Isatis tinctoria*, a variety of the indigo plant, yield a blue dye, which will ever be historically interesting, as the substance with which the ancient Britons stained their bodies, but which has been driven out of the English market by true indigo. In districts where indigo cannot be obtained, its culture may still be remunerative. The plant thrives only in deep friable loams, such as the fen lands of Lincoln and Huntingdon, and 3–4 years is the maximum period for which it can be continuously grown in one spot. The seed is drilled into the ground in March–May; the young plants are thinned out as soon as they are 3–4 in. high. By the middle or end of July, the first sowing will be ready for cropping, which should be commenced as soon as the leaves of the plants (8–9 in. high) begin to change colour. The leaves are pulled off separately by hand, and conveyed to the manufactory; in about 6 weeks, a fresh crop of leaves is produced; and sometimes a third crop is taken in the same way. The produce, however, decreases each time. A portion of the crop is left to produce seed; the flower-stem is thrown up in spring, and the seed-pods ripen about July, when they are plucked, and threshed with flails. The dye is prepared from the leaves in the following way:—The leaves are crushed in edge-runner mills; the pulp is removed, and laid up in small heaps to drain, till the mass is sufficiently dry to cohere; it is then "balled," or pressed by hand into lumps, 4–6 in. thick.

The balls are taken into a drying shed, which is roofed and well ventilated, and are spread on hurdles. When thoroughly dry, the balls are stored in a dry and airy place till the whole crop is completed; they are then submitted to the final "couching," or fermentation. This forms a winter occupation. The balls are ground to coarse powder in the edge-runners, and spread 2–3 ft. thick on the floor of the "couch." The powder is now watered and constantly turned over, to ensure the utmost possible equality in the fermentation. Considerable heat, and abundant offensive fumes, are generated; if the fermentation be too slow, the product becomes "heavy," if too rapid, "foxey"; in either case, its value is much affected, consequently the operation needs to be conducted with great skill. When completed, the mass is simply turned, till its temperature sinks low enough to admit of its being packed in casks for transport to market.

Bibliography.—T. Shortt, 'Culture and Manufacture of Indigo' (Madras: 1862); P. L. Simmonds, 'Tropical Agriculture' (London: 1877).

(See Coal-tar Products; Dyeing; Pigments.)

ELECTRO-METALLURGY.

The deposition of metals upon prepared surfaces from solutions of their salts, by electrical action, is the object of the art of electro-metallurgy. So far as can be ascertained, it has only been applied in a commercial form during the present century. Two great branches of the many processes included under this general name are extensively practised; in the one a thick non-adherent deposit, generally of copper, is required, as in reproducing metallic fac-similes of wood engravings, or electrotypes as they are termed, small statues, and the like; whilst in the other a thin adherent deposit is sought, either for the protection or ornament of the article to which it is applied. In practising electro-metallurgical processes, the principles of both chemical and electrical action are largely intermingled and brought into play, and therefore some little knowledge of these principles is essential for their intelligent conduct. The varying powers of conducting and insulation which various bodies possess has been repeatedly made a matter of investigation. Conductors are those substances which freely allow of the passage of electricity; whilst non-conductors, or dielectrics as they are often called, resist its passage. The best conductors are the metals, graphite, water, alcohol, dilute acids, oils, metallic oxides, and some few others; whilst most of the gums, silica in every form, including glass, ebonite, shellac, indiarubber, guttapercha, sulphur, wax, wool, hair, dry paper, are dielectrics; practically the insulating substances usually employed are either guttapercha, glass or indiarubber, cotton or silk; thus wires for conducting electricity are covered with either of these substances, whilst glass is commonly used for supports which require to be insulated, and also for enclosing the wires on which many articles are suspended in solution.

Taking silver as equal to 100, Matthiessen has stated that the relative conducting powers of pure metals are

Silver	100·0	Tin	12·4
Copper	99·9	Thallium	9·2
Gold	77·9	Lead	8·3
Zinc	29·0	Arsenic	4·8
Cadmium	23·7	Antimony	4·6
Palladium	18·4	Mercury	1·6
Platinum	18·0	Bismuth	1·2
Cobalt	17·2	Graphite	·069
Iron	16·8	Gas coke	·038
Nickel	13·1	Bunsen's coke	·025

The slightest admixture of alloy will materially influence the conducting effect of a metal; whilst many foreign substances which enter into the composition of metals, if not eliminated, so far interfere with their conductivity as to exclude their use for electrical purposes. Of the above, copper is the metal most commonly used for conducting; it is very flexible, easily obtained, and, whilst not being readily oxidized, can be procured with sufficient pureness to render it available for most purposes. Iron wire is rarely used for electro-metallurgical purposes, in consequence of its high resistance.

Batteries are only employed in small work, as operations of magnitude are usually conducted with the aid of magneto-electro machines. The batteries most in favour are Wollaston's, Smee's, Daniell's, Bunsen's, and Grove's. Battery selection and management are matters involving considerable experience; it may, however, be accepted, that Wollaston's is the most suitable one in cases where the resistance is not great, and where a large quantity of electricity and long-continued action, as in depositing copper and silver, are required; its action after commencement is uniform, and large plates with considerable bulks of exciting liquid may be used. Smee's is available for similar work on a smaller scale, as when of large size it is expensive. Daniell's is best when the resistance is great and a very uniform current is necessary. Grove's and Bunsen's are preferable where the resistance is still greater, and occasional currents of considerable electro-motive force, but not of long continuance, are necessary, as in gilding, nickel plating, and in brassing or coppering in cyanide solutions on iron.

Magneto-electric machines, such as those of Gramme, Wilde, Siemens and Alteneck, Weston, Elmore, and others, are extensively used in large establishments, since it has been conclusively proved that the magneto-electric machine possesses innumerable advantages over the battery for plating purposes.

The first cost of the magneto-electric machine is certainly greater than that of a battery necessary to produce the same amount of power; but the working expense is considerably less, being limited to a trifling motive power; it appears destined to supersede every other apparatus in the deposition of metals of low equivalent proportions, as the expense of the battery in such precipitations renders the process an expensive one. Hence the expense of depositing, compared with the value of the metal deposited, is very great; in the magnetic machine, on the contrary, the expense of depositing is limited to the power required to produce the rotation of the armatures.

The uniformity of the current developed in the magneto-electric machine is not the least of its many advantages. In the best constant battery, the quantity varies during the course of several hours; and even good operators find it necessary to give close attention to the state of the instrument and the progress of the deposition. With the magneto machine, the deposition goes on with extreme regularity, and, when once adjusted, may be left for any length of time without fear of derangement. So accurately is the deposition by this machine proportioned to the time of working, that, in an establishment in Birmingham where this process is extensively employed, the quantity of metal deposited is estimated by the time during which the machine works; repeated weighings having demonstrated that the relation between the time of working and quantity of deposited metal is sufficiently accurate.

Another generator of electricity, which has been practically employed in plating, is the thermo-electric pile, which consists of a number of couples of different kinds of metal, which are caused to generate electricity by their action upon each other, through the instrumentality of heat; the two best known of these are Noës' and Clamond's. It is said that Clamond's thermo-electric pile, consuming 150 litres of gas an hour, is capable of depositing a kilogram of copper at a cost of about 2s.

Every article upon which an adherent electro-metallic deposit is required must be chemically clean, and is therefore submitted to processes, differing according to its character, which have for their object removal from the surface of every trace of oxide, grease, dirt, or other foreign substances. Without this preparation the coating will not adhere firmly to the receiving surface; it is usual also with articles other than those of copper to smooth, as well as cleanse the surface, by the aid of mechanical appliances. For the latter purpose the usual means of abrasion—files, emery wheels and blocks, polishing powders, and scratch-brushes—are utilized. The latter, consisting of bundles of thin wire, applied either by hand or arranged on a spindle to be rotated, are universally used, and scratch-brushing is resorted to at all stages of deposition: a little stale beer is commonly allowed to fall on the goods whilst being scratch-brushed. Where chemical methods for cleaning can be employed, they are to be preferred, as they give very perfect results, but unfortunately they can seldom be utilized except with copper and its various alloys; in most cases chemicals may be employed to commence the cleaning, which must nearly always be completed mechanically. Copper and its alloys, brass, German silver, and the like, are usually "dipped," that is, passed through a series of chemical baths. The first are to remove all greasy substances from the surface of the metal, as these are invariably to be found there, being acquired either during the process of manufacture, or from contact with the hands. Those objects having no soldered joints, and whose size and construction do not render them liable to injury by heat, are submitted to a temperature producing red heat, whilst more delicate articles, and also those in which it is necessary to retain both rigidity and sonorousness, are immersed in an alkaline solution, composed of caustic potash; for this $\frac{1}{2}$ lb. of caustic lime, and 1 lb. of pearlash, may be allowed to each gallon of water, the lime being first made into a cream by stirring with sufficient of the water, and then added to the pearlash, which has been previously dissolved and boiled.

The mixture is kept at boiling point until it is clear, and does not effervesce under the action of dilute hydrochloric acid, when it is ready for use; but as it is liable to be effected by the carbonic acid contained in the air, it should be kept covered when not in use; to keep it in condition, a little cream of lime may be added at intervals. These mixtures are usually made in iron boilers. Sometimes exceedingly strong solutions are required, which must then be made with stick caustic potash.

Articles joined with solder in which tin is an ingredient must not remain any length of time in this liquor, or the solder will be dissolved and the copper blackened; nearly every metallic article is dipped in this solution, and afterwards thoroughly rinsed or swilled in water, and pewter, lead, tin, and Britannia metal can be transferred without further preparation to the depositing bath.

Cast iron may be cleansed by immersing in a dilute solution of sulphuric acid and water, the time of immersion entirely depending upon the proportion of acid used; thus in water containing $\frac{1}{100}$ part of acid it may remain several hours, the metal being afterwards rinsed, scoured, again plunged into the pickle, and rinsed before submitted to deposition. Spots containing silica frequently occur upon the surface of cast-iron articles, and this can be removed with hydrofluoric acid, sufficient care being exercised in its use to avoid the injurious fumes and contact with metals for which it is a solvent.

Wrought iron with an untouched surface may be treated in the same way as cast iron, but will bear a stronger pickle and longer immersion. Steel and polished iron are first scoured, boiled in the potash solution, and then passed through a bath composed of one gallon of water, a pint of sulphuric acid, with a few ounces of either nitric or hydrochloric acid or a mixture of both; if nitric acid is used, the sulphuric acid may previously have a few ounces of zinc dissolved in it, with advantage. Articles of iron or steel thus cleansed may be kept for some time in proper condition for work by immersing them in liquor rendered alkaline by caustic lime, potash, or other alkali.

Silver is heated and plunged into a boiling pickle of water and dilute sulphuric acid, then rinsed in clean water, the operations being repeated as many times as they are needed; nitric instead of sulphuric acid may be used for the pickle, and if strong the articles may be dipped cold; in this case the water must be distilled, free from chlorine or hydrochloric acid, otherwise the goods will be covered with a bluish-white film of chloride of silver. This latter method is not applicable to articles having parts of either iron or zinc, in such cases the plan is to dip in alkali and polish afterwards with powders or scratch-brush; cleansed silver may be placed in the deposit bath directly, but it is usual before doing so to scratch-brush it.

Copper, German silver, and brass, the three metals of which the bodies of most objects to be electro-plated are made, are cleansed in a series of liquids; if they are very dirty they are boiled in alkali, rinsed, and then dipped in the acids. They frequently receive a preliminary cleansing by being heated and then dipped in dilute sulphuric acid and water, but this will not serve of course for articles which are united by solder. Articles which have been cleansed by alkali must be washed in clean water before being put into the dipping bath or pickle; in fact it is advisable to thoroughly and rapidly rinse in fresh water all articles before and after any cleansing operations. The various dippings which complete the cleansing of these articles follow each other in rapid succession, and to effect this the pans or troughs are arranged in rotation. The first dip may be composed of old aquafortis, that is nitric acid or dipping liquid which has been already weakened by preceding dippings; the goods may then be run through dipping liquid composed of 4 parts sulphuric acid, 4 parts water, 2 parts nitric acid, and $\frac{1}{32}$ part hydrochloric acid. Articles that have been first cleansed by heating may be soaked in old aquafortis until, after rinsing, they have a uniform metallic lustre; they may then be dipped in strong aquafortis for a few moments and rapidly rinsed. The volume of acid should be at least 30 times that of the article to be cleaned in order to prevent too great an elevation of temperature and as rapidly weaken that of the acid. It should be here remarked that care must be taken in the choice of nitric acid, since only the straw coloured cleans well; the white acid is not strong enough, whilst the red acts too powerfully and pits copper.

The acid will be spent when its action on copper goods becomes too slow; it is then employed for the first operation, dipping in old aquafortis, or for whitening baths. Extreme temperatures have considerable effect upon aquafortis, which cleans imperfectly when either very hot or extremely cold. To impart a bright lustre, which is particularly required in metal employed for gilding, the goods may be dipped in weak aquafortis until a black coating is formed, then in old aquafortis or strong pickle as it is called, and afterwards into strong aquafortis, afterwards again and again alternately into strong aquafortis and water. Amongst the many mixtures for obtaining a bright lustre, a very good one is composed of old aquafortis nearly spent 1 part, hydrochloric acid 6 parts, water 2 parts; the articles are immersed a few minutes, rinsed to remove the black coating which covers them, cleaned, and dipped again; this bath will be found useful for gilding metal and also for copper castings. If it is desired to obtain a dead lustre, the articles are, after dipping in aquafortis and rinsing, plunged into a cold bath containing 1 part sulphuric acid to 2 parts of nitric acid and a little salt; to this the French operators add a little sulphate of zinc. The immersion in this bath will be at the discrétion of the operator, the time usually occupied being from 5 to 20 minutes: from this bath, after a long rinsing, the piece should be rapidly passed through the bath for producing a bright lustre and again immediately rinsed; this latter operation is to prevent an earthy dullness which is otherwise produced if the dead lustre bath alone is employed. It may be here observed that old aquafortis may be considerably revived by the addition of strong sulphuric acid and common salt.

The tanks or vats employed to hold the plating solutions are generally made of heavy wood, such as oak lined with either lead, asphalt, guttapercha, or Portland cement; the lining is necessary, since it has been observed that the wood unprotected absorbs considerable quantities of the solution; guttapercha lined vats will do very well for sulphate of copper solutions, but this lining will not do for cyanides, as these attack the percha vigorously. Tanks of iron or slate, enamelled, are coming into very general use, especially for gilding solutions, when of course they are of comparatively small size; the iron tanks are particularly useful for gilding, since they admit of heat being applied from below, which is absolutely necessary to the operation. The pickling and dipping liquids are often kept in vats of similar construction, but enamelled stoneware pans, well made, serve every purpose, and indeed may be used for the solutions themselves with advantage.

After dipping and rinsing, the various pieces are fixed to a brass wire, or hooked upon brass or copper hooks. Small articles of jewellery are suspended to a stout copper wire. These hooks are better if made of pure copper than of brass, and it is still better to use glass hooks, which are cheap and are not corroded by the acids. Such hooks or supports can be made by bending glass rods by the heat of a charcoal fire, or of a gas burner, to the desired shape. Those objects which cannot be suspended or attached to hooks, are put into perforated ladles of porcelain or stoneware. It is less economical, but sometimes absolutely necessary, to use baskets of brass or copper wire cloth. Those who frequently have to cleanse very small articles will find it advantageous to employ a basket of platinum wire cloth, which, although expensive in the first cost, will be found cheaper in the end, as it is almost indestructible.

When it is desired to prevent deposition upon certain parts of goods to be plated, these parts must be "stopped off" by being coated with any ordinary varnish; if for a hot solution, copal is the best for the purpose.

Quicking or coating with a film of mercury is often necessary to secure an adherent deposit; for surfaces of copper and its alloys solutions of nitrate or cyanide of mercury are applied; and for general use almost any mercurial salt dissolved in cyanide of potassium will be found effectual.

The substances used for taking moulds from objects to be copied by electrotype are beeswax, stearine, plaster of Paris, fusible metal, and guttapercha; indeed, any substance that will receive and retain an impression, and is not liable to be affected by the solution from which the metal is to be deposited, will serve the purpose. The articles to be copied are generally composed either of plaster of Paris or metal. Suppose, in the first place, the article to be copied is of metal, and a mould is to be taken from it in wax or stearine. The latter is not found to answer well alone; when used it should be mixed with wax, about half and half.

Whether the beeswax have stearine in it or not, it is better to prepare it in the following manner:—Put common virgin wax into an earthenware pot over a slow fire; and when melted, stir in a little whitening; this mixture tends to prevent the mould from cracking in the cooling, and from floating in the solution; the mixture should be remelted two or three times before using it for the first time.

The article to be copied should be brushed over with a little sweet oil; after which the superfluous oil should be wiped off with a piece of cotton. If the article has a bright polished surface, very little oil is required; but if the surface be matted or dead, it requires more care with the oil. A slip of cardboard or tin is now bound round the edge, and should rise about one-fourth of an inch higher than the highest part on the face; this done, hold the article with its rim a little sloping, then pour the wax in the lowest portion, and gently bring it level, so that the melted wax may gradually flow over; this will prevent the formation of air bubbles. Care must be taken not to pour the wax on too hot, as that is one great cause of failure in getting good moulds; it should be poured on just as it is beginning to set in the dish. As soon as the composition poured on the metal is set, undo the rim; for if it was allowed to remain on till the wax became perfectly cool, the wax would adhere to it, and being thus prevented from shrinking, which it always does a little, would be liable to crack; remove to a cool place, and in about an hour the two will separate easily. When they adhere, the cause is either that too little oil has been used, or that the wax was poured on too hot.

Rosin has been recommended as a mixture with wax, mixtures of which, in various proportions, have been used with success; but when often used, decomposition or some change takes place, which makes the mixture granular and flexible, rendering it less useful for taking moulds.

If a plaster of Paris mould is to be taken from metal, the preparation is the same as described above; and when so prepared with the rim of cardboard or tin, get a basin with as much water in it as will be sufficient to make a proper sized mould, then take the finest plaster of Paris and sprinkle it into the water, stirring it till the mixture becomes of the consistence of thick cream; then pour a small portion upon the face of the article, and with a brush similar to that used for oiling it, gently brush the plaster into every part of the surface, which will prevent the formation of air bubbles; then pour on the remainder of the plaster till it rises to the edge of the rim: if the plaster is good, it will be ready for taking off in an hour. The mould is then to be placed before a fire, or in an oven, until quite dry, after which it is to be placed, back downwards, in a shallow vessel containing melted wax, or paraffin, not of sufficient depth to flow over the face of the mould, allowing the whole to remain over a slow fire, or upon a hot plate, until the wax or paraffin has penetrated the plaster, and appears upon the face. Having removed it to a cool place to harden, it will soon be ready for electrotyping. If the mould is large and the plaster thick, the wax may be put upon the surface, and only as much as will penetrate a small way into the plaster. In both these instances the wax used is generally lost, and there is always a liability of the copper solution passing through, and causing what is termed surface deposit, making the face rough.

Moulds in fusible alloy are made from mixtures of two or more metals which melt at very low temperatures; they suit the purpose of taking moulds of small objects very well. The following are examples of such compositions:—

Tin.	Lead.	Bismuth.
1	1	2
3	2	5
1	2	3
3	5	8

These all melt at a temperature below that of boiling water; the ingredients are melted together in an iron ladle, poured out upon a flat stone, broken up, and remelted together in the same way two or three times, in order that they may be thoroughly mixed. The object from which the mould is to be taken is prepared in the same manner as wax.

The means of taking moulds with fusible metal are the following:—The fusible alloy is melted and poured into a saucer, or, what does better, a small wooden tray; the operator now watches it till it cools down into a semifluid state, or to the point of setting, when he brings the article suddenly upon it, face downwards, and holds it there until the alloy has fairly set; the object being moulded may be kept at a temperature that will keep the alloy melted, either by placing them into a water-bath or oven; after being kept in the melted state over the model for a few minutes they are removed and allowed to cool, when the mould and model are easily separated. Some of the finest moulds are taken by this process; but from the constant loss of the materials by oxidation the use of such alloys is limited.

Guttapercha, as a material for moulding, serves the purpose most admirably. Moulds of this substance are equal, if not superior, to any taken in wax, and of a depth of cutting which it would have been very difficult to have taken in wax. The method adopted for taking moulds is to heat the guttapercha in boiling water, or in a chamber heated to the temperature of boiling water, which makes it soft and pliable. A quantity of guttapercha is pressed into the saucer, and as much added as will cause it to stand above the edge of the rim surrounding the object; it is now placed in a common copying press, and kept under pressure until it is quite cold and hard. The impressions taken in this way are generally very fine; when the object is not deep cut, a less pressure may suffice, but when the pressure is too little the impression will be blunt.

Stereotypes and engraved plates of large size and fine patterns are copied in this way by the electrotype process. Guttapercha may be softened by mixing with it a small quantity of oil, tallow, or wax. Guttapercha takes a coating of black-lead readily, and the deposit goes over it easily.

A mixture of guttapercha and marine glue has been recommended for moulds as superior to guttapercha alone.

With one method of taking impressions of fern leaves and seaweeds, a piece of gutta-percha, free from blemish, and the size of the plate required is placed in boiling water. When thoroughly softened, it is dusted over with the finest bronze powder to dry the surface, to render the surface more smooth, and to prevent adhesion. The plant is then laid out upon the bronze surface, and covered with a polished metal plate, either of copper or of German silver. The whole is then to be subjected to an amount of pressure sufficient to imbed the upper plate in the guttapercha. When cold, the metal plate may be removed and the fern gently withdrawn from its bed. A beautiful impression of the fern will remain.

This process is well adapted for flat leaves, but the pressure required renders it unsuitable for many kinds of leaves, indeed it destroys the natural forms of the greater number both of leaves and seaweeds. The products of the process cannot, indeed, be compared with those electrotypes the moulds of which are taken by wax. The great merit of the process is its ease and simplicity. The method given for taking the mould of the leaf is suitable for any kind of flat mould in gutta-percha. The mould of a leaf may be taken in plaster, by placing the leaf upon dry sand, and pressing the sand under and on each side to fill up the spaces under the leaf, so as to bear the pressure of the plaster, putting a collar of paper round the sand to prevent its yielding, and then pouring plaster over the whole.

In another method of making moulds of leaves and other vegetable objects, the leaf is carefully dried, and laid upon a smooth piece of milled lead, which is placed between two steel plates, and passed between rollers; these press the leaf into the lead, and produce a complete mould. Copies from this may be taken with guttapercha or electrotype. Roseleur describes the copying of nettle and other leaves so perfect that all the hairs on their surface were to be seen. "One of the sides of a fresh leaf was covered by means of a brush with a thin paste of plaster of Paris, and after the drying of the first coat, other layers were applied, until a resisting block had been obtained with the leaf uppermost. The free side was then covered with several coats, always with a brush or pencil, of guttapercha dissolved in bisulphide of carbon, and lastly with melted guttapercha. The mould was removed from the leaf, metallized, and immersed in the galvano-plastic bath."

To cast reptiles, imbed the subject in a mould made of four parts of plaster of Paris, one of unburnt lime powder, and one of Flanders brick-dust. Dry the mould carefully in an oven, then make it red hot, and burn the subject out of it, taking care to free the mould from the ashes. Before putting this mould into the oven to dry, insert two or more iron or smooth wooden pins, one touching the object inside, the other projecting outside. When the mould is dried, and before burning, these are carefully removed, to allow escape of gas and to remove the ashes; by a proper arrangement of these holes the carbon of the article may be consumed, when the remaining ash is easily removed. Fusible metal may be cast in this mould, or a wax model may be taken of the object, pouring the wax in just before setting. The whole is now placed in water, the lime causes the mould to dissolve or break up, and the figure modelled within it may be taken and covered with copper, and the wax afterwards melted out. Flowers, insects, lizards, and other little animals may be typed in this way. In all these processes perseverance and care are the best cure for little difficulties.

When a plaster mould is to be taken, the face of the model is prepared differently to that described, in order to prevent the adhesion of the two plasters. The best substance for this purpose is a mixture of half a pound of soft-soap put into three pints of clean water, which is set on a clear fire, and the solution kept in agitation by stirring; when the mixture begins to boil, add from one ounce to an ounce and a half of tallow, and keep boiling till it is reduced in bulk to about two pints, when it is ready for use. The surface of the model must be washed over with this lacquer, allowing it to absorb as much as it can, when it assumes the appearance of polished marble; it is now prepared with a rim of paper, and the mould taken as directed for taking plaster moulds from metallic articles. When hardened, they will separate easily. Wetting the plaster model with a solution of soap before taking the cast will do, or, if the plaster model has been saturated with oil or milk, it has only to be moistened with sweet oil, the same as a metal model.

If a mould of fusible metal be required from a plaster model, the plaster may be saturated either with boiled oil or the soap and tallow lacquer, and the mould taken in the same manner as from a metallic medal.

Many electro-metallurgists prefer taking a mould in copper when the medal is of plaster of Paris. This is done by the electrotype process, the plaster model is saturated with wax over a slow fire, as already detailed, and then prepared for taking an electrotype in the usual manner. We need hardly mention that in this case the model is destroyed; but, notwithstanding, in the case of plaster models, to take a copper mould is the most preferable way, as it may be repaired in case of slight defect, and it may be used over and over again without deterioration.

When an electrotype is required of a model that is undercut, or of a bust or figure, the process which we have described will not answer, as the mould cannot separate from the model. In such circumstances, the general method of proceeding is to cast the mould in separate pieces, and then join these together. The material used for this purpose is plaster of Paris; the operation, however, to be done well, requires considerable experience. If the undercutting is not very great, a gutta-percha mould can be taken by the process described; but before removing the mould subject it to a heat of boiling water to soften the percha, which by careful manipulation may be removed without damage to either mould or model.

Parkes' process for taking a mould of any kind of model in one piece is excellently adapted for the electrotypist. The material is composed of glue and treacle. 12 lb. of glue is steeped for several hours in as much water as will moisten it thoroughly. This is put into a metallic vessel, which is placed in boiling water, as a hot bath. When the glue falls into a fluid state, 3 lb. of treacle are added, and the whole is well mixed by stirring. Suppose now that the mould of a small bust is wanted, a cylindrical vessel is chosen, so deep that the bust may stand in it an inch or so under the edge. The inside of this vessel is oiled, a piece of stout paper is pasted on the bottom of the bust, to prevent the fluid mixture from going inside; and if it is composed of plaster, sand is put inside to prevent it from swimming. It is next completely drenched in oil, and placed upright in the vessel; this done, the melted mixture of glue and treacle is poured in till the bust is covered to the depth of an inch. The whole must stand for at least twenty-four hours, till it is perfectly cool throughout; after which it is taken out by inverting the vessel upon a table, when, of course, the bottom of the bust is presented bare. The mould is now cut by means of a sharp knife, from the bottom up the back of the bust to the front of the head. It is next held open by the operator, when an assistant lifts out the bust, and the mould is allowed to reclose; a piece of brown paper is tied round it to keep it firm. The operator has now a complete mould of the bust in one piece; but he cannot treat it like wax moulds, as its substance is soluble in water, and would be destroyed if put into the solution. A mixture of wax and rosin, with occasionally a little suet, is melted, and allowed to stand till it is on the point of setting, when it is poured carefully into the mould, and left to cool. The mould is then untied and opened up as before; the wax bust is taken out, and the mould may be tied up for other casts. Besides wax and rosin, there are several other mixtures used, deer's fat is preferable to common suet and stearine. The object is to get a mixture that takes a good cast, and becomes solid at a heat less than that which would melt the mould.

If the model or figure be composed of plaster of Paris, a mould is often taken in copper by deposition; the figure is saturated with wax, as before described, and copper deposited upon it sufficiently thick to bear handling without damage when taken from the model. The figure with the copper deposit is carefully sawn in two, and then boiled in water, by which the plaster is softened and easily separated from the copper which now serves as the mould in which the deposit is to be made. When the deposit is made sufficiently thick, the copper mould is peeled off, and the two halves of the figure soldered together. The copper moulds, which are deposited upon the wax models taken in the elastic moulding, are often treated in the same manner; but more generally these moulds are used for depositing silver or gold into them, to obtain fac-similes of the object in these metals, in which case the copper moulds are dissolved off by acids.

When plaster busts or figures are wanted in copper, the most usual way is to prepare the figure with wax, as described, and to coat it over with a thin deposit of copper, letting the copper remain. Some operators, when it can be done, remove the plaster, and wash over the inside with an alloy of tin and lead melted. In this case, the copper must previously be cleaned by washing first in a solution of potash, and then with chloride of zinc; the latter mode will cause the alloy to adhere to the copper, and give it strength. In either of these cases, the deposit must not be very thick, or it will throw the figures out of proportion, such as the features of a bust. Any slight roughness of deposit may be easily smoothed down by means of fine emery.

Were any of the plaster or wax moulds attached to the zinc, and immersed in the copper solution, no deposit would be obtained, because neither the plaster nor the wax is a conductor of electricity. Some substance must now be applied to the surface, in order to give it conducting power. There are several ways of communicating this property, to be afterwards described; but the best and most simple for the articles under consideration is to apply common black-lead in the following manner:—A copper wire is put round the edge of the model, or if wax moulds are used, a thin slip of copper may be inserted into the edge of the mould, or, being slightly heated and laid upon the back, the two will adhere. A fine brush is now taken and dipped into fine black-lead, and brushed over the surface of the model; the brushing is to be continued until all the face round to the wire upon the edge, or slip of copper forming connection, has a complete metallic lustre; a bright polish is necessary to the obtaining a quick and good deposit.

In brushing on the black-lead, care should be taken not to allow any to go upon the back or beyond the copper connection, or the deposit will follow it, and so cause a loss of copper, and make the mould more difficult to separate from the deposit.

When the face of the mould is properly black-leaded, the copper wire connected with it is attached to the zinc plate in the porous cell, and the mould immersed in the copper solution; the deposit will soon spread over every part, covering the black-lead polish with less or more facility, according to the state of the solution and other circumstances. When the deposit is considered sufficiently thick for removing, which, in ordinary circumstances, will require from 2–3 days, the mould is taken out of the solution, and washed in cold water, and the connection is taken off. If the deposit has not gone far over the edge of the mould, the two may be separated by a gentle pull; if otherwise, the superfluous deposit must be eased off, and if care be taken, the wax may be fit to use over again; but when the mould is plaster of Paris, however well it may be saturated with wax or tallow, which is done by brushing it over with either substance in a melted state, the mould being cold it will not absorb the wax or tallow, hence it may be recovered again. The sulphate of copper possesses so penetrating a quality, that if the slightest imperfection occurs in the saturation of the mould by wax, or if imperfectly protected, the solution will penetrate through it, and the copper will be deposited upon the face of the object, adhering to the plaster, giving to the medal a rough, matted appearance, and seriously injuring it.

A mould in fusible alloy does not require to be black-leaded, but the back and edge must be protected by a coating of wax or other non-conducting material; it may be connected by putting a wire round its edge previous to laying on the non-conducting substance, such as tallow or wax, which should also cover the wire. Or a slip of copper or wire may be laid upon the back and fastened by a drop or two of sealing-wax; the back is then coated, but care must be taken that the wax does not get between the connection and the mould, which will prevent deposit. The deposit on this mould goes on instantaneously. When sufficiently thick, it may be taken off in the same manner as from the wax mould, the surface having been prepared by turpentine to prevent adherence. These moulds may be used several times, if care be taken not to heat them to the melting point.

The electrotypes obtained from metallic moulds prepared with the turpentine solution have a bright surface, which is not liable to change easily; but if the mould has been prepared with oil or composed of wax or plaster, the metal will either be dark, or will very easily tarnish.

In putting moulds into the copper solution, the operator is often annoyed by small globules of air adhering to the surface, which either prevent the deposit taking place upon these parts, or, when they are very minute, permit the deposit to grow over them, causing numerous small hollows. To obviate this, give the mould, when newly put into the solution, two or three shakes, or give the wire attached to it, while the mould is in the solution, a smart tap; but the most certain means is to moisten the surface with alcohol just previous to putting it into the copper solution.

When busts or figures, whether of wax or plaster of Paris, are to be coated with copper, with no other conducting surface than black-lead, it is attended with considerable difficulty to the inexperienced electrotypist. The deposit grows over all the prominent parts, leaving hollow places, such as armpits, neck, and the like, without any deposit; and when once missed, it requires considerable management to get these parts coated, as the coated parts give a sufficient passage for the current of electricity. It is recommended by some electrotypists to take out the bust, and coat the parts deposited on with wax, to prevent any further deposit on them; but this practice is not good, especially with plaster of Paris, for an electrotype ought never to be taken out till finished. Sometimes the resistance of the hollow parts is occasioned by the solution becoming exhausted of metal, from its position in regard to the positive pole. In this case a change of position effects a remedy. It may be remarked, that when a bust or any large surface having hollow parts upon it, is to be electrotyped, as many copper connections as possible ought to be made between these parts and the zinc of the battery. Let the connections with the hollow parts be made with the finest wire which can be had, and let the zinc plate in the cell have a large surface compared to the surface of the figure, and the battery be of considerable intensity; if attention is paid to these conditions, the most intricate figures and busts may be covered over in a few hours. Care has to be observed in taking off the connections from the deposit, or the operator may tear off a portion of the deposit; if the wires used are fine, they should be cut off close to the deposit surface.

Copper deposits are obtained either by simple dipping or galvanic methods. Copper deposits by dipping are seldom practised except upon iron, and are generally wanting in lasting qualities, since, from the thinness of the deposit, the iron is not protected against atmospheric influences. If the iron is steeped in a solution of sulphate of copper, 3½ oz.; sulphuric acid, 3½ oz.; water, 1 to 2 gal., for a short time, it becomes covered with a coating of pure copper, having a certain adhesion; but should it remain there for a few minutes, the deposit of copper is thicker and muddy, and does not stand any rubbing. For coating large objects a solution, 1 part sulphate of copper, 2½ parts soda lime, 7½ parts sodio-potassic tartrate, and 25 parts by weight of water has been found effective, but they require several hours' immersion. In this case, compress it by means of rollers or a draw plate, in order to impart a certain cohesion to the particles of copper. Small articles, such as hooks, pins, or nails, are coppered by jerking them about for a certain time in sand, bran, or saw-dust, impregnated with the above solution, diluted with three or four times its volume of water.

Battery electro deposits of copper are obtained by decomposing a double salt of copper with another base, such as the double cyanide of potassium and copper. This process is equally well adapted to all metals, and the deposits are fine, lasting, and their thickness is entirely regulated by the will of the operator. Dissolve about 16 oz. of sulphate of copper in 2 gal. of water, and add a solution of carbonate of soda until no more precipitate is formed; collect the green precipitate, carbonate of copper, thus obtained upon a cloth filter; stir the washed carbonate of copper in water, to which cyanide of potassium is added until the carbonate is entirely dissolved, and the solution is colourless; a small excess of cyanide will increase the conducting power of the liquor. This bath may be employed hot or cold and requires an intense electric current for its decomposition; a copper plate or foil forms the anode, which must be removed when the bath does not work. This bath is much used, but the following formula is preferable. Water 2 gal.; acetate of copper, crystallized; carbonate of soda, crystals; bisulphate of soda; cyanide of potassium, pure, 7 oz. of each; the acetate of copper is put in first and moistened with sufficient water to make a homogeneous paste, then add the carbonate of soda and some water; after stirring, a light green precipitate is formed. Three pints more water are then added with the bisulphate of soda, and the mixture becomes a dirty yellow colour. Lastly add the remainder of the water and the cyanide of potassium. The electro copper bath must be colourless.

Large pieces of silverware may be coppered in these baths. Very small articles are threaded upon a zinc or iron wire, or placed in a perforated ladle with granules or cuttings of either of these metals. Place the whole for a few minutes in a diluted but very acid solution of sulphate of copper, the zinc or the iron is dissolved, and the copper is deposited upon the silver. When the article is intended to be gilded or silvered, it is immediately passed through the "quicking" solution of nitrate of mercury, rinsed in cold water, and placed in the electro-baths, without drying or scratch-brushing.

To electrotype printing type, the surface is first cleaned by means of turpentine, dried either in the air or with hard wood sawdust, and dusted with fine plumbago. A shallow dish of pewter, termed a chase, made about ¼ of an in. deep, and of the requisite size for the work, and provided with ears for hooks to be attached, is filled with a mixture of beeswax and fine plumbago which has been previously mixed hot; it is allowed to cool until the wax has become nearly set, when the type is inverted on to its surface, and both chase and type are then placed in a press and squeezed gently, the type is lifted off to see if any wax will adhere, it is then dusted with plumbago, replaced in exactly the same position, and squeezed tightly. The squeeze, as the wax mould is then termed, is dusted with plumbago and polished with a soft brush. In large works machines are employed for this purpose, consisting of a closed case containing the plumbago, into which the squeeze is introduced, and where it is dusted by a series of brushes arranged to move irregularly to and fro by means of eccentrics; the chase is then hooked and hung in the deposit trough in the usual copper solution, a few inches from the anode. When the deposit is sufficiently thick, which will occur in from 8–12 hours, the chase is removed, washed, and heated, the electrotype removed, placed on a tray, brushed over with soldering fluid, and sprinkled with solder, which is rubbed over the interior with a rag; the electro is then filled to a requisite depth with fluid stereo metal, planed to gauge, and mounted type-high on a block of wood.

An older method is to employ guttapercha instead of wax.

Silvering may be practised by simple immersion with very good results, if care is taken to use the ingredients in correct proportions, and if the same care is exercised with respect to the purity of the ingredients and the previous cleansing of the articles to receive the deposit, which is observed in operations where the battery is employed. The simplest silvering solution is made by mixing into a thin paste 3 parts of soda, 1·25 common salt, and 1 part chloride of silver, with sufficient warm water; another mixture may be made with the chloride of silver and salt alone; in either case the paste is applied with a rubber upon the surface until it is properly coated, when it should be washed, dried, and varnished in the usual way. Another solution, which may be either used in paste or as a bath, consists of 1 part each of cream of tartar and common salt, and ⅓ part chloride of silver dissolved in boiling water in a common kettle, with the addition of a little alum; the articles are stirred up in this composition, and as each fresh batch is operated upon, a quantity of paste is added in proportion to the surface to be whitened. This bath improves greatly by use, but should it not produce the desired result, the following solution, used boiling, will be found quite effectual. It is composed of 1½ oz. nitrate of silver, 9 oz. cyanide of potassium, and 1½ gal. of water. The foregoing are practically applicable to articles of jewellery, such as earrings, bracelets, chains, buckles, studs, and the like, whilst with a little experience and attention much larger articles may be treated with success. Roseleur recommends a bath made by dissolving in an enamelled cast-iron kettle, 17½ oz. of cyanide of potassium in 2 gal. of water; in a separate vessel 5½ oz. of fused nitrate of silver is dissolved in 2 pints of water. This second solution is added gradually to the first and stirred again and again until the precipitate produced is dissolved; if necessary the whole may be filtered. It is then brought to a boiling point and is ready for use. This bath cannot be renewed, and when exhausted should be added to the waste and a new one formed. Another simple immersion process which produces excellent results is made by dissolving common soda in water, the proportions being 1 lb. of the former to a pint of the latter, and pouring a little mercury into the bottom of the vessel; the end of a glass tube is now allowed to dip into the mercury; either sulphurous acid gas or sulphuretted hydrogen is passed through the tube, the mercury merely preventing the formation of crystals; the passage of the gas is continued until the liquid slightly reddens blue litmus paper, when the whole is put on one side for a day. The liquid portion is then poured off, stirred, and again tested; if it turns the litmus paper red, soda must be added; if blue, there is too much alkali and more gas must be passed through the liquid. The solution should mark from 22° to 26° Baumé, and must not touch iron, zinc, tin, or lead. When required for use, a portion of the liquid is taken and to it is added a solution of nitrate of silver in distilled water; a precipitate will be formed, and the silver solution is added so long as this readily disappears, the condition of the bath being preserved by additions of either gas or soda and silver, when necessary. The articles are simply moved about in the bath until the required coating is obtained; it will give an excellent result upon either brass or copper.

In order to finish silver plated articles a bright vat is employed, which needs a somewhat stronger current than that used for the ordinary plating, the operation proceeding somewhat slowly, and brightening being observed to proceed from the bottom of the articles upwards, while the entire operation should be completed in about 20 minutes. A bright solution may be prepared by adding to each gallon of the usual solution of silver in cyanide of potassium 6 oz. of bisulphide of carbon, the mixture being put into a stoppered bottle, shaken, and set aside for 24 hours, and then adding to every 20 gal. of the ordinary plating solution in the vat 2 oz. of the bright solution, and the whole stirred together; this proportion must be added every day on account of the loss by evaporation, but when the mixture has been made several days, less than this may be used at the time. This operation gives a bright deposit, but by adding a larger amount a dead surface may be obtained very different from the ordinary dead surface. It is as well to remove the articles from the bright vat at once into boiling water, for unless this is done they are very liable to blacken rapidly.

The brightening solution should always be added with care, for an excess is apt to spoil the bath, and its management is always a matter requiring attention, but it is very serviceable in plating a surface which cannot easily be scratch-brushed. Another method of preparing a bright solution is to add to the preparation we have detailed above, 4 oz. of liquor ammonia, and 2 oz. of ether.

For a silvering solution which requires no mercury dip or quicking in preparing the work, for each gallon of solution dissolve 1 oz. of fine silver in the ordinary way, that is in the liquid of one part nitric acid to two parts water, evaporate and crystallize. Then add 3 pints of water until the nitrate is dissolved, take 2 oz. of iodide of potassium, dissolve in ½ pint of water and add this to the nitrate solution, when a yellow flocculent precipitate of iodide of silver will be formed, until, on the addition of a drop of the solution of iodide of potassium, no precipitate appears. The precipitated iodide of silver is repeatedly washed, and then dissolved in strong solution of cyanide of potassium in hot water, which is added gradually with stirring; when nearly all the iodide is dissolved, the vessel is allowed to rest for a few hours, the clear solution poured off, and any iodide remaining undissolved is again treated with the solution of cyanide, care being taken to avoid an excess of the latter; water is then added to make up about 1 gal., which is set on one side for at least a day, and the clear solution poured off. It is advisable that it should not be freely worked until several days after this preparation; the work is passed through the potash, scoured, washed, and immediately placed in the depositing bath; this is suitable for German silver, brass, and copper goods, and although it will not afford a dead white deposit, still that given is tenacious, and obtained without the use of mercury; it may be frequently used to advantage to give a preliminary coating to articles, which may then be transferred to the ordinary cyanide bath to receive a full deposit.

Silvered articles may be coloured by various processes; the simplest and most effectual is that in which the articles are dipped in a saturated solution of borax, and allowed to dry; a film of the borax is left on the surface after the evaporation of the water. They are immersed a second or third time, until a complete film of borax covers every part of the article; when large articles are experimented on, the solution may be applied by means of a brush. The articles thus treated must be exposed to heat, until the borax is perfectly fused; for this purpose, a heat nearly approaching to redness is required. After cooling, they should be immersed in dilute sulphuric acid, by which the borax is removed; they should be finally dried, by being shaken in heated saw-dust, and warmed, in order more effectually to drive off all moisture. This process possesses the admirable property of preventing the rapid tarnishing of the plated articles. It was observed by those who first practised electro-plating, that the silver reduced from its salts by electrical agency tarnished more rapidly than that manufactured in the ordinary way. This was ascribed to the purity of the silver, which was supposed to be favourable to its combination with the sulphurous and other vapours, by which it became tarnished. By the above process, however, the tarnishing of the voltaic silver is prevented; and it is now scarcely, if at all, more readily tarnished than that reduced in the common way. It appears that the discoloration was not produced by any external action, but that there remained in the pores of the reduced metal a small quantity of undecomposed salt, which suffers slow decomposition, and thus injures the colour of the surface. The treatment with borax completely removes this saline matter, and renders the metal unalterable from any internal action.

Solutions for gilding may be either formed by the battery or by chemical means, the best of these being that formed with the cyanides of gold and potassium. Various solutions may be used for producing different coloured gilding, either by a separate current or by simple immersion, and they are employed both hot and cold, being also varied when used for iron, steel, and baser metals. A good simple immersion solution may be made by dissolving 14 oz. of pyrophosphate of soda in 9 pints of distilled water, and adding ⅛ oz. hydrocyanic acid. The first two ingredients are heated together, and ⅓ oz. of soluble dry chloride of gold is added when the solution is cool, and afterwards the hydrocyanic acid, drop by drop, until the liquor becomes colourless; an excess of the acid renders the gilding difficult, but this may be corrected by adding a small proportion of chloride of gold. It is used hot, the articles to be gilded upon must be previously passed through a very diluted solution of nitrate of mercury, and must be continuously shaken. It is best to employ three baths, the first containing an exhausted solution of the same kind, the second one that has been but partially used, and the third a freshly prepared bath which will produce the required shade; the gilding is done in a few seconds. Green and white gilding may be obtained from a similar liquid by adding, drop by drop, a solution of nitrate of silver until the desired shade is arrived at; before gilding green or white, gild the objects yellow in the ordinary bath, pass them rapidly through the nitrate of mercury solution, and then into the gold bath having the nitrate of silver.

Water gilding is a simple immersion process, and may be effected by dissolving 5 oz. of gold converted into chloride with 4 gal. of water, and boiling it with 20 lb. of pearlash for several hours, the articles to be immersed for a few minutes in the solution, which is kept warm.

Gilding by means of a separate current is best conducted with the solution of the double salt of cyanide of gold and potassium. When formed chemically, this salt is prepared by adding cyanide of gold to a solution of cyanide of potassium, and evaporating to dryness; the resulting crystals constitute the double salt, and form an excellent plating solution alone, when dissolved in water. Other solutions, such as that composed of yellow prussiate of potash, 7 oz.; pearlash, 5 oz.; sal ammoniac, 1 oz.; pure gold transformed into chloride, 2 oz.; and water, 2 gal.; the salts are boiled together, and the chloride of gold added, dissolved in a little water just before the bath is allowed to cool. The anodes employed are plates of thin gold dipped entirely into the bath, and held by small platinum wires connected to the positive pole of the battery. The deposit should be a pure yellow; in case it is off colour, it must be scratch-brushed with care and passed through coloured materials; the anode conducts the electricity, and also maintains the metallic strength of the bath, but the addition of gold salt and cyanide of potassium are necessary at intervals; when this is required is ascertained by the colour of the bath and the deposit; when gold predominates, the deposit is blackish, and when the cyanide is in excess, the gilding takes place slowly, and is of a greyish colour. When not in use the anode must be removed, or it will be dissolved. In making solutions by the battery process, from 1½ to 2 lb. of cyanide of potassium is dissolved in each gallon of the hot water, and two plates of sheet gold immersed; the current from a couple of Daniell or Smee cells is passed for several hours; the liquor may be occasionally tested to ascertain its condition with a plate of German silver, which is made to replace one of the gold plates for a short time. When satisfactory, the bath may be immediately used; it will work well if the temperature is preserved as evenly as possible from 143°–160° F. Care should be observed when making this bath to either wholly immerse the gold plates, or else to protect the portion above the surface of the liquid by means of varnish, otherwise it is liable to be cut through at the line of division.

A great deal of the colouring in electro gilding depends upon the manner in which the current is regulated and the baths kept in condition, and to obtain excessive coloration rather by additions to the bath than by interference with the current or alteration of the temperature. A bath to be used for red gilding only may be made by adding to the ordinary bath acetate of copper in crystals ground to powder, and dissolved in water or some liquid from an old electro-copper bath. Small articles may be made to pass to red by heating them after they have been covered with acetate of copper, cream of tartar, and common salt. To obtain gold with a pink appearance, the articles are first gilt yellow in the ordinary way, then reddened, and then passed quickly through a silvering bath. To produce green or white gilding, add to the bath a dilute solution of nitrate of silver, less of this being required for green and more for white. In the general working of gilding baths, it is as well to always give inferior work, such as zinc or tin, a light deposit of copper, and the same remark holds good for steel and iron; German silver should be gilt in very weak solutions. Vessels which require only to be gilt inside, such as cups, sugar-basins, and the like, are filled with the gilding solution with an anode of gold hung in the middle, the other wire from the battery being connected to the vessel itself; parts which cannot be gilt conveniently in this way may be lightly coated by a sponge or rag wetted with the solution, and dipping in it. The battery most frequently used is either a single Smee or a Daniell.

When a gold solution which has been worked for a long time fails to yield the rich colour so necessary in electro gilding, the solution may be restored to its proper condition by evaporation to dryness. After a gilding bath has been worked for a lengthened period it is apt to yield a brownish or foxy colour, which is due to the accumulation of organic matter, from imperfect rinsing of the work after scratch-brushing, by which small quantities of the beer used in the operation enter the solution, and cause the deposit to assume shades of colour which are anything but desirable for superior work. Although it involves a little trouble, and occupies a certain amount of time, if the solution be evaporated to absolute dryness, then redissolved in hot water and filtered, the bath restored by this means will give admirable results. After complete evaporation and subsequent redissolving, a small amount of additional cyanide will be necessary; and since it is probable that the solution, after long working, may contain less than its original proportion of gold, it will be advisable, after redissolving the dry mass, to use about 25 per cent. less water than would represent the original bulk of the solution.

Gilding for cheap work may be effected by using a copper anode in the place of a gold one, and re-supplying the gold solution as it becomes exhausted, by the addition from time to time of concentrated solution of cyanide of gold; in this way, not only is the gilding of a very rich colour, but a larger surface may be coated at a small cost.

In gilding and silvering silk, cotton, and the like, one process consists in arranging the fabric in a tight position, and then immersing in a solution of acetate of silver, to which is added ammonia until the solution becomes fluid. After one or two hours' immersion the thread is to be dried and submitted to a current of pure hydrogen gas. The threads are then metallized, and will conduct a current of electricity; they are then to be gilded by the methods usually employed. Another process is to dip a piece of white silk in an aqueous solution of chloride of gold, and expose it to the action of sulphurous acid gas, which may be done by burning a little sulphur, and confining the vapour in a box; in a few seconds, the whole piece will be covered with a coat of reduced gold.

A very weak solution of sulphate of copper, applied with a camel-hair brush, and the spot touched with a steel or iron rod, will deposit a film of copper on pewter solder. This will be found a very simple and useful assistant in cases where it is troublesome to obtain a gold or silver deposit upon certain parts of work which had been repaired with soft solder. Lead edges of candlesticks, cruet-frames, and the like, may be slightly coppered in this way, by making up a bath of weak sulphate of copper solution, dipping the part to be coated therein, and touching the places to be coppered with a clean iron rod. With the exception of the extreme point, the iron rod may be coated with varnish, or with a solution of red sealing-wax, in spirit of wine, to prevent the metal from reducing the copper from its solution except where required to do so.

Good nickel plating may be effected by making up the bath with pure crystals of double-sulphate of nickel and ammonia, 1 lb. of the crystals being allowed to each gallon of water. The anodes required for, say a 50-gal. bath, should be 10 in number, each being at least 12 in. long by 6 in. wide. They are suspended on each side of the bath by copper hooks to the positive conducting pole, which may be of brass tubing with an iron core. The battery required for a bath the capacity we have indicated will be 4 Bunsen cells, about 2 gal., or a small dynamo-machine may be used instead. To prepare the double salt of nickel and ammonia, nitrate of nickel is dissolved in its own weight of ammonia, the whole diluted with 20 to 30 times its volume of liquid bisulphate of soda, marking about 24° Baumé. Nickel solutions like those of gold and silver do not readily dissolve the anodes, and consequently, unless these expose a surface considerably exceeding that of the articles to be plated, the deposit will not only be irregular but of an indifferent colour. Again, owing to the solutions of this metal being comparatively poor conductors of electricity, anodes must be placed opposite each side of the article to be plated, or surround it where its form is circular.

The cleansing baths required are a potash bath, a weak cyanide bath for brass or copper work, and a weak hydrochloric acid bath for steel or iron work. Tho surfaces of the metal to be deposited are cleaned in the ordinary way, and placed in the hot potash bath for a short time, rinsed, then dipped in either the cyanide or hydrochloric acid bath, again well rinsed, and put in the nickel vat; it is necessary that the articles should be struck, that is, receive an immediate coating, directly after immersion, after which deposition should be allowed to progress more slowly. The bath should be filled with work upon this system; after a while the power may be gradually augmented until the required deposit is obtained. Although cast-iron work may be nickelled direct, it is an advantage to give the work a preliminary coating of copper; the ordinary cyanide of copper solution may be used for the purpose, but for the cast iron it is necessary to have the solution rich in metal, and the temperature raised to 130° F. The coppering bath is advantageous, as it enables one to discover the effects of cleaning and pickling before depositing the nickel, a matter of considerable importance; and it will also be found useful to use it before plating Britannia metal and tinned iron goods. When the double chlorides of nickel and ammonia are used in preference to the double sulphates of nickel and nickel and ammonia, the solution may be weaker, since the former solution is a better conductor than the latter, and is more readily affected by electrical action; a mixture of the double sulphates and double chlorides has also been tried with tolerable success. If the deposits are of a dull yellow colour, or a pearl-grey, either the solution is faulty or the current of too low tension to yield the proper deposit, which should be nearly as white as silver.

The deposit obtained from the double chloride has a peculiarly matted surface, and is difficult to polish and extremely liable to tarnish on exposure to the air. The deposit obtained from the double sulphate is much easier to polish, but is also very hard and inflexible, and, if thick, is especially liable to separate in laminæ from the surface on which it is deposited. The solution of the double chloride of nickel and ammoninm is better adapted for coating iron with nickel than the double sulphate solution, the double sulphate solution answering better for brass.

Both these solutions become gradually changed in use; in the second, the ammonium salt is decomposed by the action of the current, and free ammonia is evolved, the solution becoming rich in nickel and losing ammonia, these changes affecting the quality of the deposited metal. These difficulties may be overcome by adding to the bath boracic acid. E. Weston, to whom this improvement is due, states that an excellent solution may be made by using 5 parts chloride of nickel and 2 parts boracic acid, or with 3 parts sulphate of nickel and 1 part boracic acid. Either of these solutions may have added to them with advantage caustic soda, potash, or lime, until the precipitates formed cease to be dissolved.

For the recovery of nickel from old solutions, a saturated solution of ammonia sulphate should be added to the old solution with constant stirring; no effect will be observed at first, but in a few moments a deposit of the double sulphate will begin to form. The precipitation should be continued until the liquid is colourless; the resulting salt is quite pure, and may be used direct in making the new solution.

Brass deposits, which are commonly made on zinc articles which have to be afterwards bronzed, may be made as follows:—To 2 gal. of water are added 4 oz. each of carbonate of copper and carbonate of zinc recently prepared, 8 oz. each of pure cyanide of potassium, pearlash, and common soda, and $\frac{1}{16}$ oz. of white arsenic; the sides of the tank are lined with one or more brass sheets, joined together, connected to the last carbon or copper of the battery, the intensity of the latter is regulated by the surface of the articles to be electro-plated. These are suspended by copper hooks to stout rods of the same metal, all connected to the last zinc of the battery. There are numerous other brass baths in use, and an excellent one, introduced by Watt, is prepared and worked as follows:—

For each gallon of solution take, say, 2 oz. of sheet brass of the best quality, cut it into strips, and place these in a porcelain capsule or stone jar; pour on about 4 oz. of commercial nitric acid, to which a little water may be added. Allow the chemical action to proceed in a cool place at first, and when the red fumes of nitrous gas cease to be visible, apply gentle heat. When the acid has become saturated, the supernatant solution must be transferred to another vessel, and a smaller quantity of acid poured on to the undissolved alloy, and this treated as before. It is advisable not to have the acid in excess; and if a small fragment only of the metal be undissolved, it is better to put it aside than to run the risk of an excess of acid. The acid solution of the brass alloy is next to be diluted with about 2 qt. of water, and a solution of carbonate of potash, salts of tartar, added gradually, to precipitate the respective metals. For this purpose 1 lb. of carbonate of potash may be dissolved in a quart of cold water, ready for use. Upon adding the carbonated alkali, care must be taken, or the effervescent mixture will overflow, carrying the precipitate with it. This precaution is specially necessary when the precipitation is near completion.

A light bluish-green precipitate is formed in the above operation, which must be allowed to subside. The clear liquor should, however, be tested with a drop or two of the alkaline solution, in order to ascertain if all the metal has been thrown down. If this is the case, the precipitate may be either washed by filtration, or by the addition of hot water, and frequent subsequent washings. Although the washing of the precipitate is a somewhat slow process, it is important to push it as far as possible, since the salts remaining in the solution do not in any way improve the working or general character of the solution itself.

After the final washing, the precipitate is to be treated with strong liquid ammonia (·880), which must be added gradually, with constant stirring. The ammonia will redissolve the precipitate, forming a dark-blue solution. To this now must be added a strong solution of cyanide of potassium, until the blue colour entirely disappears; and beyond this about 4 or 5 oz. of free cyanide must be added to assist the solution of the anode. It is even more important in this than in some other electro-metallurgical operations that the cyanide be of good quality. The brass solution should now be filtered, and water added to make one gallon. It may be worked either hot or cold, but if the former, it may be advisable to reduce it by adding a little water. The anode should be of the same quality as the alloy from which the solution was made; indeed the latter would be best prepared from a portion of the sheet of brass which is destined to act as an anode.

Steel plating on copper plates and type is extensively practised, by one method; in proceeding to prepare for work, the trough is filled with water in combination with hydrochlorate of ammonia, sal-ammoniac, in the proportion of 1000 lb. by weight of water, to 100 lb. of hydrochlorate of ammonia. A plate of sheet iron nearly as long and as deep as the trough, is attached to the positive pole of the battery, and immersed in the solution. Another plate of sheet iron about half the size of the other is attached to the negative pole of the battery, and immersed in the solution, and when the solution has arrived at the proper condition, which will require several days, the plate of iron attached to the negative pole is removed, and the printing surface to be coated is attached to this pole, and then immersed in the bath till the required coating of iron is obtained. If, on immersing the copper plate in the solution, it is not immediately coated with a bright coating of iron all over, the bath is not in a proper condition, and the copper plate is to be removed and the iron plate attached and returned into the solution. The time occupied in obtaining a proper coating of iron to a printing surface varies from a variety of causes, but a copper plate should not be allowed to remain in the bath and attached to the negative pole of the battery after the bright coating of iron begins to show a blackish appearance at the edges. Immediately on taking a copper plate from the bath, great care is to be observed in washing off the solution from all parts, and this may be most conveniently done by causing jets of water forcibly to strike against all parts of the surface. The plate is then dried and washed with spirits of turpentine, when it is ready for being printed from in the ordinary manner.

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E. S.

EXPLOSIVES (Fr., *Explosives;* Ger., *Knalle*).

The industrial applications of explosives are for blasting or to give light and sound for signalling purposes; explosives for the latter purpose are really fireworks on a large scale, and as such will be treated of in the article on Pyrotechnics. The best known explosives are gunpowder, gun-cotton, nitro-glycerine in various forms, known as dynamite, lithofracteur, giant powder; gun-cotton and its derivatives, cotton powder and Schultz's gunpowder, and to a smaller extent various fulminates and picrates.

An explosive mixture generally has two essential ingredients, one readily combustible, and the other containing oxygen, in considerable quantity, which it will part with easily. Carbon, with which hydrogen is usually associated, is almost always the combustible substance, although occasionally other oxidizable bodies, such as sulphur, are used. The carbon is most frequently in the form of charcoal, but any other organic substance containing it largely will afford the same action; the oxidizing agents are almost invariably nitrates or chlorates, but the difference in the readiness with which these two salts give up their oxygen causes one or other of them to be preferred in the particular explosive of which they form a part.

Gunpowder.—The three ingredients of which gunpowder is composed are saltpetre, charcoal, and sulphur. Its exploding point is about 600° F. The qualities which most influence gunpowder are its density, the size and shape of grain, and the condition of the charcoal. It is essential that gunpowder should be uniform in action; the denser it is the slower it will burn, even in single grains, and dense powder will offer a smaller surface to ignition than an equal weight of a less dense kind. For similar reasons, a large grain will burn slower than a number of small grains making up the same weight, and a grain of regular shape such as a cube, a cylinder, or a sphere, will offer less surface than an irregular one of the same mass; laminated or flaky forms indicate a violent powder. There are other points, which are alluded to in the following detail of its manufacture.

The chief woods from which is manufactured charcoal for powder-making are the willow, the alder, and what is popularly known as the "black dogwood," but which is really the alder buckthorn, or berry-bearing alder (*Rhamnus frangula*).

Their adoption was no doubt decided empirically, for it is not easy even to determine why any particular woods are better adapted than others for charcoal for gunpowder. Though various other woods are used for coarse blasting powder, the three named are generally selected for the best gunpowders.

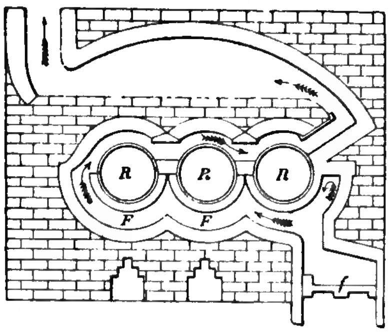
Small wood of about ten years' growth, is in all cases preferred for powder-making. Alder and willow of this age will be probably 4–5 in. in diameter; dogwood, about 1 in.; the two former woods in pieces of 3 ft. long, not less than 1 or more than 4 in. in diameter. The wood must be straight, perfectly sound, and entirely free from bark, and must have been felled during the spring of the current year. All wood is stacked on iron sleepers or on rows of brickwork; the alder and willow are provided with no protection from the weather; the dogwood is covered with straw thatching.

It is desirable that all moisture should be expelled from the wood before the latter is placed in the retorts. This will be the case after being stacked for a few months in summer. It may be safely asserted that there is no object in keeping wood for a number of years to season; on the contrary, that provided a supply of wood can always be depended on, there is nothing to be gained by maintaining a large stock of cut wood.

The wood is converted into charcoal in cast-iron retorts, set in brickwork. Fig. 592 is a transverse section of a set of cylinders; Fig. 593 is a longitudinal section of one retort. Each retort has two pipes passing out of the inner end. When set, the lower pipe *b* is closed with brickwork, being intended for use should the cylinder be turned round and reset, the upper pipe *a* only being made use of. To the upper pipe is attached a branch leading to a horizontal pipe *c*, extending behind the whole set of retorts, from one end of which another pipe *d* descends perpendicularly, joining *e* leading directly into the furnace. Each cylinder has a false bottom of brickwork, in front of which is bolted on a piece of wrought-iron plate, having a circular hole in it corresponding to the uppermost pipe of the cylinder. The cylinders are closed with tight-fitting iron doors, secured by a powerful screw. The wood is placed in small cylinders of sheet-iron R termed slips, which are placed on small iron travelling carriages, on which they can be run up directly to the mouth of the cylinders, and shot into them direct. The back end of each slip is provided with a handle to facilitate withdrawal.

Provided the cylinders are hot the wood is thoroughly charred in 2½–3½ hours. The gas and tar from the wood passes through *a c d* and *e* into the fire, which is found greatly to economize fuel, and to be the readiest means of ascertaining when the charring is properly and thoroughly done. This is shown by the flame which issues from the pipe leading into the fire becoming of a violet tint, indicating the formation of carbonic oxide. As soon as this is observed, the doors of the cylinders are opened, the slips are hoisted out of them by chain tackle and blocks, and lowered into large iron extinguishers having close-fitting lids, in which they remain for half a day, the charcoal is then discharged into coolers, large cylindrical cases of sheet-iron fitted with lids, and sent to the charcoal store. Wood yields about 25 per cent. of charcoal. Charcoal is occasionally made in large pits, as may be seen described in various works on chemistry and metallurgy. Pit charcoal is preferred for some explosive compositions, but why it is difficult to say.

592.



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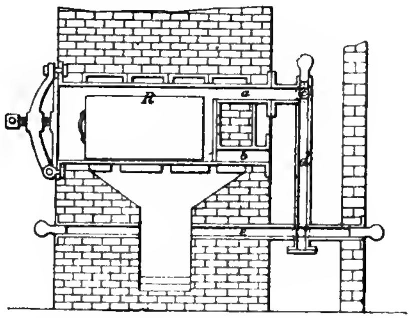


It is of the highest importance that the charring of the wood should always be conducted as nearly as possible at the same temperature, for the chemical composition of the charcoal, and the temperature at which it will ignite, is undoubtedly affected by the temperature at which it has been charred. Charcoal prepared at a low temperature is softer, more inflammable, and contains more gaseous elements than charcoal prepared at a higher heat, and the gunpowders made from these charcoals would be similarly affected. At many gunpowder manufactories, pyrometers to ascertain the temperature of the cylinders are in use.

The fitness of charcoal for gunpowder depends on its chemical composition, which is indicated by its physical qualities. If properly made it should be jet-black in colour, its fracture should show a clear velvet-like surface, and it should be light and sonorous when dropped on a hard surface. Underburnt charcoal, that is, charcoal prepared at a very low temperature, is at once known by its reddish-brown colour; overburnt charcoal, by its hardness and density. The former is greatly more inflammable than the latter, charcoal prepared at a temperature of 260° (500° F.) being readily ignited at a temperature of 338° (640° F.), while charcoal prepared at 982° (1800° F.) requires a temperature nearly double the last to inflame it. Underburnt charcoal has found favour for some small-arm powders. It certainly appears to render the powder more inflammable, and consequently quicker, but it has the disadvantage of being more hygroscopic than denser charcoal, and of rendering the powder therefore more liable to suffer damage from damp.

The analysis of some specimens of gunpowder charcoal showed:—

	Ash.	Carbon.	Hydrogen.	Oxygen with trace of Nitrogen.
Alder	1·24	87·00	2·97	8·78
Willow	2·02	85·82	2·88	9·28
Dogwood..	1·71	83·80	3·28	11·21

The average densities of the three charcoals are alder, 1·37; willow, 1·39; dogwood, 1·30. An analysis of the ash of each gave:—

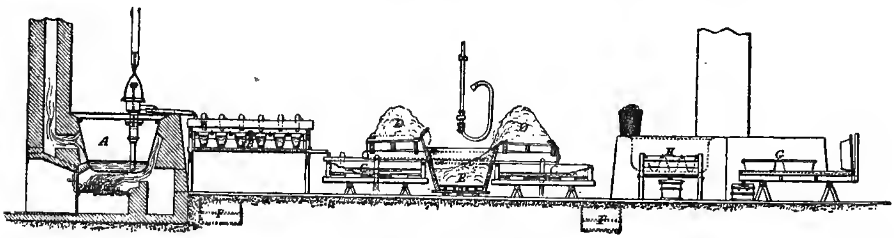
	Alder.	Willow.	Dogwood.
Silica	4·66	3·33	17·30
Phos. lime, trace Fe. ..	25·60	27·10	14·53
Lime	24·90	27·66	31·60
Mg. O.	2·77	4·25	2·05
Potash	10·53	11·50	8·20
Soda	2·21	2·70	3·15
SO_3	1·20	2·50	1·22
Chlorine	·15	·25	·54
Carbonic acid	27·82	18·68	20·62
	99·84	97·97	99·21

Proust, who paid special attention to the study of gunpowder, tried a series of experiments with mixtures of saltpetre and equal quantities of the charcoals of various woods, which he burnt together, measuring the quantity of gas evolved. His experiments have been repeated by some English chemists with very interesting results, of which the following is an abstract. 12 gr. of charcoal mixed with 60 gr. of saltpetre gave the following proportions of gas in cub. in.:—

	Gas cub. in.		Gas cub. in.
Elm	62	Willow (*Salix alba*)	76–78
Oak	61–63	Alder	74–73
Mahogany	58	Filbert	72
Willow (overheated)	59–66	Fir, Chestnut, Hazel	66
Oak „	54–56		
Dogwood (*Rhamnus frangula*)	80–84		

The saltpetre as imported is known as grough saltpetre; it contains various impurities, the principal of these being sulphate of soda, chloride of sodium, sand, and moisture. To eliminate this, an apparatus similar to Fig. 594 is employed. Here A is a boiler, B a filtering apparatus, C a cooler, D drainer, E washing vat, F F liquor tanks, G evaporating pans, H filter.

594.



About two tons of grough saltpetre is placed in a large open copper pan A, and about 270 gal. of water are added to it. Over the bottom of each pan is placed a false bottom of iron, perforated with holes 1 in. in diameter, to allow the sand and insoluble impurities to fall. In about two hours the saltpetre is dissolved and the solution boiling. The false bottoms are pulled out just before the solution begins to boil, and the scum removed from the surface. The solution is allowed to boil until no more scum rises; the copper is then filled up with cold water, again boiled briskly for a few minutes, after which it is allowed to cool.

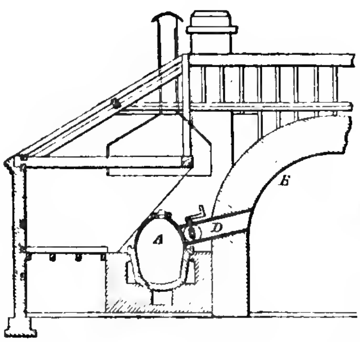
When the temperature of the solution has fallen to about 93° (200° F.), with a specific gravity of about 1·53, a hand-pump is lowered into the copper, and the solution is pumped into a wooden trough leading to another larger one termed the supply trough, furnished with six holes in the bottom, beneath which the filtering bags are suspended, Wooden plugs are provided for these holes, so that if the bags become clogged the flow of solution may be stopped.

The bags, made of dowlas, are suspended on iron hooks underneath the holes in the supply trough. They are always rinsed with hot water before the filtering commences, and require occasionally a little poured over them to prevent the formation of crystals. Occasionally a solution is found to contain so much organic impurity that it will not run through the filters. In this case a little glue, about 1 lb. to 2 tons of saltpetre, is added to the solution in the copper, which has the effect of throwing up a great part of the impurity as a scum, which can be removed before the liquor is pumped out. As soon as it is all removed the pumps are pulled up, and the coppers, if necessary, cleaned out. A wooden trough placed directly underneath the filtering bags receives the solution as it runs from them, and conducts it directly into the cooler or crystallizing cistern, a large shallow flat trough of sheet copper about 12 ft. long, 7 ft. wide, and 1 ft. deep. By the time the solution runs into it the temperature will have fallen to between 82° and 88° (180° F. and 190° F.). As the temperature continues to fall the excess of saltpetre crystallizes out; the coolers must be kept in constant agitation, to cause it to deposit the salt in the form of flour or minute crystals. This is effected by constant stirring by means of a large wooden hoe, with which also the flour is drawn to the side of the cooler, to be shovelled out with a copper shovel. As it is removed it is first thrown on to an inclined board or drainer, to allow the excess of liquor to run back into the cooler. It remains on the drainer for some minutes, after which it is transferred to the washing vat. The crystallizing process may be very materially hastened by artificial cooling.

The value of sulphur as an ingredient of gunpowder is due to the low temperature at which it inflames. It melts at a comparatively low temperature, 115° (293° F.), and inflames at about 293° (560° F.). Distilled sulphur, as used in the manufacture of gunpowder, consists of masses of clear yellow crystals in the form of rhombic octahedra, and is readily soluble in bisulphide of carbon.

Figs. 595, 596 show the iron pot or retort in which the process is carried on; Fig. 596 is a section through water-jacket, and Fig. 595 a section through pipe to subliming dome. The apparatus employed consists of a large pot of cast iron A, about 1 ft. 8 in. deep, 3 ft. $4\frac{1}{2}$ in. in diameter at the mouth, and about 2 ft. 2 in. at bottom. The metal of the pot is very thick, being about $2\frac{1}{4}$ in.

595.



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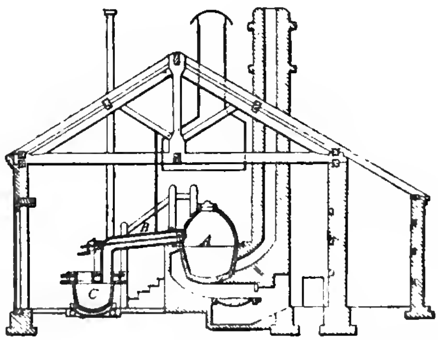


thick at the edge, and nearly 6 in. at bottom; round the top edge is shrunk a strong ring or tire of wrought iron to prevent splitting by expansion; this pot is set in brickwork; on the top of it is fitted a large dome-shaped cover, also of cast iron, secured to the pot by three wrought-iron tie rods, which are secured by screw bolts to a wrought-iron ring passing round the neck of the cover.

At the top of the cover is a circular opening, 1 ft. $6\frac{3}{8}$ in. in diameter at top, and 1 ft. $3\frac{3}{4}$ in. at bottom, fitted with a heavy cast-iron lid, the weight of which is sufficient to keep it in its place during the refining process. In this lid is a 4 in. iron plug-hole with a considerable amount of taper, through which the pot is charged. The cast-iron plug which closes it fits sufficiently tightly to prevent escape of sulphur-vapour, particularly if a little sand be thrown over it; but at the same time it acts as a safety valve, being lifted out if an unusual pressure of vapour is exerted inside the pot.

From the dome-shaped cover two pipes proceed at right angles to each other, one D to the subliming dome E, the other B to the distilling tank or receiving pot C. The first pipe is 1 ft. 3 in. in diameter, and is furnished with a throttle-valve which can be closed or opened by a handle from without, so as to shut off or open the communication between the pot and the dome when required; the other pipe is encased in a water-jacket, and can be closed or opened by means of a conical valve worked by a screw. When distilling, a constant flow of water is maintained through the water-jacket from a cistern overhead, which is filled by a force-pump in the house. There is an escape-pipe fitted to the water-jacket, to allow of the escape of water when there is a sudden development of steam, caused by the heat of the sulphur-vapour; this pipe leads directly into the receiving pot. The receiving pot is a large circular vessel of cast iron, 3 ft. 6 in. in diameter, which is set on a frame mounted on small trucks, to allow of a slight movement, when the pipe which connects it with the melting pot becomes expanded and lengthened, by the heat of the sulphur-vapour passing through it. There is a large opening through which the melted sulphur can be ladled out when necessary; this is closed by an iron lid similar to that of the melting pot, in which is also a small plug-hole, through which the depth of melted sulphur in the receiving pot can be gauged with an iron rod. A small pipe leads from another opening in the lid of the receiving pot, into a square wooden chamber lined with lead to receive any non-condensed vapour, and cause it to deposit its sulphur in the form of flowers. This chamber is provided with a tall chimney, also of wood, containing a series of steps or traps to catch as much of the flowers as possible.

The subliming dome E is a large dome-shaped building of brick, 10 ft. in diameter at base, and about 12 ft. in height. The pipe from the sulphur pot enters it near the top; the chamber is lined with flag-stones, and the floor is covered with sheet lead; it is provided with two doors, an inner one of iron, an outer one of wood, lined with sheet lead, both close fitting, through which passes a pipe to allow the escape of air; this pipe terminates in a vessel of cold water.

In the ordinary course of distilling sulphur for powder-making a small amount must always pass into the subliming dome. Very often distilling and subliming are carried on together; but in this case the temperature of the dome is not allowed to fall, and it is thus found perfectly practicable to obtain both distilled and sublimed sulphur at the same time, but it is better on the whole to carry on the two processes separately.

If distillation only is to be carried on, about $5\frac{1}{2}$ cwt. of raw sulphur is placed in the pot each morning; an extra hundredweight would be put in if both distilling and subliming together.

The fire being lighted, the conical cast-iron plug is left out of the hole in the lid of the pot, the passage into the dome is opened and that into the receiving pot closed; the heat is maintained for three hours, till the sulphur is of a proper temperature for distillation. The vapour which first rises from the pot is of a pale yellow colour, and as much of it as passes into the dome falls down condensed as flowers-of-sulphur, but at the end of three hours the vapour becomes of a deep reddish-brown colour, showing that the temperature of the melted sulphur has reached the proper point. The plug must then be inserted in the lid, the communication to the dome closed, and that leading to the receiving pot opened, allowing the heavy vapour to pass through the pipe surrounded with the water-jacket, by means of which a constant circulation of cold water is kept up round it; in this way the sulphur vapour is condensed, and runs down into the receiving pot as a clear orange liquid resembling treacle in colour and consistency. By gauging the depth of the melted sulphur in the receiving pot, it can be ascertained when the greater part of the material has distilled over; the fire is then lowered, the communication into the dome opened, and that leading to the receiving pot cut off, allowing the remaining sulphur to pass off into the dome as flowers. A low fire is maintained till the whole has been driven off, leaving the earthy residue quite free from it, and consequently loose like coal ashes, so that it may be easily ladled out next morning before recharging the pot.

When both subliming and distillation are carried on at once, the first part of the process would be the same; but when the distillation was finished the fire would be maintained for the remainder of the day, but somewhat lower, to drive off the quantity required into the dome, and in this case the subliming process would be carried on for several days, and the pot and dome never suffered to cool down altogether till the required quantity of flowers-of-sulphur had been obtained.

It is of the greatest consequence that the fire should be carefully regulated in all cases, for if the heat becomes too great, and the temperature of the melted sulphur be allowed to rise to 447° (836° F.), the vapour disengaged at that temperature is highly explosive when mixed with common air; and if the plug be driven out by the pressure of the vapour, or if air be drawn into the pot through some leakage in the pipes, an explosion invariably happens. When the distilled sulphur in the receiving pot has cooled down sufficiently, which it will do in the course of an hour or two, it is ladled by hand into wooden tubs and allowed to solidify. Distilled sulphur immediately after being removed from the tubs is placed within a boarded-off enclosure, to guard against coming in contact with any fragments of grit or sand, which might thus enter the powder, and is broken up into large lumps, which are sent up to the factory to be ground under a pair of mill-stones. After being ground it is reeled through 32-mesh wire-cloth, and is then fit for the mixing house; its fitness for use as an ingredient of gunpowder may be readily tested :—

1st. By burning a small quantity on porcelain, when the amount of residuum should not exceed 0·25 per cent.

2nd. By boiling with water and testing with blue litmus paper, which it should only very feebly redden.

As an ingredient of gunpowder, sulphur is invaluable on account of the low temperature at which it inflames, thus facilitating the ignition of the powder. Its oxidation by saltpetre appears also to be attended with the production of a higher temperature than is obtained with charcoal, which would have the effect of accelerating the combustion, and of increasing by expansion the volume of gas evolved.

Before the ingredients can be mixed they must be reduced to a powder sufficiently fine for the purpose. It is true that some manufacturers do not pulverize or mix their ingredients at all, but simply weigh out as much of each as is required in lumps and fragments, and throw them on the bed of the incorporating mill. But this obviously involves a loss of time, as the action of the incorporating mill must be at first merely that of grinding and bringing the three ingredients into juxtaposition, before any incorporation properly so called can be effected. It is important to bear clearly in mind the meaning of the terms mixing and incorporating, as they are used by gunpowder makers. Though gunpowder is really only a mixture, very intimate no doubt, of the three ingredients, and not a new chemical substance formed out of them, yet by mixing is understood only the stirring together for a few minutes of the saltpetre, sulphur, and charcoal, to get them properly distributed amongst each other; and by incorporating, the long continued trituration and grinding which the mixture undergoes under heavy edge-runners, by which a mass of the ingredients becomes transformed from a mere mixture of three different substances into gunpowder. A preliminary mixing, such as is employed at most gunpowder works, may be dispensed with; incorporation, whether performed by pestle and mortar, in the stamping mill, or under edge-runners, never.

The saltpetre is, as has been previously stated, used moist as it comes from the refinery. It is generally sent up to the mixing house after standing four or five days in the store bins, and when used contains generally from 3 to 5 per cent. moisture. For this an allowance must of course be made in weighing, and to enable the mixer to make this accurately, the percentage of moisture in the quantity sent up each morning, generally amounting to 35–40 cwt., when the factory is in full work, is ascertained by the master-refiner by drying and fusing a sample, and comparing the weight before and after the operation. A ticket with the proper weight of the saltpetre for the day's charges is given to the master-mixer, who weighs out the saltpetre accordingly.

The subjoined Table shows the weight of moist saltpetre for a 50½ lb. charge, with moisture from 3 to 6 per cent.; thus, though the proportions used in England for gunpowder are 75 saltpetre, 15 charcoal, 10 sulphur, an extra 1 lb. of saltpetre is generally added to the 100 parts to cover loss in manufacture.

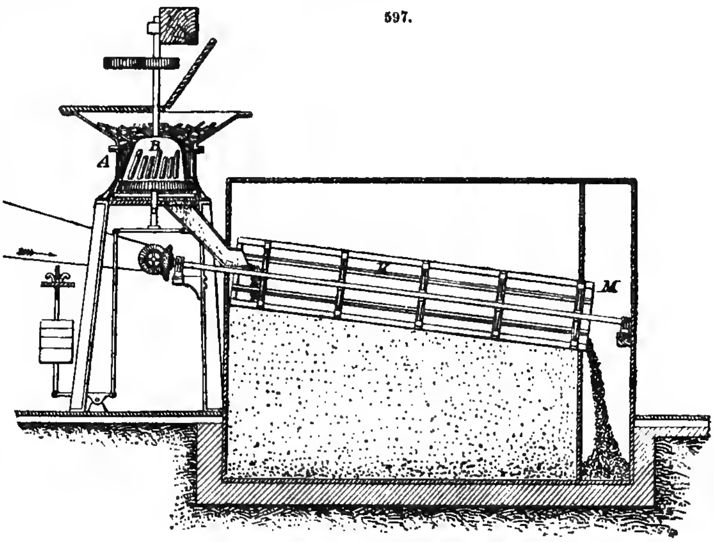
At per cent. Moisture.	Weight.		At per cent. Moisture.	Weight.		At per cent. Moisture.	Weight.	
	lb.	oz.		lb.	oz.		lb.	oz.
3·0	39	3	4·1	39	10	5·2	40	2
3·1	39	4	4·2	39	11	5·3	40	3
3·2	39	5	4·3	39	12	5·4	40	3
3·3	39	5	4·4	39	12	5·5	40	4
3·4	39	6	4·5	39	13	5·6	40	5
3·5	39	6	4·6	39	14	5·7	40	5
3·6	39	7	4·7	39	14	5·8	40	6
3·7	39	8	4·8	39	15	5·9	40	7
3·8	39	9	4·9	40	0	6·0	40	7
3·9	39	9	5·0	40	0	—	—	
4·0	39	10	5·1	40	1	—	—	

If dried refined saltpetre is employed, it is first ground under a pair of small stone edge-runners fitted with scrapers, and then passed through a slope-reel covered with 28-mesh wire.

The sulphur is ground under a pair of iron edge-runners, also fitted with scrapers, and sifted in a slope-reel covered with 32-mesh wire.

Charcoal, after being carefully hand-picked, to guard against the introduction of any fragments of foreign matter and underburnt knots of wood, is ground in a mill, Fig. 597. It consists of a cone B working in a cylinder A, each being furnished with diagonal ribs or teeth, which are widely apart at top but approach closely together at the bottom. The charcoal which is fed in at the top passes out at the bottom into a slope-reel K M covered with 32-mesh wire.

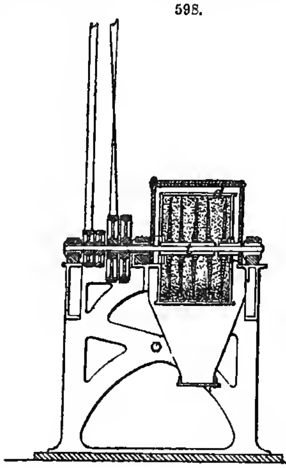
597.



Charcoal, after having been burnt, should be allowed to stand for ten days to a fortnight before being ground, for when ground fresh after burning, the finely powdered charcoal absorbs and condenses oxygen so rapidly as to generate a great amount of heat, enough to cause spontaneous combustion. The relative proportions of the three ingredients are weighed out in quantities of 50 lb., that is to say, 37½ saltpetre plus the extra weight for the moisture, 7½ charcoal, and 5 sulphur, and transferred to the mixing machine, Figs. 598, 599. This consists of a hollow drum *d* of gun-metal, 1 ft. 6 in. wide by 2 ft. 9 in. in diameter, which is made to revolve at a speed of 40 revolutions a minute. The bearings *t* are hollow to receive a shaft which passes through them. This shaft carries in the interior of the drum a series of forty-four arms or fliers, the points of which just clear the interior of the drum, and revolves at twice the speed of the drum, in the opposite direction. A 50 lb. bag of ingredients is emptied into the drum through a square opening at the top of it, and the drum and shaft carrying the fliers being set in motion for five minutes, the saltpetre, sulphur, and charcoal are thoroughly mixed together. The mixed ingredients fall down the shoot into a tub, from which they are transferred to an 8-mesh wire sieve, placed over another shoot, having a composition bag placed beneath it. On the sieve the charge is carefully sifted by hand, to guard against any foreign matters passing into it, and falls through into the bags, in which it is tied up tightly, and transferred to the expense magazine or charge-house ready for the incorporating mill.

A charge of fresh mixed ingredients is termed a green charge. Though not so easily ignited and slower in burning than gunpowder, it is, of course, explosive. Incorporation is unquestionably the most important of all the operations in the manufacture of gunpowder. The more thoroughly it is effected the stronger will be the resulting gunpowder. Provided the incorporating mill is sufficiently powerful, and is worked at a sufficient speed, a most thorough incorporation can be effected in a few hours, after which there is no object in continuing the process.

598.



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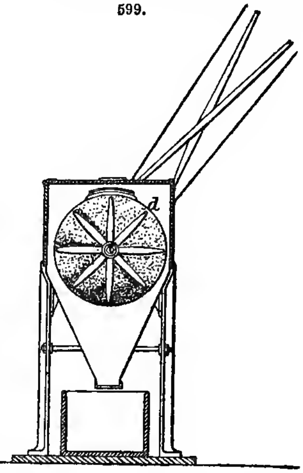
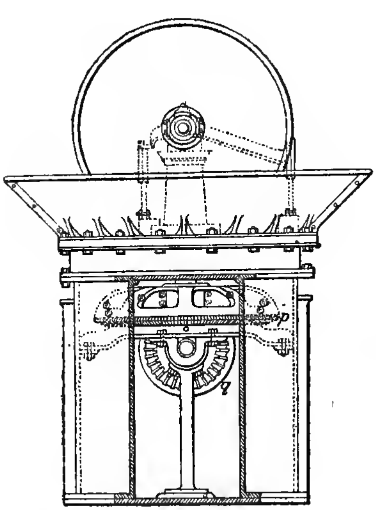


The old stamping mills, in which the ingredients were subjected to long-continued stamping under pestles working in small mortars, have been out of use for many years in England, though they are still employed in other countries. The action of such mills has very little incorporating effect, and is moreover attended with even more risk than the mills used in this country. The same remark applies to the *moulins à tonneaux*, in which a partial incorporation is effected by placing the material in a revolving barrel or drum along with some large metal or wooden balls. Such mills are often used for pulverizing the ingredients, and occasionally for incorporation, but the most effectual and speedy incorporation can be obtained with mills such as shown.

600.



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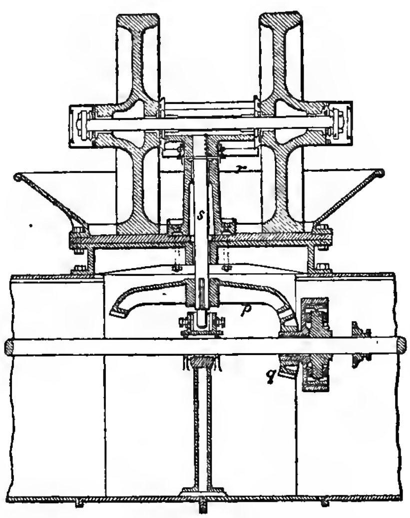


The incorporating mill, Figs. 600, 601, consists of a pair of large, heavy edge-runners, of iron or stone, which revolve on a strong circular bed, the bed being stone for the stone and iron for the iron runners. The runners are of various sizes, but must weigh 3½–4 tons each. Some of the iron runners are of large diameter, 7 ft., others about half this; those of the smaller diameter are better than the larger, as the latter cause a greater twist on the bed, and are therefore more apt to cause accident. The face of the runners should be nearly flat, with a slight bevel towards the edge. The runners are connected together by a powerful spindle of wrought iron, which rests in brass bushes placed in the cross-head, so as to allow the spindle and runners to rise and fall, according to the thickness or thinness of the layer of material on the bed. The spindle is placed in the cross-head, in order to bring one runner nearer to it than the other, and therefore to cause them to describe different paths when in motion. The spindle should have a large leverage on the runners, as their weight is so great. They must therefore be cast with as long a socket for the spindle as possible, otherwise they will very soon work loose on it. The cross-head *r* is fixed on a vertical shaft *s*, turned by a wheel *p*, driven from a pinion *q* on the driving shaft, which passes underneath the whole group of mills. By this arrangement the gearing is kept out of reach of damage from explosion. The cross-head *r* is fitted with a bracket on each side, to carry a plough of wood, shod with felt and leather, which travels round on the bed immediately in front of the runners, and thus keeps the composition from working away from them. The bed has a curb or edge round the outside and inside of the circular path described by the runners, that on the outside being formed by a sloping rim fixed all round the bed, that on the inside by the circular base of the cheese or conical socket down which the vertical shaft of the cross-head passes. Both the inside and outside curbs have gun-metal rings round them for the ploughs to work against. Every fitting and bolt is arranged with the greatest care, so as neither to break nor become loose from the jolting of the mill, and thus drop into the charge.

Various modifications of the incorporating mill have been proposed from time to time. The most important was a plan for keeping the runners and cross-head stationary, and causing the bed to revolve underneath them. This plan has the merit of greater safety to recommend it, but the mechanical difficulties in working it are very great. Another proposal was to heat the beds of all incorporating mills by steam, as heat is supposed to assist and hasten the process of incorporation, for some unknown reason.

The charges, either green from the mixing house, or dust from the dusting or granulating houses, come to the mills in wooden tubs, and are stored in strong expense magazines or charge houses. In all cases they are sifted before going to the mills, as this is the only certain plan of preventing foreign matter's getting into the mill bed. The millman takes the charge and throws one half on one side of the bed and the other on the other, and then with his rake and brush distributes it evenly over the mill bed. The runners are then moved round a quarter revolution, and the piece of mill-cake left under the runners from the former charge is broken up and distributed over the fresh charge. This portion of mill-cake is of course finished powder, and if the runners are left standing for any length of time with their whole weight on it, it becomes extremely hard. It should therefore always be broken up and distributed over the fresh charge, for if otherwise, it may adhere to the bed, and being very hard may be the cause of so much friction as to cause explosion. It is a much better plan to leave the runners on a portion of powder on which they stop than to attempt to run them off on to a leather placed on the mill bed, as must be done before the mill is washed out for repairs. Before starting the mill, about two pints of distilled water are sprinkled over the charge, the runners are then started at a speed of about eight revolutions a minute; the millman does not remain in the mill, but only goes in from time to time to push up the charge from the bed, and to add a little more water according to the state of the charge, from two to three pints are generally found to be necessary in very damp weather, and as many as eight or ten in very bright days. The watering, or liquoring, as it is called, of the charge is always left to the millman's judgment; but it would be preferable to lay down a regular scale of liquor for all mill charges, according to the indications of the hygrometer.

Large-grained powder requires to be incorporated for three hours, all small-grained powder made with dogwood for five. The times of incorporation vary with the power of the mills. Thus large-grained powder requires 3½ hours working under strong runners weighing 3½ tons, and making 7½ rev. a minute, but only 2½ under iron runners of 4 tons, making 8 rev. a minute. Small-grained dogwood powders require 5½ hours in the former mills, and 4 in the latter. All dust charges are worked ¾ hour in all mills.

As the process of incorporation approaches completion, the charge requires to be carefully watched, in order to ensure each finished charge leaving the mill in as nearly as possible the same state as regards moisture. The appearance of the powder when finished depends mainly on the state in which the charges leave the mill. If more than from two to three per cent. of moisture be present as the incorporation draws to a close, the charge must be repeatedly pushed up with the shover; if too little, some more must be added from the watering pot. The colour of the charge gives a very good indication of the amount of moisture present.

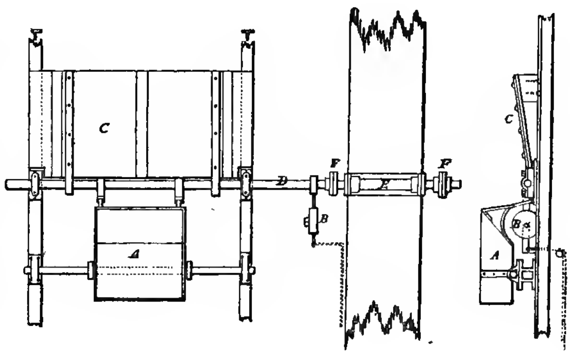
When the process is finished, the charge now known as mill-cake, being partly in the state of soft cake and partly of dust, is scraped and swept up from the mill bed, placed in wooden tubs, and transferred to the charge house to await inspection. If the charges are found to be of a proper colour and consistency, samples from each are taken, which, after being roughly granulated by hand

and dried, are flashed on a glass plate, to ascertain the thoroughness of the incorporation which they have undergone.

Incorporation is the most dangerous operation in the manufacture of gunpowder. Accidents in the subsequent processes, where large quantities of powder are subjected to treatment at one time, are fortunately rare, but in the incorporating mills they may be expected from time to time. As such mills are generally built in groups, an explosion in one is very apt to spread amongst all the others round it, particularly as the roofs of all are saturated with powder dust. To prevent this, a drenching apparatus, of which Figs. 602, 603 are a representation, is erected over each pair of runners.

The apparatus consists of a large shutter C, balanced by a counterweight B, and pivoted on a spindle D which runs through the whole group of mills. To this spindle the shutter in each mill is attached and the spindle passes through bearings in the partition walls, being connected by couplings F, so that the lifting of one shutter lifts all the others. Balanced on the pivot edge of the shutter is a large copper vessel A full of water; this is so arranged that the slightest lift of the shutter capsizes its contents into the bed of the mill beneath it. An explosion in one mill therefore lifts the shutter above it, and throws down the water into the mill bed; and though too late to do any good in the mill which has exploded, the movement of the shutter turns the spindle and drowns the charge in all the adjacent mills, and thus saves them from explosion. There is also an arrangement by which the millman can, in case of an explosion in the immediate neighbourhood, pull over the vessel of water from outside.

602. 603.

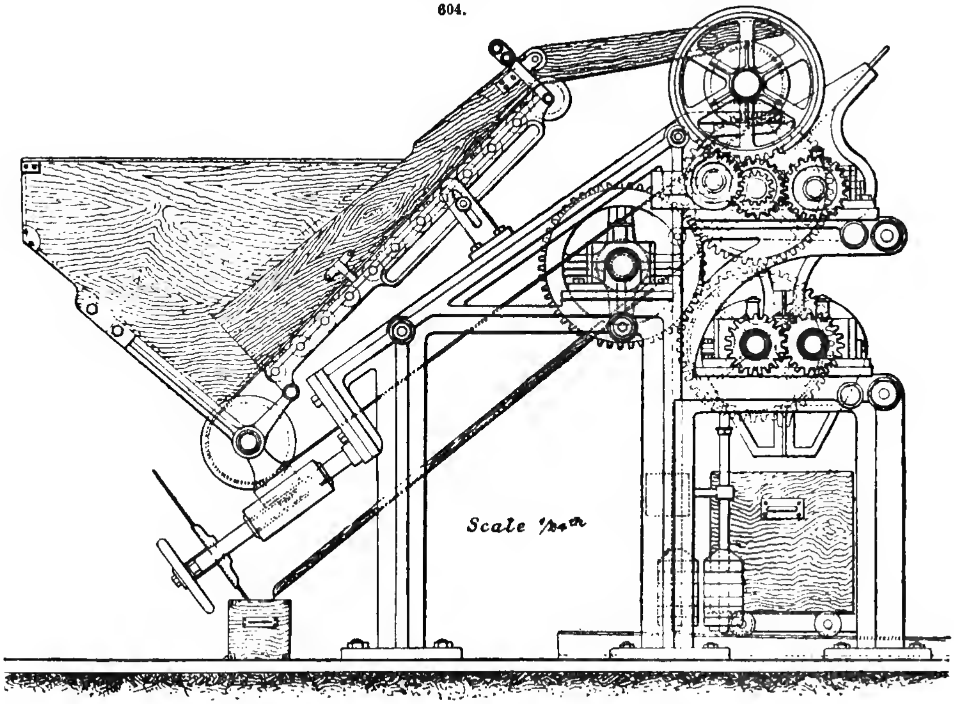


The explosion of a green charge does not, in some cases, do much damage to the structure of the mill or the machinery; that of a worked charge is very violent, and leaves generally no part of the structure standing. Consequently all mills are made of a very strong framework covered with light boards, which can be quickly replaced if destroyed by an explosion. The cake leaves the mill partly soft and partly dust; it hardens considerably if allowed to stand for a few days. In this form it would be, of course, quite unfit for use. The cake may indeed be broken up into grains, as is done in many countries, but powder made direct from mill-cake is dusty and irregular in action. It is also much more liable to absorb moisture, and therefore to cake and become lumpy.

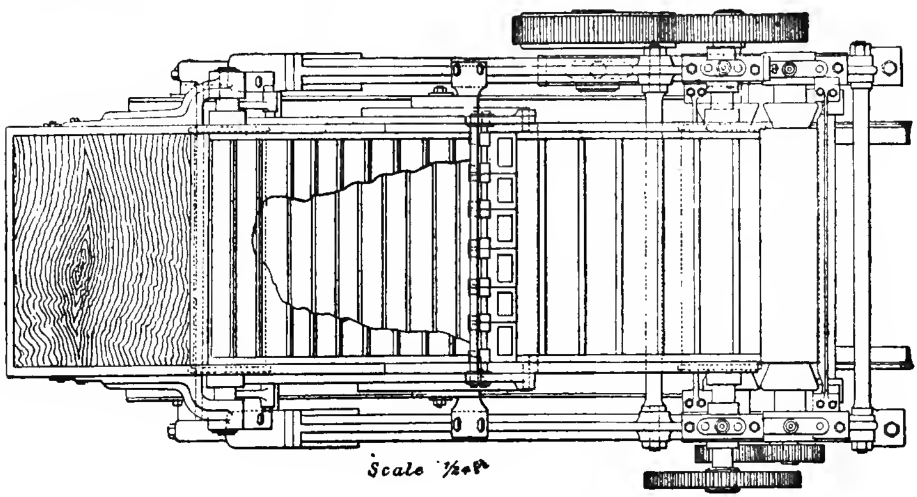
To ensure uniformity and good keeping qualities, and freedom from dust, powder must be corned or converted into firm grains. The old process is to damp the incorporated materials till they acquire a certain consistence, and then force the mass through sieves, thus forming granular fragments which are afterwards hardened by drying. There is no difficulty in thus forming good hard grains, but the moisture added partly dissolves the saltpetre, which in drying forms a hard external surface. The best way is first to compress the soft material into hard masses by pressure alone, and then to crush up these masses into the description of grain required. The pressing is to convert the mill-cake into hard cakes, of the particular density which is found to give the best results when the powder is finished.

Gunpowder is generally pressed in layers, between plates of gun-metal or copper, in a hydraulic press. Screw presses are still in use in many factories, and there are different ways of placing the powder in the presses used. The best results are obtained by pressing in thin layers. The details of the process will be described further on, but it is merely necessary to say here that the gun-metal plates between which the powder is placed are, when the press is being filled, placed on their edges and the powder thrown in between them. As they stand closely together, ½ inch apart, it follows that to ensure the powder finding its way down between them it must be reduced to a tolerably fine state of division. If taken direct to the press from the mills, the cake would not enter between the press plates; a preliminary operation is therefore necessary, namely, breaking down. If the powder is to be pressed in very thick cakes it would not require breaking down. The breaking-down machine, Figs. 604, 605, consists of two pairs of gun-metal rollers placed in a frame, one pair directly above the other. They are grooved longitudinally to get a better hold of the mill-cake; one roller of each pair works in a sliding bearing, and is held at a proper distance from the other by a weighted lever, to admit of each pair opening out a little if too large a quantity of the cake is drawn in between them. Attached to the machine is a large hopper; an endless band of strong canvas, having transverse strips of leather sewed on to it, works through an opening at the bottom of the hopper up to the top of the machine, by means of which a regular supply of the cake is carried up and dropped in between the rollers, which crush it up into fine meal; this falls through the second pair of rollers, which reduce to dust any fragment which may have escaped the action of the first

604.



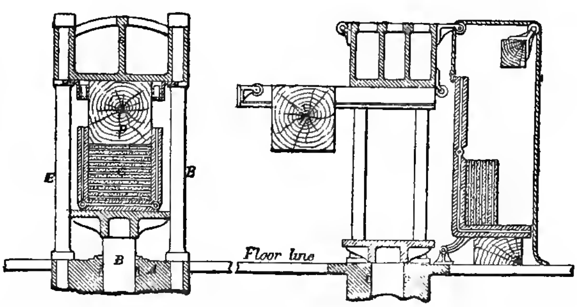
605.



pair, and finally falls into wooden tubs placed underneath to receive it; it is then ready for direct transfer to the press. Too long an interval must not elapse between the breaking down and pressing, for the meal, which should contain from 2 to 3 per cent. of moisture.

Figs. 606, 607 are the most convenient form of hydraulic gunpowder press; the press box is made of gun-metal, lined inside and out with oak boards, and is of great strength. The bottom and one side are permanently attached to each other, the other three sides are hinged to the bottom, so that they can be opened out to facilitate unloading. When closed they are secured with short, very strong, coarse-threaded screws of gun-metal; the box has two projecting gun-metal claws, which hinge on to a fixed horizontal rod of the same metal, so that the box can be turned on it, on to the table of the hydraulic press, when filled and ready for pressing, or outwards when it has to be unloaded. Being first turned down on its side, the open top is closed temporarily with a piece of board which is fitted to it; the uppermost side is uncovered and raised, and the other two sides are fastened in their places; gun-metal racks to hold the press plates, having perpendicular grooves in them ½ in. apart, are then slid in on each side, and the plates being put in, the meal from the breaking-down machine is shovelled in and falls down readily between the plates till the box is full; the racks are then drawn out, leaving the plates free with layers of powder between them, the excess of powder being carefully swept off the edge of the box; the upper side is lowered and screwed to the other three, an overhead block and tackle is made fast to the gun-metal eye on the side of the box, and the box is turned over on to the press table.

606. 607.



The box now stands on its bottom, and the temporary board being lifted off, the powder and plates will be found to have settled down several inches by their own weight; the vacant space at the top is filled up by shovelling in a few more layers of meal, placing a plate by hand on each in succession till the press is quite full; the overhead block D is run into place directly over and nearly touching the contents of the box, to secure it there and to apply the pressure until the box rises to a sufficient height. The pumps are in another building, separated from the press house by large traverses; in this building the workmen remain while the pumps are at work. The amount of pressure to be given to the contents of the press box is estimated by the distance to which the overhead block enters the press box. Large-grain powder is compressed 13½ in. and fine grain 11½ in., or thereabouts. A catch which can be adjusted to any height, and which holds back a kind of trigger, is fixed on the overhead block in such a way, that whenever the block has entered the box to the depth required, the catch comes in contact with the rising edge of the press box, and relieves the trigger, which rings a bell in the pump room. The pumps are then stopped, the escape valve opened, and the press table carrying the press box allowed to descend. The workmen then re-enter the press house and proceed to unload the box. Each plate, with a layer of hard cake adhering to it, is separated from the one beneath it, and being lifted into a wooden bin, a few knocks with a wooden mallet causes the cake to fall off in irregular fragments, which are broken into pieces of the size of a man's hand, shovelled into tubs, and removed to an expense magazine.

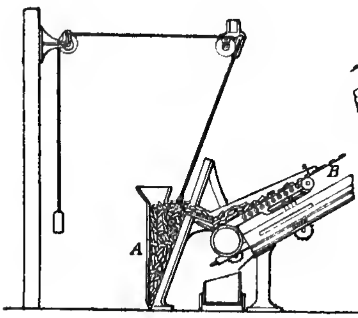
Powder is occasionally pressed without making use of the press box at all. This is only done when very great accuracy is required. If the pressure applied to powder be regulated according to the distance to which the meal is to be compressed, to ensure uniformity of results, not only must each pressing be carried on to the same distance, but there must be exactly the same quantity of material subjected to the process each time. There are other conditions also which affect the density of the resulting press cake. A sheet of canvas, the same size as a press plate, is laid on the table of the hydraulic press. On this is placed a wooden frame of the depth of the layers of meal which require to be pressed, generally ¾–1½ in.; powder meal is shovelled into the frame till it is full, and the excess carefully struck off by drawing a wooden rod over the edge of the frame. The frame is then lifted off, leaving a layer of meal of the required thickness on the press table; on this layer is first placed another sheet of canvas, then a gun-metal press plate, and finally another sheet of canvas, on which a fresh layer is spread in a similar manner, and so on, till a pile of layers of powder, separated by canvas and gun-metal plates, is built up to the level of the under surface of the overhead block; the pressure is applied in the usual way; this system of pressing, though slower than the usual system, appears to offer some decided advantages.

It is a matter of considerable difficulty to ensure uniformity of results in pressing powder. It is of the highest importance that the density obtained should be uniform, for the qualities and explosive effect of gunpowder are materially affected by comparatively slight variations in density. For instance, a difference of ·05 in the density of the charge may affect the initial velocity of a 12-lb. shot, fired with a 1-lb. charge, to the extent of about 50 ft. a second; no other difference between the two powders may be perceptible. It is necessary, when examining the densities of press cake, in order to ascertain if it is fitted for the manufacture of a particular powder, to have it previously dried.

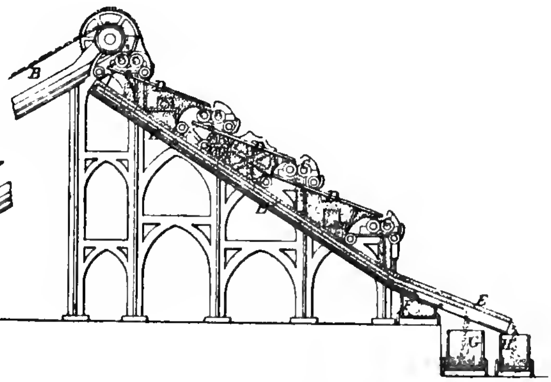
It is found in practice that, though uniformity cannot be guaranteed in pressing, very tolerably close results can be obtained. To attain these in the finished powder, the density of every pressing, after it has been converted into grain, sometimes of every glazing, is taken, and the different pressings or glazings are then mixed in the proportions to give the density required. Thus if the density fixed for the powder be 1·67, and the densities of two pressings be found to be 1·70 and 1·64, they would be mixed in equal proportions, and would give a powder of 1·67 density; powders which, however, differ to a great extent in density are never mixed.

Gunpowders now in actual use may be divided into grain powders and compressed powders. The granulation of grain powder is effected by passing the press cake between revolving toothed rollers of gun-metal; in the machine, Figs. 608, 609, 610, 611, and 612, A is the hopper with raising arrangement, B endless band, C C rollers, D D short screens, E E long screens, F G boxes for

608.

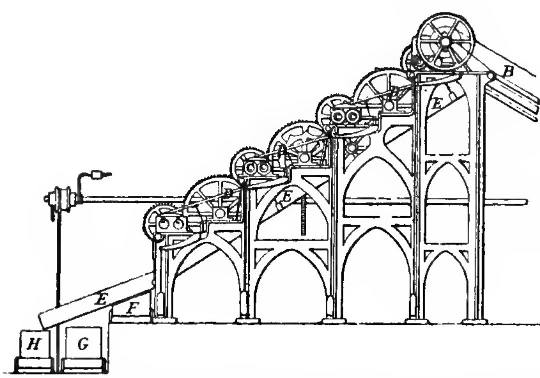


609.

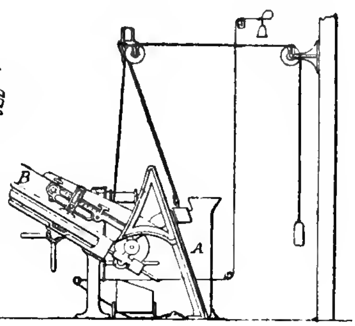


dust and grain, H box for "chucks." The four pairs of rollers C are arranged in a slanting direction, one above the other. These are set in the two strong side frames of gun-metal. Each pair is adjusted at the proper distance apart by set screws; but the back roller of each pair works in a sliding bearing, kept up by a weighted lever to admit of the rollers opening out and admitting an excess of material to pass through without injury to the machine; the two upper

610.



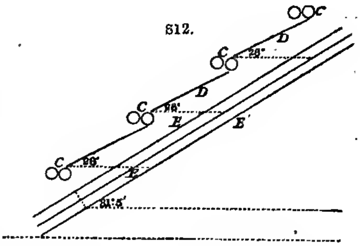
611.



pairs of rollers have coarser teeth than the lower pairs. Slanting rectangular screens D′ D are placed from underneath each of the three upper pairs of rollers C C to the top of the next, to convey any fragments which escape proper crushing in one pair into the teeth of the next pair. Underneath the whole is a long rectangular frame carrying two long screens E E, Fig. 612, to separate the proper size of powder, and a board E′ underneath to receive the dust and carry it down into a tub placed to receive it. Both the short screens and the long frame are attached to the framework of the machine by strips of lancewood, and receive a vibratory motion by means of a polygonal wheel, which works against a circular wheel running loose on an axle fixed on the screen frames.

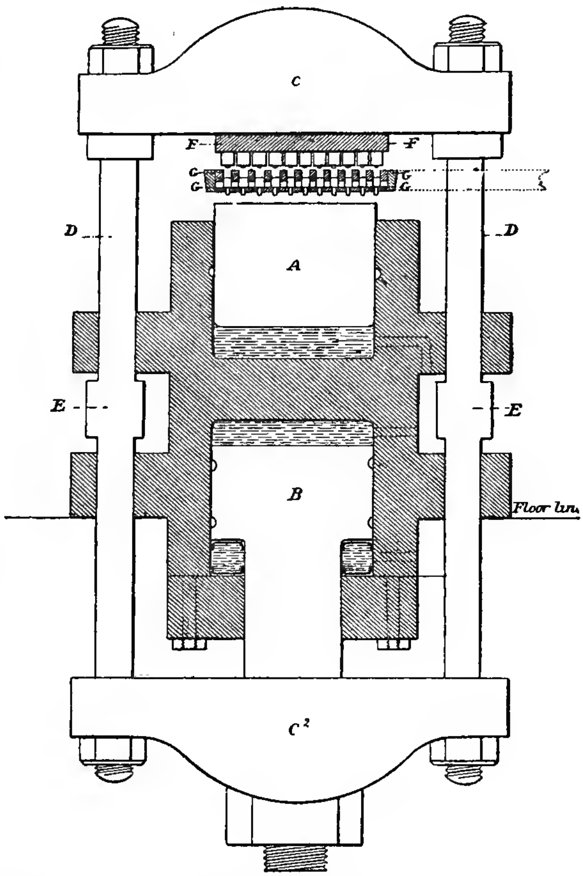
The press cake is placed in a hopper at the back of the machine, and carried up by means of an endless band, as in the breaking-down machine. The first pair of rollers have pyramidal teeth ¼ in. high; the second pair, similar teeth, ⅛ in. high; the two lower pairs have chisel-shaped teeth, formed by cutting longitudinal V-shaped grooves and circumferential rectangular ones. The two lower pairs are replaced by smooth ones. When fine-grain gunpowder has to be granulated, the arrangement and sizes of mesh of the screens may be easily remembered, as only one size of powder is required, and the size is defined by the fact that it must pass through one mesh, and not pass through another. The short screens therefore between the rollers are covered with the size of mesh through which the grains must pass, to allow all fragments of the right size to fall through, but which carry on the pieces which are too large to the next pair. The upper screen of the long frame underneath is covered with the same wire; the lower one with the size of mesh wire on which the grain required must be retained.

612.



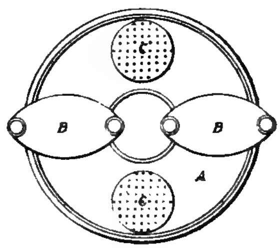
Attention must be paid to the angles at which the different screens are placed. This varies in different machines, and the proper inclination can only be ascertained by experiment. Some fragments of too large a size will escape all the rollers, and consequently require a third box to receive them. These pieces, or "chucks," require to be passed through the machine again. When the hopper has reached the limit of its travel upwards, a clutch is relieved which stops it, and a bell is rung in the watchhouse, where the workmen then re-enter and place the grain and dust in tubs ready for transmission, the former to the dusting houses, the latter to the mills for reworking.

613.



The machine used for making compressed powder is shown in Figs. 613, 614, and 615. There are two rams, an upper one A to press the pellets, and a lower one B to raise and lower the cross-head C. The upper cross-head is connected with a lower one C_2, by powerful side rods D D of wrought iron. On these rods there are stops E E, so adjusted as to admit of the upper cross-head being brought down only far enough to admit the upper punches to touch closely the mould plate, and close the openings of the moulds. F is the upper plate fixed to the cross-head, and carrying the upper punches. G G is the lower double plate, which is fixed in the revolving table, and which carries the lower punches hanging loose in it. A (Fig. 614) is a circular revolving table carrying four mould plates, each containing 200 moulds. B B are the top cross-heads of the rams. There being four mould plates, two are being pressed at the time the other two are being filled. Thus 400 pellets are pressed at one time. The revolving table consists of a framework of gun-metal, having the top boarded over to prevent the powder falling down into the machine. It is traversed round by hand by means of a rack and pinion. The mould plates are of gun-metal, being made double, as in Fig. 615. Here A is a small charge of powder placed in the mould, the bottom of which is closed by a tightly-fitting steel punch B fitting it accurately. This punch has a shoulder on which it rests loose on a plate C. The lower end of B rests on the upper surface of the hydraulic ram D, and an upper punch E of larger diameter than the mould brought down on the surface of the mould plate; the punches are blued to prevent oxidation; a pellet is made by bringing the top punch down on the plate and fixing it there so as to confine the powder, then by raising the lower punch by means of the ram till a proper amount of compression has been given to the powder, the pressure is stopped from beneath, and the upper punch raised, the finished pellet being raised out of the mould by the pressure of the ram underneath. Any form can be given to the pellets by altering the shape of the moulds and punches, and hollows or perforations can be made in the pellet if required.

614.

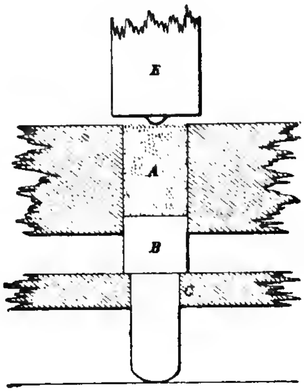


The rams are worked by means of a hydraulic accumulator, loaded so as to give a pressure of 1000 lb. on each punch in the mould plate. From 10 to 20 seconds generally suffices to give the density required.

There are other varieties of machines used for this purpose which are self-feeding, but they are liable to clog with powder meal, and therefore are best used with grain powder.

Granulated powder contains much dust, and the grain itself is not in a condition to be made use of as powder, being rough and porous on the surface, and very angular in shape. It is freed from dust by placing it in revolving reels, and then glazed by causing the grains to rub against each other in revolving wooden barrels, Fig. 616.

615.

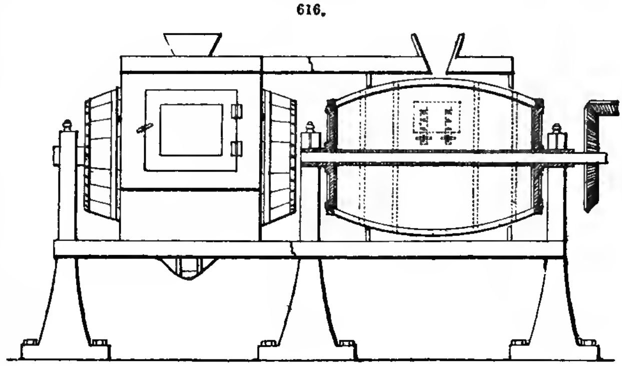


On leaving the reels or glazing barrel, the powder requires only to be stove dried to be fit for use.

Stoving is effected in large chambers, heated with steam pipes. Gloom stoves or drying rooms, having a large metal dome built into one wall, under which a fire was made, were formerly used. The present steam stoves consist of large chambers having an arrangement of steam pipes running along the floor, and provided with double doors, which can be closely shut, and with ventilators at top and bottom, which can be closed or opened from without, so as to increase or lower the internal temperature. The temperature is maintained at 52°–54° (125°–130° F.). The stove is fitted with wooden racks, on which are placed the trays, either of sheet copper, or of wood, with a canvas bottom for containing the powder.

The powder is generally 24 hrs. in the stove altogether, being put in one morning and withdrawn the next, but does not actually get more than 18 hours of the full temperature, as the heat of the chamber must be lowered, to admit of the workmen remaining in it when putting in or withdrawing the trays which hold the powder.

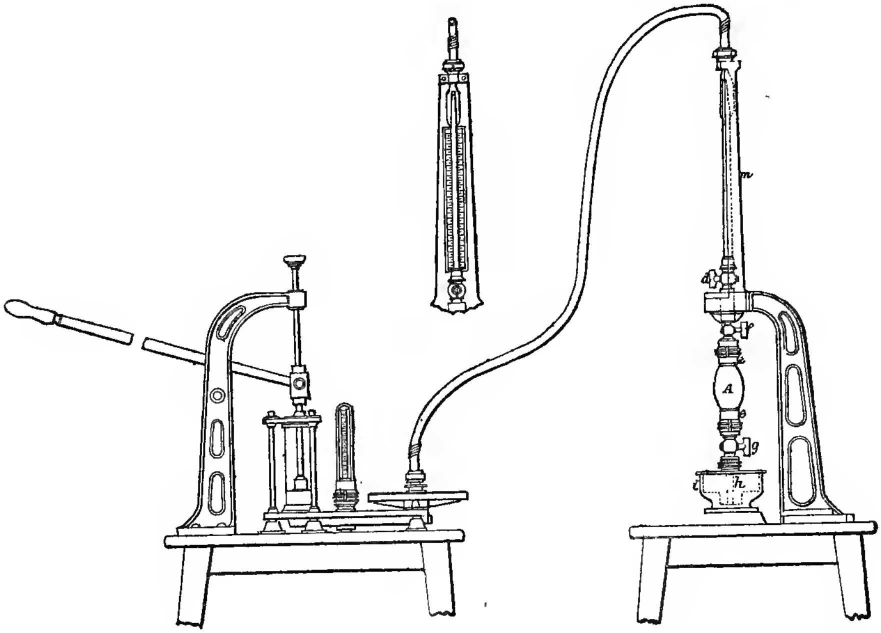
616.



Density is the most important quality of gunpowder, and must be most accurately determined, which can only be done by means of the mercury densimeter.

The densimeter, Figs. 617, 618, consists of a barometer tube *m*, supported on a stout metal stand, and having a cock *d* at the bottom by which it can be closed or opened. Attached to the top of the tube is a flexible tube communicating with an air-pump, by means of which the air can be exhausted from the tube. A glass globe A fitted with metal collars *e* e^1, on which again are screwed other collars provided with stop-cocks *f g*, can be attached to the bottom of the barometer tube by means of a closely fitting screw. The lower collar of this globe is provided with a nozzle *h* which dips into an iron bowl filled with mercury *i*. If, then, the lower cock *g* be kept closed and the other ones opened, the air can be exhausted from the barometer tube and globe; and the lower cock being then opened, the mercury rushes in, rises up till it fills the globe, and continues to rise in the tube

617. 618.



till it has attained the same height from the surface of the mercury left in the bowl as the column in an ordinary barometer stands at the time.

In taking the density of a sample of powder, the air is first exhausted from the tube and globe, and the mercury allowed to fill them. The upper and lower cocks of the globe are then closed, the nozzle is taken off, and the globe unscrewed from the barometer tube and weighed. This weight, the weight of the globe filled with mercury, is registered.

The globe is then emptied, and a definite weight of the powder, generally 100 grammes, is introduced into the globe. The globe is then attached to the barometer tube as before, the air exhausted, and the mercury allowed to enter and rise in the tube as before. The stop-cocks attached to the globe are provided with diaphragms, the upper one of chamois leather, the lower one of fine wire gauze, to prevent any particle of powder being carried out of the globe. As soon as the mercury has risen to the proper height, the stop-cocks attached to the globe are again closed, the nozzle unscrewed, and the globe taken off and weighed. The second weight, the weight of the globe full of mercury, added to the weight of the powder, and *less* the weight of the volume of mercury displaced by it, is also registered.

The density of the powder is then calculated by the following formula:—

$$\text{Density} = \frac{D \times 100}{(P^1 - P) + 100}$$

where D is the specific gravity of the mercury at the time of experiment, P the weight of globe full of powder and mercury, P^1 the weight of globe full of mercury alone, and 100 the weight of powder employed.

Guncotton.—This explosive is formed by the action of concentrated nitric acid on cotton, and has the composition indicated by the formula $C_6H_7(NO_2)_3O_5$. A number of similar products are known, but only one is used as an explosive agent. Some of the others are largely used for making collodion.

The operation of cleansing the cotton waste is effected by boiling it in a solution of carbonate of soda. After the soda has been thoroughly removed by washing in water, the cotton is completely dried by means of heat, and the passage of expanding air between the fibres.

The cleansed and perfectly dried fibre is then treated with acid. The acid used for the purpose is a mixture of one part of highly concentrated nitric acid, with three parts of concentrated sulphuric acid. Much heat is evolved in the operation of mixing the two acids. The mixture must be allowed to cool before using it. Suitable quantities of acid liquor are placed in stone jars, kept cool by immersion in water, and into these jars dried cotton is gradually introduced, in the proportion of 1 lb. of fibre to 15 lb. of acid, and left to soak for a period of 48 hours. By the action of the acid a chemical change in the composition of the cotton is effected, the elements of the acid liquor, in the form of peroxide of nitrogen, being substituted by chemical process for a portion of the hydrogen of the cotton fibre, and the fibre is thereby converted into a highly explosive compound termed guncotton. The chemical action does not destroy the texture of the cotton.

After the uncombined acid liquor has been removed from the fibre as far as practicable by means of a centrifugal drying machine of the usual description, the acidulated cotton fibre is thrown in small quantities at a time into a cascade of cold water, and is well washed to free the fibre from every trace of uncombined or free acid.

A certain amount of care must be exercised during the process of immersing the fibre in the acid, as well as in the operation of sousing the acidulated material in the cascade of water. There is not the slightest danger of explosion in these portions of the operation, but without care and attention be bestowed, portions of the material are liable to be destroyed, with violent escapes of ruddy fumes produced by rapid chemical action.

One hundred parts by weight of cleansed and dry cotton fibre, furnish about one hundred and seventy-five parts of pure guncotton fibre, weighed in a dry state. The acidulated fibre, or as it may now be correctly termed, the guncotton, is afterwards submitted for a considerable period of time to the action of a pulping machine, such as is ordinarily in use in paper mills. When the cotton fibres have been reduced to pulp of a proper consistency and degree of fineness, and every trace of free acid therein has been neutralized, the pulp is collected on strainers and conveyed to the granulating machine, or to the hydraulic presses, in case the pulp is to be formed into compressed charges or discs in place of being granulated. It is sent out either wet or dry. In the former case it should contain 10 per cent. of moisture, and will require redrying for use unless exploded by a dry primer of guncotton, or an excessively strong denotator such as a sextuple.

Cotton powder or Tonite.—The guncotton used in the manufacture of cotton powder is crushed to a flour meal consistency; this is next purified by being subjected in large vats to strong agitation by an air blast, while it is brought to a boiling point by a jet of steam, and a dose of carbonate of ammonia is thrown in the vat; all the unstable nitrogen compounds are destroyed at that temperature, and the nitrous fumes so difficult of extraction by the old process are, by the aid of ammonia, reduced into their simple elements, nitrogen and water; the water in the vat from a colourless state has now become dark brown. This operation takes three hours, and the guncotton is then quite safe for dry storage; of course it is subsequently separated from the dirty water until quite clean. Nitrate of baryta has some properties which render it especially suited for nitrating guncotton, namely it is scarcely soluble in cold water, so when the charge dries it does not separate and distort the shape of the cartridge; it also contains the largest amount of oxygen under the same volume. So that with the fineness of the guncotton and the density of the baryta, the charges of the cotton powder can be made to density 1·500; which it is claimed produces intense local action. The safety of cotton powder against blows or similar causes of explosion is illustrated by the fact, that whereas dynamite is usually exploded with seven grains of fulminate of mercury, it takes fully fifteen grains to ensure the explosion of cotton powder.

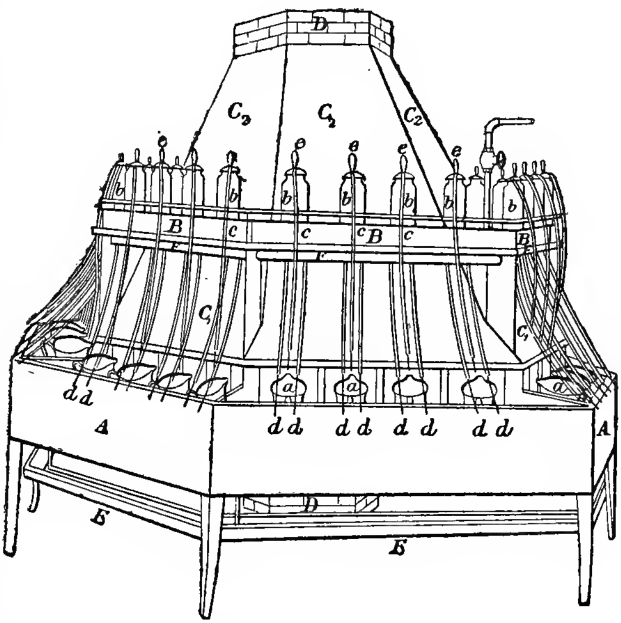
Schultz's Powder.—In Schultz's powder, the cellulose is obtained from wood. The wood is first sawn into sheets, about $\frac{1}{16}$ in. thick, and then passed through a machine, which punches it up into grains of a uniform size. These are deprived of their resinous matter by a process of boiling in carbonate of soda, and are further cleansed by washing in water, steaming, and bleaching by chloride of lime. The grains, which are then pure cellulose, are converted into nitro-cellulose in the very same way as cotton, by being treated with a mixture of nitric and sulphuric acids. The nitro-cellulose thus produced is subsequently steeped in a solution of nitrate of potash. Thus the finished compound is similar in character to nitrated guncotton.

Nitro-glycerine Compounds.—Nitro-glycerine, the most powerful explosive used in industry, is formed by the action of nitric acid upon glycerine at a low temperature; although the process of manufacture is very simple, still from the dangerous nature of the resulting product particular care is necessary, in order to conduct it without injury to those employed. The glycerine should be free from the adulteration often found in it, such as fatty acids or British gum, and of the greatest specific gravity possible, say at least 0·88. The nitric acid must be strong and very pure, having a specific gravity of not less than 1·45. As acid of this strength cannot ordinarily be obtained in the market, it must be prepared for the purpose by careful distillation from sodium nitrate and sulphuric acid. Before it is used the nitric acid is mixed with twice its weight of strong sulphuric acid. This does not take a direct part in the production of nitro-glycerine, but absorbs the water which is formed during the reaction, thus preventing dilution of the nitric acid.

Liecke prescribes the following formulæ for manufacturing the three several preparations, mono-nitro-glycerine, di-nitro-glycerine, and tri-nitro-glycerine:—Mono-nitro-glycerine; dissolve 100 grammes of glycerine in 200 grammes of nitric acid, sp. gr. 1·3, and then add 200 cubic centimetres sulphuric acid, the product should be $\left.\begin{matrix}C^3H^5O^2H\\NO^4H\end{matrix}\right\}O^4$. Di-nitro-glycerine; sulphuric acid, containing one equivalent of water, two volumes nitric acid, sp. gr. 1·4 one volume, mix the acids, lower the temperature to 0° (32° F.) or below, and drop into it one volume pure glycerine, product $\left.\begin{matrix}C^3H^5O^2H\\2\,NO^4\end{matrix}\right\}O^4$. Tri-nitro-glycerine; sulphuric acid 3·5 parts, nitrate of potash 1 part, cool to -18° (0° F.) produces $KO + 4\ SO^3 + 6\ HO$, from this the concentrated fuming nitric acid is separated by decantation, and being maintained at -18° (0° F.). 0·8 parts pure glycerine is very gradually added, producing $\left.\begin{matrix}C^3H^5O^2NO^4\\2\,NO^4\end{matrix}\right\}O^4$.

The acids when mixed are placed together, in a receiver from which the mixture can be drawn as it is wanted. The apparatus employed for making nitro-glycerine on a comparatively small scale is shown in Figs. 619 to 621. A A are wooden troughs placed round a brick chimney D, and containing the earthenware pitchers *a a*, which hold the acid mixture. On the shelf B are arranged bottles *b b*, which contain the glycerine. These are loosely closed by wooden stoppers with broad rounded tops, having holes through which indiarubber tubes *c c* are passed, these tubes reaching to the bottom of the bottles, and carrying small glass nipples at their other end; *e e* are conical wooden plugs, which are passed through the same holes as the rubber tubes. G is a steam pipe arranged on the shelves *b b* behind the glycerine bottles. The air main F passes under B, and carries on its lower side a number of small short pipes, two for each pitcher, to which the rubber tubes *d d*, which hang over the pitchers, are attached, and in these are inserted glass tubes long enough to extend to the bottom of the pitchers. In the elevation these tubes are out of the pitchers, but in the section they are in place as if in use.

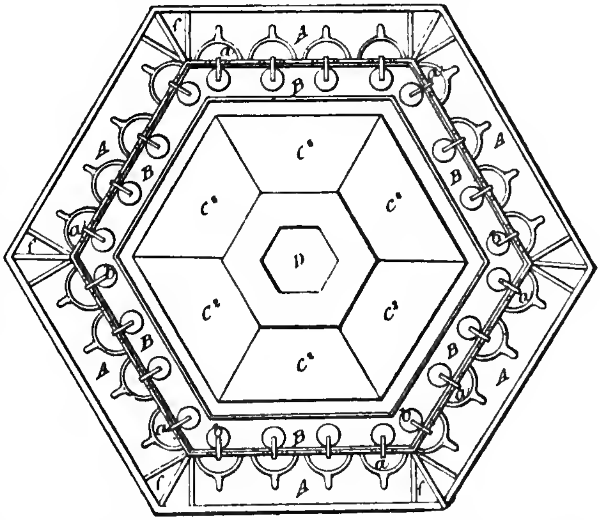
619.



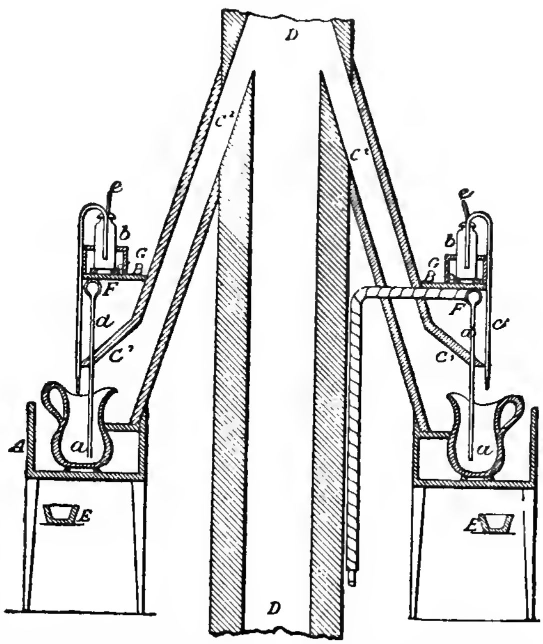
The troughs are made tight in order to contain ice water, with which the pitchers are surrounded. Partitions with openings at the bottom are arranged at the corners *f f* of the troughs. These only contain water, and are convenient as affording opportunities for quickly emptying a pitcher into water, should this become necessary. In one corner of the trough is a pipe, from which the water may be drawn off into the escape *l* when the operation is finished. The pitchers are arranged on narrow wooden strips, which raise them some two inches off the bottom; thus the cold water has full access all round them, and when in position they are well under the overhanging hoods C C¹. The hoods are flat wooden boxes, wide at the bottom but narrow at the top, where they fit into openings in the chimney D. At the lower part of the chimney a grate and fire door, not shown, is placed on the floor below.

The charge for each pitcher is from 18 to 20 lb. of the mixed acids, according to their strength, and when ready, all are set in place in the troughs, covered with glass plates and surrounded with ice and water, when they are allowed to stand until the acid in the pitchers has fallen to the temperature of the surrounding ice water, when the covers are removed and the air tubes passed through holes in the hoods down into them, then they receive a strong current of air from a pump driven by steam. The air current keeps the contents of the pitchers continually agitated, and is rendered perfectly dry by being drawn through sulphuric acid, whilst it is thoroughly cooled just before it enters the air main over the troughs. The glycerine in 2 lb. charges is then allowed to flow, and as each tube C C is a siphon, it is started by drawing through a glass tube in the outer end. As soon as the glycerine runs freely, the suction tube is withdrawn and a fine glass jet is substituted for it, from which a stream is directed into the pitcher beneath. Should the glycerine be too thick to flow easily, which occurs in cold weather, the bottles are warmed as much as may be necessary by the steam pipe G. The glycerine, as it flows into the acid, is rapidly acted on and converted into nitro-glycerine, the reaction taking place being represented by $C_3 H_8 O_3 + 3 H N O_3 = C_3 H_5 N_3 O_9 + 3 H_2O$, and is accompanied by a considerable evolution of heat, which must be removed; for should the temperature rise too high, the glycerine is oxydized and forms other substance. If the temperature is started at 0° (32° F.), it should not be allowed to exceed 9° (48° F.); and at 10°-13° (50°-55°) there is a great danger of firing taking place, hence the necessity for keeping the liquid in the pitchers cold, both by surrounding with ice-cold water and by means of the air current passing into the acid. The latter performs most important work, as by keeping the acid mixture in constant agitation, the heat which is generated is quickly diffused through the whole, and prevents any sudden local rise of temperature. The glycerine is much lighter than the acid, and is liable to collect in little pools above it, and if these were broken up and a quantity of glycerine suddenly brought into contact with the acid, the action would be so rapid that it could not be controlled. This, of course, cannot take place if the whole mixture is kept in constant agitation. Thermometrical observations are frequently made while the glycerine is running into the pitchers, and if the temperature is found to be rising too rapidly, the glycerine is then running too fast, and its flow is checked by pressing down the short stopper *e*, which slightly compresses the rubber tube, so that less liquid can pass. Should the temperature continue to rise the plug is forced tighter in, closing the glycerine tube altogether, when the flow is stopped and the contents of the pitcher cool rapidly. As soon as the proper degree is indicated the plug is loosened and the flow again set up. If the limit of temperature is exceeded firing takes place, indicated by copious evolution of red nitrous fumes, and in extreme cases by flames. Usually when this action occurs it is easily controlled by stopping

620.



621.

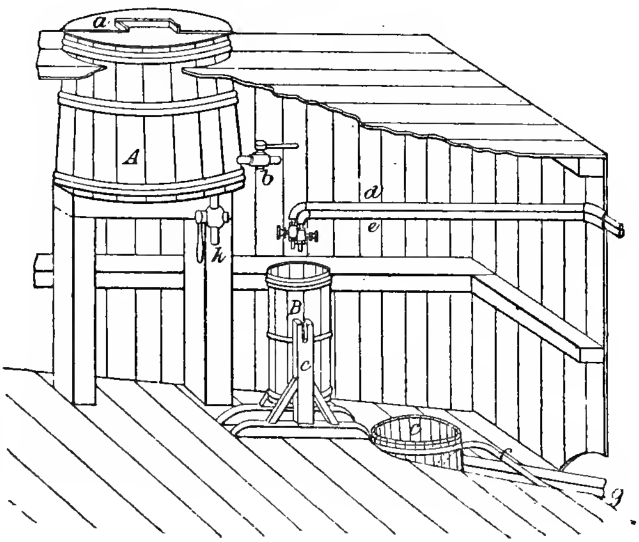


the stream of glycerine and stirring the mixture vigorously, but if it is violent the vessel must be at once emptied into water.

Acid and other irritating fumes are given off in large quantities during the operation of conversion, and these are removed through the hoods into the chimney, which is in communication with a fire, or other suitable means for causing a powerful draught, which draws all the fumes upwards and enable them to be discharged into the open air; the arrangement indicated on the plan is of course unimportant, and can be conveniently modified if required. As soon as the requisite quantity of glycerine has been run into the pitchers the conversion is complete, but the nitro-glycerine has to be separated from the large quantity of acid still remaining. This is almost entirely sulphuric, as the nitric acid has been nearly all used up in reaction. The nitro-glycerine is partly in solution and partly suspended in the heavy acid liquid. On diluting the acid the portion in solution is precipitated, and the whole of the nitro-glycerine settles to the bottom.

Fig. 622 is of the separating and washing apparatus. A large wooden tub A is sunk through the floor of the converting room; it is filled about three-quarters with water, and has a cover with a square opening in which is placed a leaden strainer; by means of a rubber hose connected with an air pipe a current of air is led to the bottom of the tub, and vigorously agitates the water in it; the pitchers, when taken from the converting room, are emptied through the strainer into the tub, when the acid liquor descends in fine streams and is diffused through water.

622.



When all the pitchers have been emptied the air pipe is withdrawn and a short time allowed for settling, the heavier nitro-glycerine collects at the bottom, so that the lighter acid water may be drawn off from above it, a wooden stop-cock *b* at the side of the tub, a short distance from the bottom, but above the level of the nitro-glycerine, serving to pass off the acid liquid by means of a short length of hose into the drain G; the nitro-glycerine is drawn off in small quantities into the washing tub B through the wooden cock *k*, which is fitted in the lowest part of the inclined bottom of A.

The wooden tub B is lined with lead and supported by trunnions in a wooden frame *c*, the trunnions being placed just above the centre of gravity, so that the tub will stand upright and yet be easily turned or inverted; pipes D and E are provided with valves within easy reach of the workmen standing by the tub; one is for water, and there is attached to it a short piece of hose, the other is connected to the air main, and has a length of hose sufficient to reach to the bottom of the washing tub.

The portion of the nitro-glycerine having been drawn into B, the air hose is put in and a stream of water turned on, the air current causes a strong ebullition, raising the nitro-glycerine and spreading it through the water; as soon as the tub is full the latter is turned off, the hose removed, when in a few minutes the nitro-glycerine rapidly settles to the bottom, and the water may be poured off by turning the tub on its trunnions. This is repeated until the nitro-glycerine is thoroughly washed, when it is poured into a copper pail, from whence it is poured into earthen jars and allowed to stand covered with water until it clears; it is then ready for use. The wash-water decanted from B falls first into the tub C, from which the water runs off by the siphon pipe F into the drain *g*. Thus any nitro-glycerine which may have floated or been accidentally poured into C has an opportunity to settle, and so be saved. With any apparatus such as that described, employing 24 pitchers, about 80 lb. of nitro-glycerine can be made in 5 hours, not including the time required for cooling the pitchers, which will vary with the season of the year.

In some larger works the apparatus is arranged upon an extensive scale, in buildings built at different heights and separated from one another by embankments, so high that the top of each covers the top part of the apparatus in the particular building it is designed to protect. The correct atomic quantities are weighed out into a large vessel called the mixing vessel, where the nitric and sulphuric acids are mixed; they remain there for a considerable period until they cool down, so that when they are to be operated upon there is no room for any increment of heat by chemical development. When in this condition they are weighed off in the presence of the chief chemist, taken up an incline to a higher level termed the nitrating house, where they are mixed with the glycerine in a very large apparatus, where as much as 1500 lb. of nitro-glycerine is treated at each operation. After the nitrating the explosive is allowed to flow down by gravity into a lower building, which contains a large tank holding many tons of water, so that should the chemist be unable to control the action he may run the charge into the water, and by thus diluting it, stop the chemical action forthwith. The stirring or mixing arrangements are all effected by machine power, and so arranged as to be mechanically under the control of the operator in charge, who can adjust everything, so that neither quantity nor speed can be exceeded in any way.

The process of washing is effected by means of compressed air, working at a pressure of from 45 to 50 lb. on the square inch, and the whole of the contents of the large washing vessels are surged over and over again, an indefinite number of times, through the vessel, so that every particle is repeatedly submitted to the purifying process. A portion of the charge having been decanted the chemist takes samples and tests them, with regard to their neutrality, by means of liquid litmus; if a small quantity of it discolours a sample of the nitro-glycerine, the operation of washing is continued until little or no trace, if possible, of the acid remains. As soon as the process is satisfactory, the charge is allowed to run down by gravity into the final washing and filtering house, where it is treated with alkaline solution to neutralize any remaining acidity that may cling to the particles of nitro-glycerine; it is usually then tested again, and the washing afterwards continued from 15 to 20 minutes longer.

At the end of that time a final sample is taken and tested in the laboratory both for purity and neutrality; when if satisfactory it is allowed to flow into a filter, which is a large oval vessel sufficient to contain nearly 3 tons weight. In the centre there is a cylinder with a thick blanket fastened over the end of it by copper hooks, for the purpose of allowing the mixture to drain down into it, so that no foreign matter of any kind may pass, and any aqueous substance that may cling to the nitro-glycerine, when decanted, does not usually percolate through the blanket, unless there is great carelessness on the part of the men who are attending to the process. The communication between the buildings is carried on by means of troughs, and it is not touched in any way by workpeople, until it has been absorbed in the inert base with which it it is mixed, and rendered commercially available.

It has been practically very unsafe and inconvenient to use nitro-glycerine as a blasting agent unless it is mixed with some absorbent. It therefore forms the essential ingredient in a number of semi-solid mixtures, such as dynamite, lithofracteur, duolin, giant powder, rendrock, sebastin, and the like, which are of great commercial value; of these the most important is dynamite, inasmuch as the best quality or No. 1 consists of 75 per cent. nitro-glycerine and 25 per cent. kieselguhr, the latter being a siliceous earth forming a fine white powder of infusoria, which has a high absorptive power, being capable of taking up from two to three times its weight of nitro-glycerine without becoming pasty. Artificial silica, prepared by precipitating it from a solution of sodium silicate by sulphuric acid, has been proposed and used with some success by W. N. Hill. The process of making dynamite is simple, since the nitro-glycerine is merely mixed with fine dry powder in a leaden vessel with wooden beaters, the kieselguhr having been burnt in order to destroy any organic matter which may be present. The explosive properties of dynamite are similar to those of the nitro-glycerine contained in it, as the absorbent is quite inert. It freezes at the same temperature as its nitro-glycerine, and when in this state it is exceedingly difficult to fire it; it should only by thawed by placing it in a warm pocket about the person, or in a water bath, which may be readily extemporized if necessary; dynamite is far safer than pure nitro-glycerine, as from its softness it will bear blows better, and so is therefore not so sensitive to percussion or to friction; its firing point is the same as nitro-glycerine, and if it takes fire it burns with a strong flash, leaving a residuum of silica. It must not contain an over-charge of nitro-glycerine as otherwise the latter will exude, especially if exposed to high temperatures, which have a tendency to render the nitro-glycerine fluid and less easily retained. In some works when weighed out into the quantities in which it is used, the cartridges are submitted to a slight pressure in a small machine, and those which show any signs of exudation are rejected.

Recently guncotton has been employed as an absorbent for nitro-glycerine, and it is claimed that in this form the explosive gives as good results as the pure chemical itself; a second quality dynamite is sometimes made, composed of nitrate of soda 69, paraffin 7, charcoal 4, and nitro-glycerine 20 per cent.; or nitrate of potash 71, paraffin 1, charcoal 10, and nitro-glycerine 18 per cent. Lithofracteur is a mixture containing soda saltpetre 4, coal 12, kieselguhr 30, sulphur 2, nitro-glycerine 52 per cent. Duolin is a mixture of 30 fine sawdust, 20 saltpetre, and 50 per cent.

nitro-glyoerine. A number of such mixtures may be made, as any dry powder may be taken as an absorbent, but they are of no special value, inasmuch as it is improbable that any useful effect is obtained from ingredients, other than the nitro-glycerine; those containing such salts as nitrate of soda are objectionable from their liability to exudation.

In packing cartridges of dynamite for export the cartridges are separately rolled up in parchment paper, and are then packed into a cardboard box containing 5 lb. Ten of these are packed in black tarred paper fastened with cement, and the whole enclosed with a stout wooden box.

Picrates.—Picric acid formed by the action of nitric on carbolic acid possesses marked explosive properties; if heated it takes fire and burns rapidly without explosion, but all the picrates are exploded with violence by heat or blows. When used as explosive agents, they are mixed either with nitrate or chlorate of potash. Chlorate of potash mixed with picrate of potash, the most violent explosive of the picrates, is very powerful, but so sensitive to friction or percussion as to render it practically useless; with nitrate of potash instead of chlorate a less violent mixture is obtained, but one still sensitive to accidental explosion. A mixture of saltpetre and picrate of potash, either with or without the addition of charcoal, has been made in quantities for use in blasting, but its sensitiveness has led to many accidents, which prevent its general use. Picrate of ammonia has very different properties to those of the potassium salt; when a light is applied to it it burns with a strong smoky flame, aud it is not very sensitive to either blows or friction; when mixed with saltpetre it may be used as a substitute for gunpowder. The picrate is prepared from picric acid and ammonia, the acid is dissolved in water and ammonia added to neutralization. This is repeated several times, and the liquid allowed to stand, when the ammonium picrate crystallizes out in large quantities, the crystals, drained and dried, are then ready for use. The mother liquid may be used for the preparation of several lots of the ammonium salt, until it becomes charged with impurities, when it may be otherwise treated, or thrown away; in this way a considerable amount can be expeditiously prepared with little labour and without much loss. With the addition of a small quantity of charcoal to the picrate and saltpetre, a mixture may be made which, when carried through the usual gunpowder processes, affords a powder of good grain, less hygroscopic than gunpowder, and possessing valuable properties as an explosive.

Fulminates.—The highly dangerous and strongly explosive salts of fulminic acid are all called fulminates, with them are also classed the powerful and dangerous chloride and iodide of nitrogen and other similar substances; the only two of these which are of any commercial value are fulminate of mercury and fulminate of silver, the former of which is almost exclusively used in the preparation of percussion caps, for fire-arms, and detonators for use with the nitro-glycerine and nitro-chemical compounds, such as dynamite, lithofracteur, tonite, guncotton, and the like Fulminate of silver being used in minute quantities for children's toy cracks, pistol cracks, bonbons and similar trifles. Fulminate of mercury is prepared according to the German method by dissolving 1 part of mercury in 12 parts of nitric acid, sp. gr. 1·375; to this solution 16·5 parts of absolute alcohol is added by degrees; heat is then applied till the effervescence and cloud of gas disappears, when as the action becomes more violent, an equal quantity of alcohol to that before employed is gradually added; the product affords 112 per cent. of the mercury used. Another method is to dissolve by gentle heat 10 parts of mercury in 100 parts nitric acid, sp. gr. 1·4, and, when the solution has reached the temperature of 54° (130° F.), to slowly pour it through a glass funnel into 83 parts of absolute alcohol; as soon as the effervescence ceases, and the white fumes are not evolved, the whole is filtered through double paper, washed through cold water, and dried over hot water at a temperature not exceeding 100° (212° F.), the fulminate is then carefully packed in paper boxes or corked bottles; the product is about 130 per cent. of the weight of the mercury used. The latter method is the safest and cheapest, but in any case the manufacture is a very dangerous operation, and wherever practicable, fulminate of mercury should be kept damp, when it is practically harmless. When dry, its crystals are small and of a brownish-grey sparkling colour, it is soluble in boiling water, and deposits in pearly grey spangles as the solution cools; a pint of boiling water will dissolve 67 grains of fulminate, it explodes violently both by friction and percussion, with a peculiar cracking noise, but only burns with a sudden flash when ignited unconfined in the open air; commercial fulminate of mercury is usually largely adulterated with chlorate of potash.

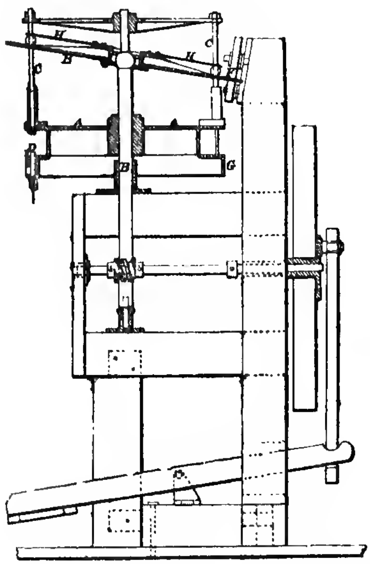
Composition for percussion caps and fuzes, used in the British service, is made from 6 parts, by weight, of fulminate of mercury, 6 parts of chlorate of potash, and 4 parts of sulphide of antimony. Another cap composition is composed of 12 parts fulminate of mercury, 26 parts chlorate of potash, 30 nitre, 17 sulphur, 14 ground glass, and 1 of shellac varnish. Detonating composition for time fuzes, 6 parts chlorate of potash, 4 parts sulphide of antimony, and 4 parts of fulminate of mercury, this is damped with a varnish composed of 645 grains of shellac dissolved in a pint of methylated spirits, in the proportion of 24 minims to 100 grains of composition. In the manufacture of percussion caps, the copper blanks are cut out and stamped to the required shape from strips of metal rolled to the required gauge, the blanks are then placed in a gun-metal plate with the concave side uppermost. A tool, composed of a plate of gun-metal, in which are inserted a number of copper points, each of the same length, and so spaced apart as to exactly fit each point into a cap when inverted over a plate containing the blanks is dipped into a vessel containing the cap composition, which has been previously moistened with methylated spirits, it is then removed, placed over the blanks, and a slight blow serves to deposit a small portion of the cap composition into each cap. A similar tool is then dipped into shellac varnish, removed and placed on the cap, when a drop of varnish from each of the copper points falls into the caps, which are then allowed to dry; this is a very safe and efficacious method.

In the detonators made in England by the Cotton Powder Co., the fulminate of mercury, while wet, is mixed with very finely ground guncotton and chlorate of potash, about in the proportion of 6 parts of fulminate and 1 part each of guncotton and chlorate of potash.

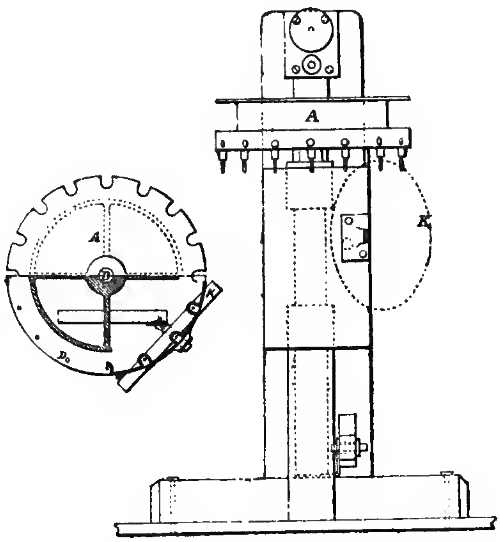
The water in which the fulminate of mercury is usually stored, is first drained off and replaced by displacement by ether or alcohol, or a mixture of the two. While the fulminate is still moist with ether, the guncotton and chlorate of potash are added, and the mixture well rubbed together. This compound is next distributed in the detonator shells standing in a frame, and each detonator is put separately in a machine for pressing the paste.

Figs. 623 and 624 are a vertical section and part front view of this machine, with various sections of the rotating table.

623.



624.



A is the table turning with the vertical axis B; this table carries a number of spindles C, corresponding to the holes D, in which the detonators containing the powder are put for the purpose of being compressed. The spindles C are, in rotation, brought down into the caps by springs H, the motion being controlled by the oscillating disc E, which is kept at a fixed angle by the rollers F.

By rotating the table A it is evident that all the spindles will alternately be depressed, as they travel towards G, and lifted as they travel towards D, so that the workman may stand in front of the machine without fear of any cap injuring him by explosion. There are other spindles below the holes D. As the table rotates the lower ends of these spindles come in succession against the periphery of the lifting wheel K, are lifted, and eject the loaded tubes from the holes D.

This machine has received some modifications since its first introduction, and been so arranged that instead of one, a large number of detonators can be pressed at one time; it is so surrounded with guards that any explosion taking place cannot possibly effect the operator, the detonators being also pressed whilst containing a certain per centage of moisture instead of dry, suitable means being provided for afterwards dispersing this moisture.

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FEATHERS (Fr., *Plumes;* Ger., *Federn*).

The word "feathers" is applied in a comprehensive sense to the external covering, or plumage, of birds, without reference to the minor distinctions arising from the variety of form, and of industrial application, of the several portions constituting the whole. Feathers consist of epidermic growths, in the form of horny sheaths, scales, or plates. The most complicated are those termed "contour" feathers, from their governing the outline of the bird's body; they are divided into the following parts:—(1) The main stem, or axis, composed of a proximal hollow cylinder, or "quill," containing a series of light, dry, conical capsules, imbedded, at its lower extremity, in the skin of the bird; supporting (2) the "vane," which consists of (*a*) a four-sided solid "shaft," extending to the upper extremity of the feather, filled with a peculiar elastic substance termed "pith," slightly curved, of horny exterior, like the quill, most commonly single, but, in the case of some birds, supplemented by a second, usually smaller, "after-shaft," bearing (*b*) a number of lateral processes, springing from both sides, consisting of plates, arranged with their flat sides towards each other, tapering to points at their outer ends, and known as "barbs"; these are again provided with tapering processes, termed "barbules," which are themselves sometimes serrated in a similar way. Contour feathers are generally arranged only in circumscribed patches, and are rarely distributed evenly over the body. The first plumage of birds is but temporary, consisting of bundles of long, loosely-barbed filaments, diverging from a small quill, and originally encased in a thin sheath, which crumbles away on exposure to the air. This covering of "down-feathers" is succeeded by the true feathers, a portion of the former being, however, retained.

The economic uses of the various kinds of feathers depend upon the development of their respective parts; and these features afford a convenient basis for the division of this article into the following heads:—Common Feathers, Down, Ornamental Feathers, and Quills.

Common Feathers.—One of the most common and wide-spread applications of feathers is for the stuffing of beds and cushions. The essential qualities are downiness, and absence of hard shafts; for this purpose, therefore, the feathers of water-fowl, and, in a lesser degree, of domestic poultry, are best suited. The feathers are plucked from the recently killed bird, most commonly by hand; but a machine, termed a "pectoplume," has recently been invented for the purpose. This consists of a table, on which the bird is laid, and of a wheel, whose periphery is provided with indiarubber fingers or pickers, so arranged that as they come above the surface of the table, they pinch whatever they meet, releasing their burden as they pass below. The plucked feathers are assorted by the action of a current of air, the light ones being blown over a sliding lip into a receptacle, while the heavy ones fall into a trough. The machine is worked by a treadle, and is said to pick a fowl in about a minute. The feathers cast off by birds during the moulting season are equally serviceable, and, as they are then very easily removable by hand from the living bird, might be plucked and utilized in enormous quantities, whereas at present they are wasted, to the value of many thousand pounds sterling annually. Feathers having strong, stiff shafts may be rendered useful by stripping off the barbs.

The bales of feathers, as received, contain much dust and sand, as well as animal germs, and coarse feathers. The removal of the first impurities is effected by beating with a stick (after drying), and shaking thoroughly in a sieve; the vermin are destroyed by passing the feathers through highly heated rooms or stoves, which process also improves their appearance.

A novel application of feathers is their conversion into a textile fabric, as carried on by Bourguignon, of Donchéry, Ardennes, Bardin et Fils, Paris, and others. The process adopted by the former is as follows:—The barbs of the feathers are first cut off by ordinary scissors, and are then placed in quantity in a bag, and subjected to a thorough kneading. In a short time, the mass becomes a homogeneous down, of great lightness, and is then ready for the ordinary felting process (see Woollen Manufactures). About 1½ lb. of it will make 1 sq. yd. of fabric, which is warm, light, waterproof, and durable, and will take any dye. The material may also be woven with cotton and woollen yarns. According to a second plan, the feathers are placed on a feed-table, whence they pass under a drum, set with lateral steel knives, which break the feathers; hence, they pass between three small rollers and a superposed fluted and chased iron roller, with a to-and-fro motion endwise, as well as a revolving motion, by which the reduced feathers are ground quite small, and, falling upon a travelling apron, pass on to a spiked drum, running within a cage, and destined to reduce any pieces which have escaped the rollers. The pounded feathers fall to the bottom of the machine, whence a fan removes them to a receptacle where they are mixed with wool in any desired proportion. Thence they pass to the carding and felting machinery. Bardin's method consists essentially in the manufacture of a chenille from feather-barbs. The fibres or barbs of the feathers are first stripped from their stems; a thread of linen, cotton, wool, or silk, sized or not, is then stretched upon a table; and on it, feathers are laid transversely. A second thread is then stretched over the feathers and the first thread; the two threads thus embrace the feathers in transverse position, and their respective extremities are attached or fastened. One of the joined ends of the two threads is then fixed to the table, while the other is grasped freely by the hand, or by a crank, and twisted, thus completing the manufacture of the feather chenille. This chenille may be employed, single or doubled, for trimming ladies' apparel, and for other purposes. To make a feather fabric, each twisted feather chenille is employed as an ordinary weft thread, and passed through the warp of any material, by a weaving machine, taking care, by means of a comb or brush, to raise the barbs or fibres of the feathers out of the warp threads. In this manner is obtained a material furnished on the exterior with feather fibres, similar to fur or plush. This fabric is very soft. To manufacture a feather fabric with a double face of feather fur, it is necessary during the weaving, when the twisted chenille is introduced into the warp, to raise or lift out above the warp, with a brush or similar instrument, a part of the fibres of the chenille, and to separate another part from beneath. By this method, is obtained a fabric furnished with feather fur on both sides, the warp being in the middle of the double feather fur. To give variety of appearance, feathers of different colours may be employed, and other filaments or materials may be mixed with them, especially when stuffs, rugs, and like products are made. The chenilles and feather fabrics may be subjected to the usual dressings and finishings if desired.

Our consumption of feathers for upholstery has been computed at 700 tons annually, which figure is probably far short of the truth. Besides the large quantities produced at home, we imported in 1878, 20,602 cwt. of bed feathers, valued at 91,679*l.*; this total was contributed as follows:—Germany, 6183 cwt.; China, 5026; France, 3906; Russia, 2642; Italy, 820; other countries, 2025. The greatest diversity of value is to be noticed in the imports from these countries, thus:—German, about 97*s.* a cwt.; Chinese, 47*s.*; French, 55*s.*; Russian, 151*s.*; Italian, 229*s.* In 1877, Austria exported 24,293 metrical centners (of 110¼ lb.) of feathers, valued at over 500,000*l.*; in 1878, the exports were 22,408 centners. Russia exported from Archangel, in 1878, 10 tons, valued at 650*l.*, the whole of which went to Holland; and from Revel, in the same year, about 20 tons direct to England, increased to nearly 50 tons in 1879.

Down.—The loose, soft, fluffy barbs, which are attached to the lower part of almost all feathers, are supplemented, in the case of many birds, by an "accessory plume," the whole being generally known as "down." The growth is developed principally on aquatic birds, and is the secret of the superiority of their body feathers for upholstery purposes. Two or three species of water fowl are remarkable for the abundance, softness, lightness, and elasticity of their down; these are the eider-duck, king-duck, and wild swan.

The eider-duck (*Anas mollissima*) is an inhabitant of the Arctic seas and shores of both hemispheres; throughout the open waters of the Arctic Ocean, the bird is very plentiful, and great numbers resort every year to breed on the coasts of Nova Zembla, Spitzbergen, Lapland, Norway, Iceland, Greenland, Davis' Strait, Baffin's Bay, Newfoundland, and Labrador. Less commonly they appear as far south as some parts of Sweden and Denmark, the Færoes, Hebrides, Orkneys, Shetlands, and Farn Isles, also in Massachusetts Bay, and on the coast of Maine; but the down yielded in these low latitudes is markedly inferior to that produced in colder climates, as might reasonably be expected. In Iceland and Norway, eider-duck farming is a recognized and remunerative pursuit; and the marine islands, and low-lying margins of estuaries, frequented by the bird—which is never seen on fresh water—are the object of special legislation. Nidification commences in May, and lasts for 6–7 weeks; the nest is lined with down plucked by the duck from her own breast; about 4–6 eggs are then laid. The farmers remove a portion of both eggs and down, whereupon further supplies are furnished by the duck; the partial robbery is re-perpetrated, and again for a third time. The produce of the three harvests will scarcely reach 3 oz. of impure dirty-brown down. After the third abstraction, the drake contributes about 1½ oz. of whiter material, the removal of which will drive the birds away, while the former outrages are tamely submitted to. The gathered down is separated into different qualities, according to its specific gravity, by stirring it up with a stick in a sieve; this at the same time eliminates the dirt. The yield of cleansed down is about half of the crude material. It is sewn up in little bags for export; and constitutes the most valuable and esteemed variety. The down of the dead bird is inelastic, and therefore valueless.

The king-duck, found in great abundance on the coasts of Spitzbergen and Greenland, and in lesser numbers on the shores of Newfoundland, affords large quantities of down, second only to that of the eider in value, and indeed seldom or never distinguished from the latter in commercial circles. The king-duck does not appear to receive the same consideration as the more valuable eider.

Heavy down, such as that afforded by swans, geese, and ducks generally, is employed for lining and stuffing winter garments. Real eider-down is more often used in bed coverlets, about 1½ lb. of it ordinarily sufficing. The industry has been much injured by the introduction of cheap inferior down, whose quality may be estimated from the circumstance that the weight of the coverlet is increased threefold. The local value of Icelandic eider-down in 1876 was 20*s.* a lb.; it is now about 9*s.* The export from Iceland in 1870 amounted to nearly 8000 lb.

Ornamental Feathers.—Feathers selected for ornamental purposes are of two kinds:—(1)

those manifesting beauty and brilliancy of colour; and (2) those in which the barbules are long and loose, giving beauty of form. Among the first class, are included the feathers, and even the entire skins, of a vast number of birds, principally natives of the tropics, which are not, however, systematically reared for the purpose, but rather hunted in a wild state. The most important commercially are, perhaps, the marabouts (*Leptoptilos argala*, and *L. javanica*) of the E. Indies, and the various species of humming-birds, and birds of paradise. The second class embraces the ostrich and its allies, and deserves fuller description, as ostrich-farming is now an established industry. The present distribution of the ostrich (*Struthio camelus*) is much more restricted than formerly; yet, on the African continent, it is found from S. Algeria to the interior of the Cape Colony, wherever open country occurs. The differences observed between individuals from far distant places has given rise to opinions that more than one species existed in Africa, but these have been disproved. Once widely known in Asia, the bird is now to be met with only in Syria, in the Hauran, whence the skins are taken to Damascus, for despatch to Marseilles. The plumes of wild ostriches are said to differ in quality, according to the locality whence they are obtained; those from well-watered districts are long and heavy, but stiff and ungraceful, from the thickness of the shafts; those obtained in the Kalahari, and adjoining districts, are shorter and lighter, and possess finer shafts, which allow the vanes to droop in a graceful curve.

The countries of N. Africa still continue to furnish considerable supplies of ostrich feathers. The value of the plumes annually exported from Egypt is 150,000–250,000*l.* These are not produced in Egypt, but come from Kordofan, Geziré, Darfour, Baghirmi, Wadai, and Somali-land, and a few from Arabia. They are brought on camels to the Nile, and come in barges up the river to Cairo, the great market for this merchandise. The African feathers which reach Egypt are classed in two divisions—"Sennaar," and "Kordofan." The former are thick, dry, and brilliant, and are often mixed with those from Wadai. They are brought in by desert caravans to Kartoum, and there undergo considerable picking and sorting, which operations are repeated at several stages before arriving at Cairo; and this fraudulent packing is so skilfully done as to deceive inexperienced buyers. These feathers constitute about $\frac{2}{3}$ of the total exported from Egypt; about $\frac{3}{4}$ of them are derived from domesticated birds, which are farmed by the Arabs, and yield a plucking every 6 months. The Kordofan feathers resemble the graceful Barbary plumes in colour and quality. They are obtained entirely from wild birds shot in the desert, and are often brought by caravan direct to Cairo. The Arabian feathers, from the Téméni country, on the S. borders of Arabia, were divided into three classes—"Aleppo," the most perfect in grace, colour, and richness; "Hedjiaz," or "false Aleppo"; and "Yemen," distinguished by beautiful whiteness, and poverty of plumage. The two first are now almost unknown, and the last are so inferior as to be scarcely saleable. A few parcels of mixed Arabian feathers are shipped from Aden. The shipments from Egypt are by steamer from Alexandria direct to Marseilles, or by land. The exports of this article from Tripoli, in 1879, were valued at 235,000*l.*; and from Bengazi, 25,000*l.* The feathers are brought to this port from Timbuctoo, Houssa, Bornou, and Wadai, the first being considered the finest. They are entirely from wild birds, and are brought usually in bulk by traders to Tripoli, and there sorted and packed for shipment to France, England, and Germany. From Algeria, wild ostriches have been exterminated by French sportsmen, but the colonists are commencing to farm them on a small scale. Numbers of feathers are also brought by caravan from the confines of the Sahara, viâ Tindoof, Teezoon, Tarodant, and Wadnor to Mogador, where they are sorted, packed, and shipped; the shipments, in 1878, were 34 cwt.: 28 cases, value 15,000*l.*, were for Great Britain; and 8 cases, value 4500*l.*, went to France. The value of the feathers exported annually from Senegal is about 2500*l.*; they generally go to Bordeaux. They are brought from the Soudan, and the countries of the Senegal River, where the birds are both hunted and domesticated by the natives. The values of the exports from all Egyptian ports, in 1879, were:—To France, 56,500*l.*; Great Britain, 40,500*l.*; Italy, 2250*l.*; Austria, 2000*l.*

Ostrich-farming.—The rearing of ostriches has assumed considerable importance, notably in our S. African colonies. The natural home of the bird is there found in the "karroo" plains and sweet-grass flats of the interior, and though it sometimes resorts to the long sour-grass of the coast, it will not thrive on the "strand veldt," or sour-grass of the sandstone ridges. This is explained by the fact that alkalies are essential to the health of the bird and the proper development of its feathers; and where care is taken to supply this deficiency, in the shape of food, less difficulty will be found in selecting a site for the farm. The country must be open, and the soil should be sandy in places. Opinions vary as to whether the birds should be confined in a narrow area, and fed by hand; or be allowed to run free over a large space, and pick up their own living. The latter plan seems to produce feathers of the best appearance. The paddocks must be well fenced with loose stone walls, or post and wire fencing, about 4 ft. high. The number of birds allowed on an acre may vary from 30 birds on 8 acres, to 23 birds on 500 acres, according to the nature of the land, and the amount of food artificially supplied. Shed accommodation must be provided, for the birds to seek shelter in by night or during storms, and over-crowding must be carefully avoided. The birds require water, and are fond of bathing during the hottest season. In the matter of food, considerable latitude is observed. For young birds, lucerne, thistles, herbs, and indigenous grasses suffice; as the season advances, these may be supplemented by fruit and grain (barley, maize, &c.). A mature bird will require 20 lb. of lucerne, or 3 lb. of grain, daily. If necessary, lime must be supplied, in the form of bones, besides which, a little sulphur and salt should be provided.

The birds are paired at the age of 5 years, one male being coupled with one or two females. Separate pens are provided for this purpose. Nidification begins in July. Laying commences in August, and lasts for about 6 weeks, the eggs numbering 15–20 from each hen. If not removed for artificial incubation, the birds take turns in sitting on them, till they are hatched, in October. On taking away the young brood, the hen will lay again about December, but is then not nearly so prolific. It is seldom that the birds are allowed to hatch out their brood, much better results being obtained by the use of artificial incubators. The form of incubator most commonly employed is that devised by A. Douglass, of Hilton. It consists of a deal box, about 3 ft. square, open above, and resting upon a copper or zinc pan, 3 in. deep, and of the same area as the box. This pan contains hot water, the vapour of which ascends through suitable openings into the box above. The temperature of the water is maintained by an oil lamp burning beneath a portion of the pan, separated by a wall from the incubating room, to avoid the ill effects of the fumes upon the young chicks. The heat is constantly regulated by means of thermometers: the temperature of the box should be 39° (102° F.) when it receives the eggs; after 2 weeks, it is reduced to 37¾° (100° F.); and, in 2 weeks more, to 36½° (98° F.). Incubation lasts for 42 days. The eggs are turned and aired, by opening the box and removing the blanket covering once or twice daily. A fortnight before the incubation is finished, the eggs are examined against the light, to ascertain how soon the hatching may take place; and a week later, those containing weak chicks are carefully punctured near the small end, to assist the occupants in effecting their escape. The proportion of failures should not exceed 1 in 12; in natural hatching, it amounts to 4 in 20. Another good reason for adopting artificial incubators is that the birds' feathers are in primest condition at the time of incubation, and that many of them get spoilt during the time when the birds are sitting. As soon as hatched, the chicks should be kept in a warm but well-ventilated coop, which may be constructed of a box, containing a lot of chenille, or other warm material, hanging from the roof. They are fed at first on bread-crumbs, bran, and water; on the fourth day, they may be let out during the day into a little enclosure made around the incubator, and may then have grain, bread, and green vegetables. They are taken in at night. Until 3 months old, mortality is great among them; and even after that age, many break their legs, and have to be killed.

The bird yields its first plumes at the age of 8 months, and continues to do so at intervals of 8 months throughout its life, which varies, according to different authorities, from 8 to 100 years, but may probably average 25–35 years. The first feathers are small, and of little value. The gathering of the plumes is a delicate operation, performed either by plucking them out bodily, or by severing them near the base, by means of a sharp knife. The former plan was long the only one, and gives the greater weight of feather; but it is now generally superseded by the latter, as it often produces a kind of irritation fever in the birds. When cutting is adopted, the stumps require pulling out about a month or 6 weeks later, unless they have already been shed naturally. Neither method appears to cause the bird any appreciable pain. The operation is performed while the birds are placed singly in a padded crib, or are so densely packed as to leave no room for kicking.

Ostrich-farming is being experimentally undertaken by the Acclimatization Society of Victoria, on the Wimmera and on the Murray Downs, and has quite recently been instituted in South Australia. Many circumstances have had an unfavourable influence upon the results attained, so that these have not hitherto been encouraging; nevertheless, the industry is being persevered in, and a parcel of the feathers sent to the London market were pronounced better than any from the Cape. Still more recently it is stated that African ostriches have been introduced into the Banda Oriental and the Argentine Republic; it is intended to keep the breed quite distinct from the native Rhea, as crossing them produces a sterile race with inferior plumes.

Classification, Value, and Uses of Ostrich Plumes.—As the feathers are gathered, they are sorted according to their quality, the operation being generally entrusted to negroes. The best white plumes, known as "bleeds," are only the tail, and primary wing feathers; the black plumes are secondary wing feathers. The classification of Cape ostrich feathers, for London markets, are as follows:—(1) White; *wild:*—bleeds, fine; Prima, best; Prima, long usual; I. and II. mixed; seconds; seconds and thirds mixed; thirds; *tame:*—finest quality, cut quill; Prima, usual; Prima, ordinary defective tops; seconds; seconds and thirds mixed. (2) Femina:—light colour, good quality; usual; half-dark; dark. (3) Byoks:—white, with black spots. (4) Boos:—tail feathers, white usual; light fem.; dark fem. (5) Black:—long and medium good; medium and short; short. (6) Drab:—grey, long and medium; medium and short; short. (7) Spadones:—white and light fem.; fem.; drab. The relative qualities of the feathers from different countries are in the following order, beginning with the best:—(1) "Aleppo," from Syria; the finest in plumage, breadth, grace, and colour; very rare; (2) "Barbary," from Tripoli; (3) "St. Louis," from Senegal; (4) "Egypt"; do not bleach thoroughly white; (5) "Mogador," from Morocco; (6) Cape; as good in colour as "Aleppo," but of inferior quality; (7) "Yemen," or (erroneously) "Senegal," from Arabia; plumage thin and poor. Prices fluctuate somewhat, and range from over 60*l.* a lb. down to a merely nominal figure. In spite of enormously increased production, the demand seems to keep pace with the supply, though the price has fallen somewhat. Wild feathers always sell more readily than tame ones, the reason being that the latter are much stiffer, and less graceful, have "galleries" in the quill, and resume their stiffness, even after dressing and curling. The principal application of the plumes is for the decoration of court and military dresses, ladies' bonnets, hearses, &c.

Before use, the plumes are either bleached or dyed. They are first washed in soap lather, rubbed well with the hands, and passed through clean scalding water. The bleaching of white feathers is performed in the following way. The feathers are first exposed to the action of sun and dew, for about a fortnight, are washed in a hot bath containing Spanish white—the softest and purest white chalk,—and are then passed through three clean waters; next, they are blued by a rapid passage through a cold bath containing indigo; after this, they are sulphured, by being suspended in a sulphuring stove; and are finally hung upon cords to dry, being occasionally shaken, to open the fibres. A more recent process, invented by Viol and Duplot, is to immerse the feathers in resinous essences, such as turpentine, or in essential oils, at about 30° (86° F.), and to subject them to the action of light, for a longer or shorter period, according to the degree of decoloration desired. After this, they are finished in the usual way, by scraping the barbs with a blunt edge, so as to produce the much-admired curl. Dark-hued feathers, after being bleached by the last-named process, may be dyed almost any shade. Another method of bleaching is by a bath containing 4–5 parts permanganate of potash in 1000 parts water; a similar solution of sulphate of magnesia is added, and heated to 60° (140° F.) max. The previously washed feathers are put into the bath, taken out, rinsed, and passed through sulphuric acid at $1\frac{1}{2}$°–3° Tw.

Artificial Ostrich Feathers.—The Americans are said to be manufacturing large quantities of artificial ostrich plumes, the quill being composed of celluloid, or rattan cane, and the barbs of silk waste.

Other Plumes.—Besides the ostrich, there are many giant birds, belonging to the families *Struthionidæ* and *Apterygidæ*, possessing plumes of more or less value. One of the most important of these is the Rhea, or South American ostrich (*Rhea americana*), whose range extends from Bolivia, Paraguay, and S. Brazil, as far as the Straits of Magellan; while two other species, Darwin's Rhea (*R. Darwini*), and the long-billed Rhea (*R. macrorhynca*), share with it portions of the same territory. The birds are at present ruthlessly hunted, and, a few years since, were being killed at the rate of 300,000–500,000 per annum. Though, from their hardy nature and omnivorous habits, the birds are easily kept in confinement, little has yet been done in this direction. The feathers are collected chiefly in the Banda Oriental, Bahia, Blanca, Entre Rios, as well as Patagonia, and are shipped from Monte-Video and Buenos Ayres. The exports from Argentine ports in 1874 were:—To the United States, 19 tons; France, 18 tons; England, 2 tons; other countries, 21 tons. Their value is put at about 4*s.* a lb., the male feathers bringing the higher prices. They enter European commerce as "vulture feathers," and the majority of them, the dark-greys, are made into feather-brooms.

Imports of Ornamental Feathers.—Our imports of ornamental feathers, including ostrich plumes, in 1878, were as follows:—From France, 120,928 lb.; British possessions in S. Africa, 78,947; British E. Indies, 25,313; Egypt, 12,394; Aden, 4946; Malta, 4485; Holland, 4346; Morocco, 3083; Belgium, 1551; other countries, 8806; total, 264,799 lb., value, 1,002,902*l.*

Quills.—The feathers of geese are almost the only ones whose quills are utilized; though the crow, swan, eagle, hawk, owl, and turkey, render occasional contributions. Quills for writing are obtained almost solely from the five outer wing feathers of the goose, the second and third being the best; the direction of the curve of left-wing feathers gives them a preference. The feathers are taken in the spring from living birds; the quills of fattened dead birds are worthless for the purpose. For the manufacture of tooth-picks, and similar articles, however, such choice is not necessary. Writing quills are prepared in the following way:—In order to remove their greasiness, and pellicles of skin, and to render the quills hard and elastic, they are heated in a fine sand-bath, at a temperature of 54°–82° (130°–180° F.). This causes the inner skin to shrivel up; the outer one is scraped off while the quill is still warm. While still soft and warm, the quill may be stamped with any desired device. Feathers which will not afford quills suitable for pens are ingeniously utilized in France. They are first thoroughly soaked in water; a machine then removes the quill; next, the thin horny layer covering the shaft, and termed *brilliantine*, is stripped off by a penknife, and, when dyed, is used in bonnet trimmings. The broad side of the vane is also removed by hand. The shaft is then placed, small end foremost, under a roller that forces it against a cutting edge, which removes the "upper shaving" of horny material that divides the vane on one side; a similar operation is performed on the "lower shaving." These shavings are further shredded by cutting-cylinders, and are used, under the name of "feather-bristles," for brush-making, while short and waste scraps form stamens, &c., of artificial flowers. The soft, white, elastic pith, forming the interior of the shaft, is ground fine, and used for flocking wall-paper. Finally, the quills proper are thrown into water, and well washed to remove the outer skin; next, they are cut into tooth-picks, by means of dies in a press; and then placed in a wire basket, and agitated in water, to wash out the pith; after which, they are dried, and made up into bundles. Quills are also largely consumed for holding the hairs of artists' brushes, for anglers' floats, as a covering for cigarettes, and for friction tubes.

Feathers and feather manufactures will be included in the proposed Wool Exhibition at the Crystal Palace, in June–October, 1881.

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FIBROUS SUBSTANCES [derived from Plants] (Fr., *Fibres Végétales;* Ger., *Pflanzenfasern*).

The "fibrous" portion of plants consists essentially of cellulose $C_6H_{10}O_5$, a carbohydrate which shows great resistance to reagents that produce a marked effect on the other portions of plants. This resisting property constitutes the value of such fibres for the production of textile and other fabrics. The industrial application and commercial value of a fibre depend principally upon its physical qualities of length, strength, elasticity, firmness, and colour, and upon its capacity for taking dyes. The majority of these qualities are affected more or less by the mode of cultivation, the period of harvesting, and the method of preparation.

The varying position of the fibres of different plants has given rise to a threefold classification:—

(1) Monocotyledons, or endogens, are plants which do not form a true bark, and which grow by virtue of a building up of tissue from within. These plants yield "foliaceous" fibres, imbedded in the cellular tissues and pulp of their roots, stems, and leaves, which fibres rarely attain sufficient development to be of commercial utility, except in tropical and sub-tropical regions, and may, in almost all cases, be separated by simple mechanical processes.

(2) Dicotyledons, or exogens, are plants which do possess a bark, and whose growth is purely of an external character. Their fibres reside in the sheath of bark or bast, and hence are called "cortical." They are abundant in temperate climates. The fibres are in an agglutinated condition, held together by means of a tenacious gum, the removal of which necessitates special, and in some cases laborious, treatment.

(3) In a few plants, the seeds are enveloped in a hairy covering within the pods; these are termed "seed hairs," or "capsular" fibres.

Examination.—Having regard to the fact that many fibre-yielding plants still remain to be examined, and for convenience of reference to the characters of, and means of distinguishing, fibres treated of in a subsequent part of this article, instructions for conducting chemical and microscopical investigations, as suggested by Vétillart and others, may here be briefly given.

The first step is the separation of the fibres from the remaining portions of the plant, which may be effected by boiling the sample in a solution containing 6 per cent. of carbonate of potash or soda. When the separation is accomplished, the sample is well washed, pressed, and dried. If the washing does not suffice to complete the disunion of the fibres, they may be bruised under water in a porcelain mortar, with a pestle of hard polished wood. The separated fibres are then divided into three portions:—(1) For examination longitudinally, in neutral liquids; these are at once placed to macerate in water and glycerine; (2) for longitudinal examination, under reagents, are put aside to dry; (3) for examination in transverse section; this sample is straightened as well as possible, and then put to dry.

A.—Of sample (1), some threads are taken, and placed on a glass slab under a microscope; they are then bathed in pure concentrated glycerine, two or three entire isolated fibres are picked out, laid parallel, and moistened with sufficient glycerine to keep them in place. Care must be taken that the ends are intact, and the fibres entire. Their length is then estimated; and the operation is repeated upon a number of samples. The mean length is, perhaps, most correctly stated as that which occurs the greatest number of times.

B.—These fibres are next examined in neutral liquids having a refractive power as nearly as possible like that of the object itself, such as a solution of chloride of calcium, of the consistence of clear syrup, or glycerine, either alone or with the addition of a little camphor-water and a few drops of acetic acid. One or two fibres are laid in the liquid on a glass plate, being curled spirally, to diminish their length, and are covered with another thin sheet of glass. Repeated observations are then made as to whether the fibres are solid, or in flattened bands; whether rounded or prismatic; whether smooth, or fluted, or striated; whether an internal cavity is visible, and whether it is large, continuous, or interrupted. A number of measurements of the diameter of the fibres are then made, carefully noting the maximum, miuimum, and mean, and the degree of tapering or irregularity.

C.—Sample (2) is next examined under reagents—iodine solution and sulphuric acid diluted with glycerine. The former is prepared as follows:—1 grm. pure iodide of potassium is dissolved in 100 grm. distilled water, and an excess of iodide is added, to ensure constant saturation. It is kept in glass-stoppered bottles, always containing a few pieces of the iodide. The solution is liable to change at the end of a few months, and must then be renewed. The dilute sulphuric acid is thus prepared:—2 volumes of pure concentrated glycerine (Price's) are mixed with 1 volume of distilled water in a flask; the latter is plunged into cold water to the level of its contents, and 3 volumes sulphuric acid, sp. gr. 1·845, are added with constant agitation. This solution also undergoes gradual change by absorption of moisture, when a slight addition of acid becomes necessary.

Some thoroughly dry fibres, in a complete state of division, are selected from the sample, and briskly rubbed between the fingers; they are then placed on a glass plate on the object-holder, and covered by a few drops of the iodine solution. The latter is allowed to thoroughly penetrate the fibres, and the excess is removed by blotting-paper. The test is then covered with a small piece of glass, along one edge of which are poured a few drops of the sulphuric acid preparation. The liquid penetrates between the two glasses, and advances towards the other side, where slips of blotting-paper are placed to absorb it. The current is maintained for a little while, by occasionally adding a few drops of the acid, and renewing the blotting-paper. The result of this operation soon becomes evident in the distinct coloration of the fibres. Wherever cellulose is present, it assumes a blue or violet tint; where the cellulose is lignified, or penetrated by foreign matters, it becomes yellow. This tint, which varies from bright-yellow to brownish-yellow, appears also in the fragments of tissue adhering to the fibres, and iu the matters occasionally found in their interior cavity. The coloration must be clear and pronounced, and the fibres must be in perfectly sound condition; when the results are imperfect, the sulphuric acid preparation may need strengthening. The blue colour will disappear in a few hours, and the yellow will not last beyond a day or two. The reagents occasionally disclose striations or transverse lines of deeper tint, generally arising from folds in the fibre, which afford additional characteristics.

D.—Sample (3) is divided into transverse sections, perpendicular to the axis of the fibre; these furnish the most precise indications of the form, structure, and thickness of the walls, of the fibres. Sufficient fibres are taken to form a bundle about as thick as a goose-quill. About 1 in. of this is cut off, and tied in the middle by a thread. One end of the bundle is placed in thick glue, and then the other end, and both are pressed between the fingers, to ensure the close adhesion of the fibres, and to express the superfluous glue. The bundle is then hung up to dry, an operation requiring at least 12 hours in summer, and 24 or more in winter. When the mass is firm enough to bear cutting, it is divided by a razor into very thin sections, which give the best results when they exhibit the consistence of wax. Several examples should be taken from different parts of the sample, and especially from both ends of the fibres.

E.—The sections are next examined in one of the neutral liquids before prescribed. If the glue does not dissolve in it, recourse may be had to boiling in distilled water. After drying between blotting-paper, the sample is submitted to the microscope, while lying in the neutral liquid. The fibres are occasionally flattened, and present an oblong section, which should be measured both ways.

F.—The application of reagents follows. Into 2 or 3 drops of the iodine solution, is put some powder or fragments of the glued sample. In cold weather, the glass plate should be warmed, to facilitate the solution of the glue. The iodine solution should be absorbed gradually, and the powder should be spread as equally as possible. The excess of iodine is removed by blotting-paper, the sample is covered by a second glass, and the sulphuric acid is introduced, as in previous tests. Notes are made of the exterior form of the sections, the thickness of their walls, and the form of the central cavity. Some fibres appear to be composed of a compact and homogeneous substance, others have concentric coats, which assume varying shades of blue; some present fissures or perpendicular striations on both the interior and exterior surfaces, and which seem to radiate from the centre; some contain a yellow granular matter, while others are empty; and some are bordered with a yellow line.

G.—It is often useful to examine the fibres as they exist in the plant, to determine their position, relative abundance, and nature. Sections are taken of the fibre-yielding portion of the plant, which must be either freshly cut, or soaked in water. These are placed to macerate for several hours in a mixture of glycerine and water, and are then treated with a few drops of concentrated glycerine, which penetrates them, and renders them transparent.

H.—These sections may also be examined under reagents, in which case, they are not macerated in dilute glycerine, but in alcohol, in order to eliminate any resinous matters they may contain. They are then dried, before the treatment with iodine.

The foregoing tests are intended for distinguishing the fibres of one plant from those of another. They will be repeatedly referred to in subsequent portions of this article. To discriminate between vegetable fibres and animal fibres (see Hair, Silk, Wool) the following observations will suffice :—

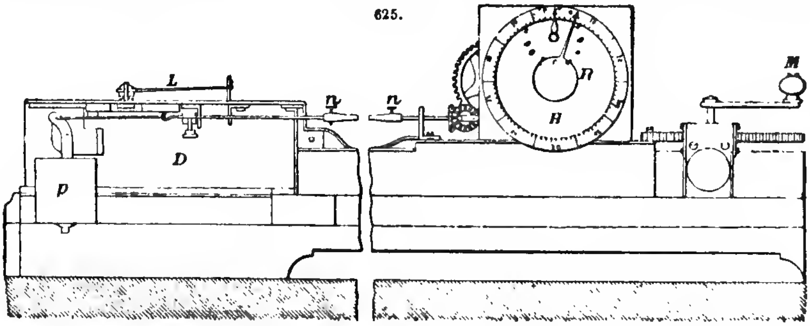
Vegetable fibres, heated in solutions of alkalies or acids, swell up, dissolve, and decompose into glucose or grape sugar. They burn readily, and with a flash.

Animal fibres, boiled in solutions of caustic alkalies, swell up, dissolve, and decompose with evolution of ammonia. They carbonize with difficulty, and only on continued application of heat, and emit an odour like burning horn or feathers.

A ready method of estimating the proportion of fibre (cellulose) yielded by a plant, is to macerate it, for some hours, in water; crush it, by passing it between wooden rollers; subject it to the action of a weak (6 per cent.) solution of carbonate of soda, and then to steam at a pressure of 4–5 atmos., until the cellulose is extracted as a yellowish-brown mass. This is a preliminary test of the value of a plant for paper-making (see Paper). Several other methods are described by Bevan and Cross, in their paper mentioned in the Bibliography at the end of this article.

Fig. 625 shows an apparatus for determining the resistance, elasticity, and torsion, of fibrous threads. The clasps *n* receive the ends of the thread; they may be twisted or untwisted at will,

625.



and be moved either towards or from each other; H R is a graduated dial-plate, the needles of which indicate the number of turns per unit of length; D is a dynamometer, with a needle L, movable under the influence of the traction; *p*, a constant weight; M, the handle by which the traction is exerted upon the thread.

Having treated of vegetable fibres generally, it now remains to enumerate such as are already known, and to point out where they will grow, how they are prepared, and to what purposes they are or may be applied.

Abroma augusta—Devil's Cotton.—Exogen; perennial; small tree. A doubtful native of the interior of the Indian peninsula, flourishing in gardens up to 30° N. lat., and eastwards to the Philippines. Grows well and quickly, and yields 2–4 crops yearly of bark fit for peeling; 3 trial cuttings gave 271 lb. of clean fibre. The bark is separated from the shoots by maceration in stagnant water for 4–8 days in summer; in the cold season, a three times longer steeping is necessary, and greatly weakens the fibres. The latter are naturally white and clean, and require no dressing; they are about $\frac{1}{10}$ stronger than *Crotalária juncea* (Sunn hemp)—say 74 lb.: 68 lb.—and are much more durable in water. Used locally, as substitute for hemp, in cordage; equal to jute for paper-making.

Abutilon Avicennæ [Sida Abutilon]—American jute.—Exogen; herbaceous annual. Now become a troublesome and hardy weed of the Middle States of America. The plant is being recommended for cultivation, as yielding a fibre which may be applied to all the purposes for which jute is now so largely imported into America. The seed is to be sown broadcast on rich soil, and to receive plenty of manure, when the yield is confidently expected to be 4–7 tons of dry stalks to the acre.

A. indicum [Sida indica, S. populifolia]—Country mallow.—Common in most parts of India, and in Burmah. Stem yields a strongish fibre, fit for rope-making, and occasionally applied to that purpose in the Bancoorah district.

A. oxycarpum is a shrub of various parts of New South Wales, Queensland, W. and N. Australia; yields a textile fibre. *A. polyandrum* on the Nilgiri Hills, and about Nundidroog; yields a long, silky, hemp-like fibre, suited for ropes. The fibres of *A. venosum*, *A. amplum*, *A. auritum*, *A. molle*, *A. striatum*, are utilized in S. Africa, Brazil, Australia, and the E. Indies. In Algeria, *A. indicum* is extensively cultivated.

Acacia leucophlæa—Panicled acacia.—Exogen; tree. Found in Sholapore, on the Coromandel coast, in Ceylon and in Burmah. The bark is macerated for 4–5 days, and beaten; it yields a tough, strong fibre, used locally for making large fishing-nets and coarse cordage.

Adansonia digitata—Baobab or Monkey-bread.—Exogen; tree. Native of W. Africa, notably about Sierra Leone, Angola, Loando, Senegal, and Inner Africa; long been naturalized in India, but fouud only in two districts of Bengal—at Hazareebaugh, scarce, and at Nowgong, wild. Two acres have been experimentally cultivated at Calcutta. The fibrous bark is obtained in the following manner:—The hard outer bark is first chopped away all round the tree, after which the inner bark is stripped off in large sheets. These are beaten soft with sticks, and shaken to remove the pithy matter. The fibres are then dried in the sun, and pressed into bales for shipment. Small trees produce finer and softer fibres than large ones. They are said not to suffer much injury from the treatment, and to replace the bark in 6–8 years; but this appears very doubtful. The fibres are very strong, and are used by the Africans for making rope, twine, and sacking. In India, they are in repute for elephant ropes. Quantities of the bark have been imported into this country from Portuguese W. Africa, and met with ready sale to paper-makers, at 9*l.*–15*l.* a ton. It produces an exceedingly strong paper, suitable for bank-notes, and has, on this account, received much attention; but the very slow growth of the tree, and the careful cultivation and shading it requires while young, render it a very precarious source of paper fibre, under these conditions. On the other hand, it seems to coppice well, sending up shoots of 10–12 ft. in height in a year. It is suggested that, when the trees have reached a fair size, they should be coppiced annually, after the manner of osiers.

Agave americana—Century-plant, Mexican or Spanish aloe (FR., *Pite, aloès;* MEX., *Pita, Maguey*).—Endogen; 24–36 ft. Indigenous to all parts of tropical America, from the plains to 10,000 ft.; now naturalized in S. Europe, Mauritius, Algeria, throughout India, and the Pacific Islands. The plant requires about 3 years to come to perfection, but it is exceedingly hardy, easy of propagation, very prolific, and grows in arid wastes where scarcely any other plant can live. It perishes after inflorescence, which does not occur till the 8th–20th year, but it then sends up numerous shoots. In Mexico, 5000–6000 plants may be found on an acre. The average number of leaves is 40, each measuring 8–10 ft. long and 1 ft. wide, and yielding 6–10 per cent. by weight of fibre. The culture of the plant is being extended in America, but not in the proportion which its value deserves. In India, it is all but neglected; it grows wild in many parts, and is sometimes cultivated as a hedge-plant, but its fibre, seldom and badly prepared, is harsh and brittle, though of good colour. Care would effect great improvements.

The native methods of preparing the fibre are very primitive:—(1) The leaves are cut, and steeped in water; then beaten with sticks, and rubbed with stones, or scraped with shells or wooden blades, to remove the non-fibrous portion; and finally washed, and bleached in the sun. This plan causes stains, and a tendency to rot, and thus reduces the value of the fibre. (2) The leaves are cut, and deprived of about 6 in. of the pointed end; then well beaten or bruised with wooden mallets on a smooth surface of stone or wood, tied in bundles of 4 leaves, and laid in heaps to ferment. The beating removes much of the sap; and the fermentation helps to loosen the fibre, without damaging it. When the heat has subsided, the bundles are thrown into water, and steeped for about a fortnight; after washing, the fibre appears clean and white. It is then dried, shaken, and packed.

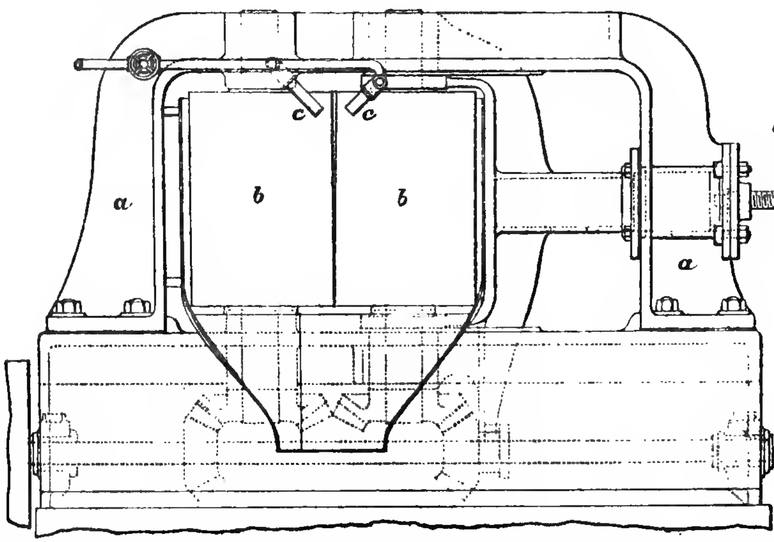
The process of retting has been proved injurious to the fibres of all endogens, and mechanical contrivances have been invented for separating the fibres from the leaves of the agave, and similar plants. In employing the machines described below, an abundant supply of water is a matter of great importance, as its copious use expedites the process, and ensures a fibre of good colour and strength. The leaves should be cut before they are over-ripe: it is preferable to cut them too soon rather than too late, as over-ripe leaves produce coarse fibre of inferior colour. They should be put through the first process immediately after they have been cut, as the longer they are allowed to lie before crushing, the more difficult is the separation of their fibres.

Fig. 626 represents the crushing machine. It consists of a cast-iron framing *a*, in which are placed two vertical iron rolls *b*, slightly conical, and having their surfaces lightly grooved, to facilitate the gripping of the leaves. One roll revolves in fixed bearings; the bearings of the other roll are fixed in a sliding frame, the centre of which works in and out of a hollow trunnion, in which is placed a strong volute steel spring, which can be set by a hand wheel *d*, so as to regulate approximately the elastic play given. Both rolls are driven by gearing fixed in the bottom part of the framing of the machine, the wheel which drives the sliding roll being set free to move backwards and forwards on the driving shaft, by means of a feather on the shaft.

The leaves are passed singly edgeways through the rolls, and the pressure thus applied squeezes out the juices and non-fibrous parts. Two water-taps *c* are fixed on the framing of the machine, in such a manner that each side of the leaf has a jet of water applied to it at the moment of pressure, in order to wash away the juice, &c., which exudes; below the rolls, is a copper guard, which catches the water, juices, &c., and conducts them into a drain beneath the machine.

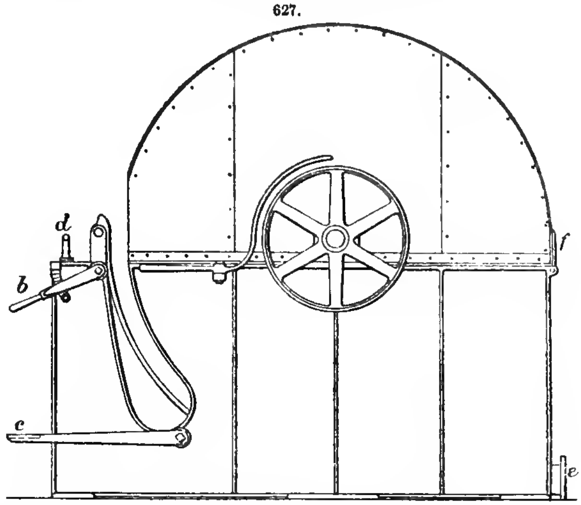
With leaves of small growth, one passage through the machine will ordinarily suffice, but it is advisable to pass leaves of luxuriant growth through a second time; they may now be passed through in bundles of 2–3, as the pressure is then more effective, and is less liable to damage the fibre. Between the first and second passages, the leaves must be well washed, and not allowed to lie long, otherwise the fibres will be stained. Immediately after leaving the crushing-machine, the leaves must be thoroughly washed, squeezed by the machine hereafter described, and then taken to the scraping-machine.

626.



This is illustrated in Fig. 627. It consists of an iron drum, revolving at a high speed between two iron frames, the whole being covered in with a sheet-iron casing. At each side of the framing, is an opening for the admission and exit of the fibre. Inside the casing, are two curved wooden shields, which, by means of two levers *b*, and two treadles *c*, are brought nearer to or removed farther from the periphery of the drum. The levers actuate the upper, whilst the treadles act on the lower, ends of the two shields. Their position can thus be regulated, according to the work to be done. When used as a scraping-machine, the periphery of the drum is furnished with a series of hard wood scrapers, or blades, fixed in holders with a packing of indiarubber, in order to render elastic the blows of the blades on the fibre. The machine is made wide enough for two men to work at the same time. They stand in front of the machine, one inserting fibre through the opening on his right, the other through the opening on his left. The workman introduces the leaves through one of the side openings, allowing them to rest on one of the curved shields or aprons; he then fastens the other ends of the leaves, by twisting them round one of the two hooks *d*. In order to scrape the leaves, he raises one of the levers *b*, which has the effect of bringing one of the curved shields, and with it the leaves, up to the scraping-blades, which, revolving at a high speed, strike the leaves gently but effectually, and remove all their non-fibrous parts. When the upper part of the exposed leaves has been well scraped, one of the treadles *c* is depressed, which brings up the lower part of the shield, and thus exposes the ends of the leaves to the action of the blades.

627.

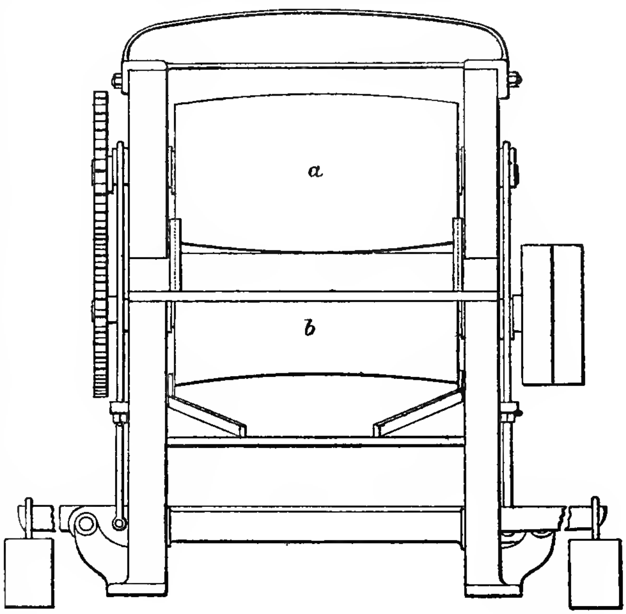


When the scraping is complete, the lever and treadle are released, the leaves are withdrawn, and their position in the machine is reversed, the part already scraped being now twisted round one of the hooks *d*. By a little manipulation, every part of the leaf is fully exposed to the action of the blades, and thoroughly scraped. When used as a scraping-machine, an arrangement is applied inside the frame, by which the refuse material scraped from the leaves flies off the blades on to the ground beneath and in rear of the machine. With some leaf fibres, scraping is unnecessary. If the outer skin of the leaf is soft and tender, and if the non-fibrous part is mostly juice, crushing, washing, and squeezing suffice to extract the fibre from the leaf; any small non-fibrous particles which cling to the fibres, even after washing and drying, are effectually removed by brushing.

After leaving the scraping-machine, the fibre is again washed, 2–3 times, according to the growth of the leaf, the state of the fibre, the supply of water, and the cost of labour; the more thorough the washing, the better the colour of the fibre will be. The washing is best carried out in shallow troughs, or in a stream having a depth of 12–24 in. A supply of clean running water is of very great importance. The fibre is held by one hand, and violently agitated in the water, whilst the other hand removes any leaf still adhering to it; a small wooden blade, about 12 in. long, much facilitates the operation. Several machines have been constructed to wash the fibre mechanically; but their use is attended with certain evils and expenses. As a rule, where the agave and kindred plants grow, labour is cheap, and therefore it is better and more practical to wash the fibre by hand. An additional advantage which hand-washing presents over machine-washing is the fact that some leaves need much less washing than others. In machine-washing, all leaves must be washed alike.

Between the washings, the leaves or fibre should be passed through the squeezing-machine, shown in Fig. 628. It is constructed like an ordinary mangle or wringing-machine; the rollers are very strong, the top one *a* being convex, and the bottom one *b* concave, so that the expressed juice and water have a tendency to flow towards, and to drop off, the middle of the rollers. The fibre should be put through the squeezing-machines in bunches of several leaves, so that the pressure may be more elastic. When thoroughly clean, the fibre should be dried, by preference in the open air. The best mode of drying is to have lines, about 2 ft. apart and 2½ ft. above the level of the ground; the fibre is laid on these lines in the sun, air circulates beneath, and the drying is soon effected. When half-dry, the fibre is turned over, so as to expose all parts equally.

628.



The thoroughly dry fibre may be stored until a convenient time arrives for finishing it, or it may be finished at once. The latter plan is far preferable, as delays frequently involve stained or inferior coloured fibre. Great care must also be taken to keep the fibres parallel to each other, as when they lose their parallel position, and become entangled, every succeeding operation causes a loss of long fibre, and an increase in the percentage of waste fibre; in addition to this, the blades of the scraping-machines, and the brushes of the brushing-machines, need more frequent repairs and renewals.

The finishing process is very simple. The scraping-machine (Fig. 627) is again brought into operation, the wood scrapers being removed, and their places on the periphery of the drum being filled by brushes of kittool or other brush material. The fibre is fed into, reversed, and removed from, the machine in exactly the same manner as already described in the scraping of the leaves. The effect of brushing is to free the fibre from all extraneous matters, and to brighten it. When used as a brushing-machine, a small fan is fixed inside, at the bottom of the framework; this collects the dust, &c., and drives it out through the opening *c*. At *f*, is a small door or shutter opening outwards; on the inside of this, is fixed a comb, which, when the shutter is closed, comes into contact with the brushes, and clears away the tow or short fibre which may adhere to them. The shutter is opened from time to time, and the comb is freed from the accumulated tow.

In some districts, where the leaves are of very rank growth, and the fibres are long and coarse, it is advisable to pass the dry fibre through a breaking or softening-machine, before brushing. Several of these machines are illustrated and described under *Linum usitatissimum* (Flax). After being brushed, the fibre is made up into hanks, and packed into bales by means of a hydraulic press. The most practical way is to have a wooden box fixed in the press; one side and one end of the box are constructed to let down. It is filled with hanks of fibre, and when these are pressed into a bale, and secured, the side of the box is let down, the bale is rolled out, and the box is refilled with hanks of fibre for the following bale.

The machines described above are made by Thos. Barraclough, of Manchester, who was good enough to furnish the drawings which illustrate them. They can be driven by steam, water, or cattle power; a gear suitable for 2 horses, or 2–4 bullocks, suffices to drive a small set of machines, viz. one crushing-machine, one squeezing-machine, and two scraping-machines, being that portion of the set which is used during the time the leaves are being cut. The same gear is afterwards used for driving the two scraping-machines, transformed into brushing-machines, and the softening-machine (where required). The squeezing-machine is also made to be worked by hand. The hydraulic pumps for the press can be easily worked by hand, in the absence of steam or water power.

629.

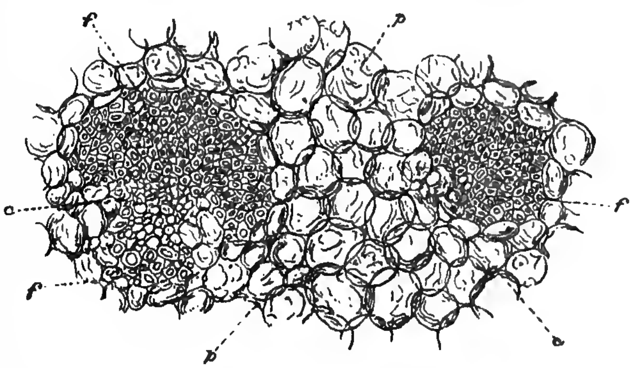
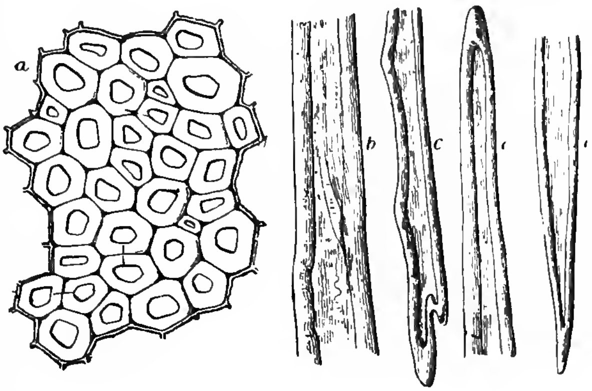


Fig. 629 shows a section of the leaf of the plant, magnified 100 times: *a*, fibro-vascular bundles, coloured yellow by test H, described at the commencement of this article; *b*, centre of the bundle, containing large ducts, and tissue in course of formation; *c*, parenchyma. Fig. 630 shows the fibres, longitudinally and in section, under test F: *a*, section of a bundle of fibres, the shaded portions of which are coloured light-yellow, the outer ring dark-yellow; *b*, a fibre, coloured yellow; *c*, ends of fibres, also coloured yellow; mag. 300. The filaments are large, white, glossy, very light, stiff, and tenacious; they separate easily on rubbing. The isolated fibres are short and thin-walled, and have a large central cavity. They swell towards the middle, and terminate in blunt points, as shown; sometimes they are lobed or bifurcated. The thickness of the walls varies greatly in different parts of the same fibre. The exterior surface is often uneven towards the point. The lengths are max., 0·1375 in.; min., 0·059 in.; mean, 0·0984 in.; the diameters are max., 0·0013 in.; min., 0·00078 in.; mean, 0·00098 in. The length of the fibre varies from 3 to 7 ft.; the colour of the commercial article is white to straw-colour. Its main faults are the stiffness, shortness, and thinness of wall of the individual fibres, and a liability to rot; but these are greatly reduced by the crushing of the fibres in the above-described machines, so as to liberate the interior viscid juice. The breaking strain of a rope of this fibre has been stated at 270–362 lb., as against Russian hemp at

630.

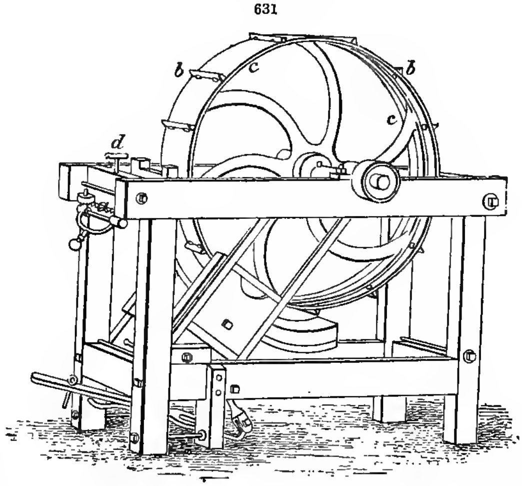


160 lb. Its uses are various. In its native countries, it is applied to the manufacture of ropes, twine, fishing-nets, hammocks, &c. It is exported for admixture with Manilla hemp (*Musa textilis*), for all kinds of cordage. Bleached and dyed, it is made into matting and imitation horsehair cloth, with good effect. The short fibre separated by the processes described above, may also be carded and spun; while the waste is an excellent material for strong wrapping and envelope paper. The fibre, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost 5·55 per cent. of its weight, as compared with Manilla hemp, 6·07; phormium, 6·14; hemp, 6·18–8·44. Some slips of sized paper, weighing 39 gr., made from this fibre, bore an average weight of 89 lb., as against Bank of England note pulp, 47 lb. It is the most highly approved of all paper fibres, making a strong, tough, smooth paper, which feels like oiled paper, and, even while unsized, may be written on, without the ink running. Its price is governed by that of Manilla hemp, being generally 7*l.*–10*l.* a ton less than the latter. With proper care in the preparation, this difference should be much reduced. The fibre prepared in India is harsh and brittle, though of good colour; it is not met with in commerce.

A. sisalana—Sisal or Grass hemp (Mex., *Sosquil;* C. Amer., *Cabuya;* Yuc., *Henequen*).—This species of agave has many features in common with the preceding. The chief home of the plant is Yucatan, but it is a native also of Mexico, Honduras, and Central America, and has been successfully introduced into Florida. It has likewise been recommended for culture in Victoria. In Yucatan, two varieties are distinguished—the *yashqui*, producing the better quality; and the *sacqui*, yielding the greater quantity. The cultivation of the plant is very simple. The land selected is stony and dry. The young plants, 2–3 ft. high, are set out about 12 ft. apart, and weeded twice yearly. In 4–5 years, the lower leaves are cut off, the operation being repeated annually for 10 years and upwards. At intervals of 2 years, 5–10 new shoots are thrown up; one of these is left to replace the parent stem, while the others are removed to form new plantations. The leaves measure 2–6 ft. long, and 4–6 in. wide. The annual yield of clean fibre is about 1 ton an acre.

The native mode of preparing the fibres is to scrape away the pulp from each side of the leaf, by means of a triangular strip of hard wood, with a sharp edge, working against a board. Washing and sun-drying complete the operation. The process is well suited to preserve the fibre, but it is very slow, the yield being only 5–6 lb. a man per diem. Beating the leaves, steeping them in an alkaline solution, or retting them in water, and hackling or combing the fibres, have been unsuccessfully attempted. The machines described for the preparation of the fibre of *Agavè americana* (p. 913), and of *Ananassa sativa* (p. 917), are equally well adapted for this. Special machines also have been introduced. One of these, known as Patrullo's, and made by R. H. Allen and Co., New York, is shown in Fig. 631. The thick end of the leaf is first inserted, while the other is held by the grip *a*; the brass scrapers *b*, affixed to the periphery of the wheel *c*, remove the pulp from that portion of the leaf. The latter is then turned round, the clean end being twisted around the T-piece *d*, which holds it securely. The machine is covered by a wooden hood when working. It requires 2 H.-P., and should have a velocity of 120–150 rev. a minute. The out-turn of clean fibre is about 350 lb. a day. Four hands are employed: 2 cleaning; 1 carrying away the pulp, or *bagasse*, as it is called; and 1 drying the fibre. The two last may be boys. The *bagasse* is used as cattle-food, and would perhaps make inferior paper. The fibre is sun-dried for about 4 hours, and is then pressed into bales, usually 3 ft. by 2 ft. by 2 ft., and weighing 300–400 lb. The bulk of the fibre is consumed by the United States; this amounted, in 1876, to 41,500 bales; 1877, 51,400; 1878, 48,645; 1879, 65,142. New York is the chief importer. Small quantities are shipped to London, Liverpool, and Hamburg. The exports, in 1879, from Progresso, Yucatan, were expected to reach 70,000 bales, of 600 lb. The market value is regulated by the price of Manilla hemp; being somewhat weaker, it brings 5*l.*–10*l.* a ton less. London prices fluctuate between 20*l.* and 30*l.* a ton. Its sole commercial application seems to be for the manufacture of

631



cordage; locally, its use is extended to mats, hammocks, and coarse sacking. The finest twine is made from it in Merida, Yucatan.

A. vivipara [Fourcroya Cantula]—Bastard aloe.—This species is common in the N.W. Provinces of India, and it, or a very closely similar variety, is found in America, from Virginia to Florida. It grows often in clusters, and is reproduced by seeds, which are said to vegetate on the branches till the stem dies, when the young plants fall and take root. In India, the leaves are made to yield their fibre by retting them for 20 days, and then beating them on a plank, and washing well. The fibre is reported strong and useful, and is used for making mats, ropes, and twine, finding a ready local sale.

Aloe sp. div.—Endogen. *A. ferox* in Natal, *A. vulgaris* and *A. succotrina* in S. Europe, Asia Minor and S. Africa. In the Zambesi country, the natives extract a good fibre, called *konge*, from the leaves.

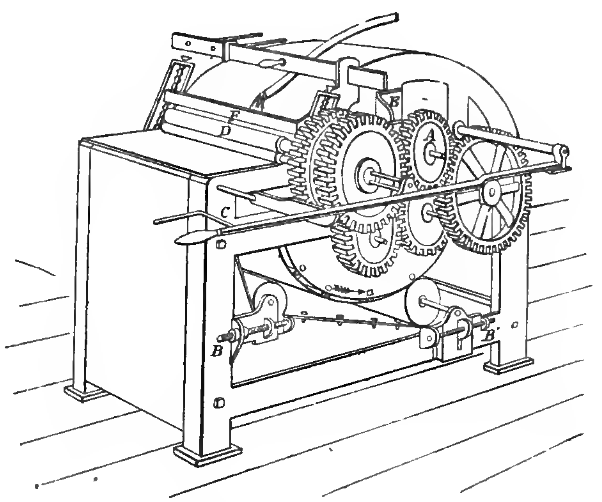
Ampelodesmos tenax—Diss.—Endogen. This plant grows wild on the Algerian coast, over an area of 250 leagues, and is said to yield 84 per cent. of fibre. The plants are crushed, and steeped in limewater for 3–4 days, and in an acid solution for a like period. The fibres are thus disengaged; they are then beaten under water. The average length of the fibre is placed at nearly 5 ft.; and its cost, at 4*s.* 6*d.* a cwt. It is applicable to the manufacture of paper, and, it is said, to that of coarse fabrics, and cordage.

Ananassa sativa [Bromelia ananas]—Pine-apple (Fr., *Ananas*; E. Arch., *Piña*).—Endogen; perennial, 2–3 ft. This plant abounds in China, Malacca, Singapore, Assam, the Tenasserim Provinces, Java, and the Philippines, and is also found (naturalized) in the Peninsula and N. Provinces of India, and in Ceylon. In the Azores and Bahamas, it is cultivated for its fruit. It succeeds in the open air as far as 30° N. lat., growing without any care, and in almost all soils. In India generally, it is grown solely for the sake of its fruit, the Rungpore district of Bengal being the only place where its fibre is utilized. In the other eastern homes of the plant, the fibre is the chief object of attention.

The plant is perpetuated by shoots from its base, and multiplies rapidly. The leaves, measuring about 3 ft. long, by 1½–2 in. wide, may be removed bodily, after harvesting the fruit. When the plant is grown for its fibre, however, as in the Philippines, it is customary to pluck the fruit before it matures, as this causes a considerable extra development of the leaves. The method of extracting and bleaching the fibres, as conducted by the Chinese in Singapore, is as follows:—

The first step is the removal of the fleshy sides of the leaf. A man, sitting astride a narrow stool, extends on it in front of him a single leaf, one end of which is held beneath him; he then, with a kind of two-handled bamboo plane, removes the succulent matter. Another man receives the leaves as they are planed, and with his thumb-nail loosens the fibres about the middle of the leaf, gathers them in his hand, and by one effort, detaches them from the outer skin. The fibres are next steeped in water, washed, and laid out to dry and bleach on rude frames of split bamboo. The processes of steeping, washing, and exposing to the sun, are repeated until the fibres are considered to be properly bleached. In the Philippines, the blunt edge of a potsherd is used, and the fibre is carefully combed, and sorted into four classes.

632.



The above processes are, of necessity, exceedingly tedious, and unsuited to the needs of a commercial undertaking. To supersede them, several machines have been invented. Some of these have been already noticed on pp. 913–916, when speaking of similar fibres. Fig. 632 shows the Sanford and Mallory machine, which is said to be capable of cleaning 6000–8000 pine-apple leaves daily. It consists of an iron framework, about 4 ft. square, carrying a cylinder 30 in. in diameter, covered with an elastic material, and armed with transverse teeth and scrapers, of varying construction, according to the kind of plant worked upon. About half the circumference of the cylinder is in contact with, and drives, an endless elastic belt, similarly armed with teeth and scrapers, and capable of adjustment to bear with more or less pressure against the cylinder. The width of feed is 16 in. The feed rollers, one elastic, and the other of corrugated metal, move more slowly than the cylinder and belt, and thus hold the leaves firmly, while introducing them to the combing and scraping processes within; they have also a reverse motion, so that the leaf may be withdrawn when half dressed, and its ends reversed. During the operation, cold water from a 1-in. pipe is kept flowing over the cylinder and belt, and among the fibre, so as to dissolve and wash away the viscid juices of the plant, and prevent that action of the atmosphere which tends to discolour the fibres. The machine weighs about 9 cwt., requires 1 H.-P., and can be worked by one man, with two boys to feed in the leaves and take out the fibre. The speed required is 80–90 rev. a minute. When the leaves are so thick as not easily to enter the rollers, they should be crushed between rollers, which will also cut them into strips lengthwise. The reference letters indicate:—A, change-pinion for regulating speed; B, tightening-screw for belt; C, lever for reverse motion; D, feed-rollers; E, stud-plate for adjusting intermediate motion; F, perforated trough for distributing water over the plant being crushed. Fig. 633 shows a modified form.

633.

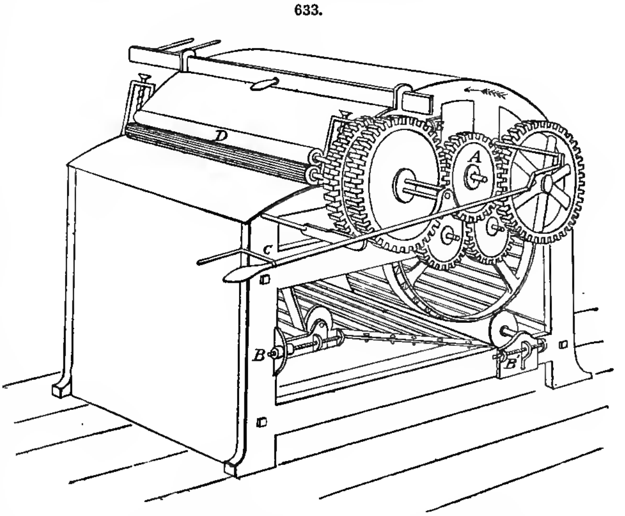
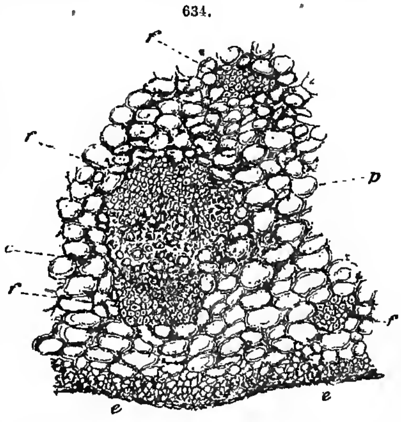


Fig. 634 shows a section of the leaf of the plant, magnified 100 times: *a*, epidermis; *b*, fibro-vascular bundles, which present the singular peculiarity of being coloured blue by test H; *c*, centre of the bundle, containing ducts, and tissue in course of formation; *d*, parenchyma. The filaments are very fine, transparent, strong, and supple; they separate easily by washing and trituration. The isolated fibres are fine, uniform in diameter throughout, but of varying size; they are solid and glossy, supple and curly. They taper very gradually towards the ends, which latter are never sharp, but generally rounded, or blunted. The lengths vary from 0·118 in., to 0·354 in.: mean, 0·196 in.; the diameters are max., 0·0000274 in.; min., 0·0000137 in.; mean, 0·0000216 in. Scarcely any fibre possesses such a combination of good qualities. Its breaking strain has been estimated at 260–350 lb., a 12-thread rope breaking at 924 lb.; it is remarkably durable, and unaffected by immersion in water; and is white, soft, silky, flexible, and long in the staple. In the Philippines, and in Singapore and Malacca, the untwisted fibres are woven into textile fabrics—the *Nipis de Piña* of the former—which are considered the finest in the world. The fibre, intended for a similar purpose, is a large article of commerce between Singapore and China. Fishing-lines and ropes are also made of the fibre; and in the Rungpore district, the leaves are retted for 4–5 days, and the fibres are converted into twine, used by local shoemakers. The facts that the plant is in great abundance and found growing wild, needing next to no care for cultivation, while yielding a most valuable fibre, which is capable of being manufactured, on flax machinery, into textile fabrics, and requiring only to be tanned in order to afford an excellent rope-making material, point it out as deserving unusual attention on the part of tropical agriculturists. A sample of the fibre, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost 6·49 per cent. by weight, as compared with flax, 3·50; Manilla hemp, 6·07; coir,

634.



8·18; Russian hemp, 8·44. Slips of unsized paper, weighing 39 gr., made from the fibre, bore an average weight of 74¼ lb., as against Bank of England note pulp, 47 lb. It works "wet" in pulping; but makes a good and very strong paper, which bears ink well. (See Fruit—Pine-apples.)

Andromachia igniaria.—Exogen. Native of Quito. Affords a good fibre.

Andropogon Martini—Roussa grass.—Endogen. Native of India; universally spread over the trap districts of the Deccan. Yields a useful fibre for paper-making, after the extraction of its valuable oil (see Oils—Nemaur grass-oil). *A. involutus*, *A. saccharatum*, *A. Iwarancusa*, in India, *A. condensatus*, in the Argentine Republic, *A. tenuis*, *A. sericeus*, *Heteropogon insignis*, in S. Australia, all afford fibres; further, *A. gryllus* and *A. Ischæmum* in Europe.

Anona squamosa.—Exogen. The fibre is employed in Guadaloupe and Angola.

Antiaris saccidora—Sack-tree.—Exogen; large tree, 18 ft. in circumference at base, and 100 ft. high. It flourishes in Malabar, Travancore, the N. Concans, and Ceylon. The strong fibrous liber, or inner bark, of this tree is locally used as sacking, and might be employed for cordage, matting, and paper-making. Trees 9–12 in. thick are selected, and subjected to a severe beating with a stone or club, till the parenchyma, or outer bark, is removed. The fibrous inner bark is then stripped off in sheets, the tree being often cut into sections, yielding ready-made sacks. The sacks are filled with sand, and dried in the sun; they are kept hung in smoke when not in use, and last 10–12 years. The tree is also said to be found in Venezuela, where it provides the *marima* shirts of the natives.

Apocynum cannabinum—Colorado hemp.—Exogen; 9 ft. A native of N. America, being found in a wild state on the bottom lands of the rivers, especially in Colorado. It is recommended for culture in Victoria. It yields a fine, white, strong fibre, which has been used from time immemorial, by the Indians of the Colorado river, for cordage and clothing. It is exciting the attention of paper-makers in the E. States, and may be valuable as a textile fibre. *A.* [*Pæderia*] *fœtidum*, *A. sibiricum*, *A. syriacum*, grow in great profusion in S. Siberia, Turkestan, Krim, Trans-Caucasia, and on the Adriatic. In Turkestan, they occur most abundantly in the province of Semiretschi, in the lands of the Ili, and on the banks of the Syr; also throughout the khanate of Kokan, in the valley of the Zariavschane, and around the Aral. In the lands of the Ili, the plants cover the steppes, and their fibre, under the name of *cum*, is used for nets, fishing-lines, rope, and twine, but not for textiles. In other districts, the fibre is more carefully prepared, for textiles. It is separated by a short retting, is very strong and elastic, easily divisible, bleaches and dyes well, and has a length of 6–12 ft.

Areca catechu—Areca or Betel-nut Palm (see Nuts).—The spath of the leaf contains so much fibre that it is employed in a crude state, by Singapore shopkeepers, for packing up parcels, and is used by the Hindoos for making water vessels, caps, dishes, and umbrellas; it is so fine that it can be written on with ink. The vigorous growth and wide distribution of the tree make it deserving of the attention of paper-makers.

Arenga saccharifera [Saguerus Rumphii]—Vegetable bristles (MALACCA, *Ejoo;* SUMATRA, &c., *Anon*).—Endogen. This palm is found throughout the Asiatic islands, especially in low, moist situations. The stem in early life is covered with the sheaths of fronds or leaves, the sides of which afford quantities of a black, horsehair-like fibre. Each tree yields about 6 leaves annually, and each leaf gives about ¾–1 lb. of the fibres. These may be removed without injury to the tree; indeed, they drop off as it advances in age. The fibres are of several qualities and sizes; some are so coarse and stiff as to be suitable only for brush-making; the majority closely resemble black horsehair, and possess all the qualities required for rope-making; the finest are used for caulking ships, stuffing cushions, and as tinder. Commercially, the most valuable fibres are those of medium size. Their breaking strain was recorded as 96 lb., as against coir at 87 lb.; their durability is most remarkable, exposure to wet, and even being packed away in a wet state, having no effect upon them; moreover, cables made of this fibre float on the water. A sample of the fibre, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost 4·15 per cent. of its weight, as against Manilla hemp, 6·07; hemp, 6·18–8·44; coir, 8·13. These properties have caused the fibre to be most extensively used in the East, for making cables and standing rigging; for running rigging, it gives place to coir (*Cocos nucifera*), which is more pliant and elastic, though less durable. It undergoes no preparation, either before or after being twisted into rope. The best is produced in the Spice Islands; that of Java is coarser. It is an important product of the Sulu Archipelago, and is met with in a very fine state at Manado, in Celebes. Its local cheapness and abundance commend it to rope-makers. The unusual resistance of the fibre to the action of water has caused it to be advocated as a covering for telegraph cables.

Artocarpus sp. div.—Exogen. *A. integrifolia* and *A. incisa*, in the E. Indies, New Zealand, Polynesia, and New Guinea, afford useful fibre, much employed by the natives under the name of *ti*.

Arundo karka.—Endogen; reed, 8–12 ft. Native of India, most luxuriant in Bengal. The split stalks form the *durma* mats of Calcutta; in Scinde, they are beaten, to yield a fibre, called *moonyah*, used for making ropes and twine.

A. Sellowiana—Pampas grass.—A grand autumnal flowering reed. Grows in Uruguay, Paraguay, and La Plata, and has been recommended for culture in Victoria. Its leaves yield a fibre useful for paper-making. Probably identical with *Gynerium argenteum.*

A. saccharoides, in Venezuela, furnishes the fibre for the sombrero hats of the peasants.

Asclepias syriaca—Syrian swallow-wort, Silk-weed.—Exogen. A native of Syria, and cultivated as far north as Upper Silesia; abundant also in the United States, Canada, and portions of S. America, notably the Argentine Republic. It is easily propagated both from seeds and from root divisions; it thrives luxuriantly in light soil, and will grow on any poor land. The seeds are covered with a silky down, 1–2 in. long; this, when removed, is capable of several useful applications. In America, the fibres are used principally for stuffing beds, &c., and for hat-making. In Russia and France, textile fabrics are produced from them, and the French firm of Puech Frères has recently introduced a new style of woollen cloth, termed "silver cloth," made by an admixture of 20 per cent. of this down with 80 per cent. of wool. The fibre may be advantageously used also in felts. The bast fibres of the stem of the plant, prepared like flax or hemp, yield a long fine thread, of glossy whiteness.

The similar seed down furnished by *A. curassavica*, and *A. volubilis*, both natives of the W. Indies, is locally used for stuffing purposes. *A. asthmatica* and *A. spinosa* also yield textile fibres.

Astelia sp. div.—Endogen. *A. Banksii* and *A. Cunninghamii*, in New Zealand, furnish leaves respectively 4 ft. and 4 ft. 9 in. long, from which, long and fine fibres are extracted by retting.

Astrocaryum acaule.—Endogen; palm, trunkless leaves, 8–10 ft. high. Grows in the dry Catinga forests of the Upper Rio Negro, Brazil. The rind of the leaf-stalks is used by the Indians for making baskets.

A. vulgare—Tucum thread.—Stem, 40–50 ft. Found growing on the dry forest land of the Amazon and Rio Negro, and is carefully cultivated by the Indians where it is not met with in a wild state. The unopened leaves furnish a fibre, which is extracted and prepared in the same way as that of *Mauritia flexuosa*, and is superior in fineness, strength, and durability. The thread is used chiefly for bow-strings and fishing-nets; in places where *Mauritia flexuosa* does not grow, it is employed also for hammocks, which fetch a high figure in Rio Janeiro. Retting the leaves has been tried, and failed, because decay ensues in less than a week. Practised hands can extract only about 2 oz. fibre per diem by the native method.

Attalea funifera—Bahia Piassava.—Endogen; tree, 30–40 ft. This palm grows in forests in the Brazilian province of Bahia, extending southwards to the Rio Pardo, and perhaps beyond that river. It is utilized chiefly in and near Commendatabalu, Una, Ilheos, Porto Seguro, Marahu, Rio de Contas, Santa Cruz, Cazane, Tapiroa, Cannavieros, and Itaparicu. It is not found far inland. The trees grow wild, being propagated by nuts, which are the food of birds and monkeys, and thus get widely spread. No care or expense in cultivation is attempted. The trunk is bare for three-fourths of its height, when the foliage commences. The unopened leaves are enveloped at the base in coarse chocolate-coloured fibres, which constitute a portion of the Piassava fibre of commerce. They are removed from the leaves by the natives, who use a small axe for the purpose. Only young trees are selected, so as to secure the freshest fibre; the taller trees are neglected. The severed fibres are gathered from the ground, taken home to be roughly hackled, straightened, and cleaned, and are then handed over to native packers, who use the most primitive contrivances for pressing it into bundles, of about 1 *arroba* (32 lb.). The packing-sheds are always on a river, for convenience of shipment. At the port of Bahia, the fibre is sold in bales weighing 80–100 lb. The exports from Bahia to foreign countries, in 1878–9, amounted to 126,000 cwt.

The native population have employed the fibre for ages, as it is very durable and not attacked by ants. Its local application is solely for cordage purposes, for which it is well adapted, as the rough-edged fibres twist into a very firm rope, which is so light as to float on water. A considerable trade is done in it with the interior. In Europe, this fibre is employed almost exclusively in brush-making. Denmark and Germany now have a large trade in the article; but the bulk of it comes to this country. In N. America, it is little used. The total foreign consumption is estimated at about 5000 tons a year. The London market value fluctuates between 15*l.* and 25*l.* a ton.

The term "Para Piassava" is commercially applied to the fibre yielded by another palm (see *Leopoldinia Piassaba*).

Bambusa arundinacea—Bamboo.—Endogen; gigantic grass, 70–80 ft. This most useful genus flourishes throughout the tropics of both hemispheres, growing luxuriantly in moist places, while some of its varieties prefer to climb the high lands. As a possible source of "stock" for paper-making, it has attracted much attention, and been made the subject of several experiments. The method of planting it, most commonly adopted by the natives of India, is by shoots, or the lower part of the halm, with a portion of the rhizome, set out during the rains; but heavy and constant rain for some time afterwards is essential. In Algeria, propagation by stem cuttings is found to succeed admirably. Cultivation from seed is, perhaps, the most certain plan; but it is open to the serious disadvantage that the plant then requires 10–15 years to attain a growth sufficient to admit of cropping. The plant will not grow in poor or waste soils, but prefers the rich land on the banks of streams. Abundance of moisture, supplied either naturally or by irrigation, is absolutely essential. Thousands of acres of wild bamboo jungle exist in the tropics, but very little of this is available for the purposes of the paper manufacturer, as experience has shown that shoots of the year are the only ones which can be used. This fact, coupled with the equally important one that an abundance of bamboo is essential to the very existence of the native races of the E. Indies, renders it certain that, for industrial undertakings, the plant would have to be systematically cultivated. It remains to be proved whether the cost of such cultivation, together with that entailed in the preparation of the product, might not be much better expended upon a plant which would yield fibres fit for textile manufactures in the first place, and equally or more valuable for paper when in the form of rags.

Estimates as to the available annual product of young shoots vary considerably. Thomas Routledge, of Claxheugh, the great advocate for the culture of bamboo as a paper-making material, would divide an acre into 12 beds, each 96 ft. by 26 ft., crossed by 12 paths 96 ft. by 8 ft. 8 in., and one intersecting road, 208 ft. by 16 ft., thus leaving a planting space of 2496 ft., or 29,952 ft. in the 12 beds; placing the stems 2 ft. apart would give 7488 stems, which, grown to a height of 12 ft., are estimated to weigh 12 lb. each, thus giving 40 tons of green stems per acre. These lose 75 per cent. by drying = 10 tons, producing 60 per cent., or 6 tons of "paper-stock." On the other hand, by present methods of cultivation, the plants are never set at less than 5 ft. to 8–10 ft. apart, though these limits might be reduced by the aid of manure and irrigation. Also, only a portion, say 50–75 per cent., of the shoots may be removed from each stool, or the parent plant will die. At the end of 15–30 years, the plants flower and die, when re-stocking would be necessary. Robert Thomson, Superintendent of the Jamaica Botanic Gardens, believes that bamboo plantations there will yield annually 5–10 tons (dry) of young shoots. The young shoots must not be cut close to the ground, but a few nodes above it; foliage starts from the nodes which are left, and maintains the action of the roots. In Jamaica, three crops have been taken in two years; and some bamboos deprived of every shoot were luxuriant again in four years. After heavy rain, the young shoots spring from the ground to a height of 25 ft. in about 5 weeks.

The bamboo has established its reputation as affording an excellent paper material, and thousands of tons of it have been consumed in America and this country, the supplies having been drawn from the W. Indies. Efforts have been made in Brazil to utilize the fibre for textiles, in mixtures with wool and silk. The expenses entailed for machinery, and for boiling the stems for 3 weeks in caustic soda solution, are surely not warranted by the result. Attention has been hitherto confined to the above-named species and to *B. vulgaris*; but *B. Tulda*, *Dendrocalamus giganteus*, and *D. strictus*, await investigation and trial.

Bauhinia racemosa—Bun-raj, or Arree.—Exogen; small tree. Found throughout Bengal, Mysore, and the mountains of the Concans. The bark stripped from the green branches is made into strong rope, used locally for various purposes; the fibre is not exported, and is low priced.

B. scandens [anguina].—A climbing shrub, found in the Concans, Assam, and Travancore, and very common in Silhet. Its fibre is much used by the Nagas. A line made from it supported 168 lb. for 45 minutes, and stretched 6 in. in 3 ft. Major Jenkins reported, however, that, either from the nature of the material, or the mode of its preparation, it was so harsh and stubborn, and the fibres stuck so close together, as to cause the heckles to tear it to pieces, and injure its strength.

B. Vahlii—Patwa, or Mahwal.—Gigantic climber. Found among the forests of the Sewaliks and the hot valleys of the Himálayas, from the doons of the N.-W., to the valley of Assam. The stems are cut in July-August. The outer bark is stripped off, and thrown away; the inner is used for making ropes and cordage. It is either soaked in water, and twisted while wet; or it is boiled, and beaten with mallets, to render it soft and pliable. The cordage prepared from it is not very durable, and rots if kept constantly in water. It has, however, been used in making suspension bridges in the Himálayas. Though very abundant, the fibre is not collected for sale.

B. Hookeri, in S. Australia; *B. reticulata*, *B. rufescens*, &c., in Senegal and Angola; *B. splendens*, in Venezuela; and *B. coccinea*, in Cochin China, are all turned to account for their fibre.

Beaumontia grandiflora—Vegetable silk.—Abundant in India. Furnishes the best seed hairs yet known, though least utilized. The fibre is said to be not only the most lustrous and most purely white, of all the so-called "vegetable silks," but possesses besides a remarkable degree of strength. Moreover, the hairs are very easily separated from the seeds. The dimensions of the fibres are 1·181–1·771 in. long, and 0·001287–0·00195 in. in diameter.

Bœhmeria nivea [Urtica nivea, U. tenacissima]—China grass (FR., *Ortie de Chine*; GER., *Chinagras*; ASSAM, *Rheea*; MALAY, *Ramie*; SUMATRA, *Caloec*; JAPAN, *Tsjo*, *Karao*; CHINA, *Tchou ma*, *Chu*).—Exogen; shrub, 5–8 ft. The range of this plant is very wide, especially if we admit the identity of several locally-distinguished species or varieties. As a native, it occurs abundantly in China, Japan, the Philippines, Java, Sumatra, and the Eastern Archipelago generally; in Siam, Burma, Singapore, and Penang; as well as in Assam, Nepal, and in some parts of the Lower Provinces of Bengal, as Rungpore and Dinagepore. Its natural limits appear to be about 36° N. lat., in Corea and Japan, and between 9° and 10° S. lat., in the Moluccas. Under cultivation, it has been proved to flourish in almost every part of India; and it has been successfully introduced into many foreign countries. It thrives in Natal, where an indigenous variety attains a height of 24 ft.; in Mauritius; in Algeria, especially near Relizane, and in the plain of the Habra, in the province of Oran, its cultivation has been attended with great success; the island of Corsica offers similar prospects; S. France, especially the Departments of Vaucluse and Alpes Maritimes, is now producing large quantities of the plant; in the Channel Islands, and even in Great Britain, it does not refuse to grow, though its culture probably could not be made profitable; the alluvial and upland soils of the S.-W. States of America are well suited to the plant, and its culture is being successfully carried on in Louisiana and California; it is grown in Martinique, Jamaica, and Trinidad; it has been naturalized in Mexico; finally, it is recommended for culture in the rich and warmest forest valleys of Victoria, where irrigation can be applied; in the open ground, it suffers from the night frosts, which, however, do not prevent fresh shoots being sent up during the hot season. An allied variety, *B. calophleba*, recently discovered in Lord Howe's Island, deserves attention and investigation.

Cultivation of the Plant.—The plant is generally propagated by roots, cuttings, or suckers; it may be grown from cuttings as readily as the willow. It requires a great deal of moisture, and appears to thrive best under shade in the tropics. It differs from all allied textile plants by being perennial, and it is said that the quality of the first year's crop is improved upon in subsequent years. Analysis of the stems shows 4·14 per cent. of ash; of this, the alkalies amount to 48·76 per cent. (potash, 32·37), and the phosphoric acid to 9·61 per cent. These figures suffice to show the very exhausting nature of the plant, and explain the importance attached by the Chinese to its careful manuring. At the same time, it must be remembered that the fibre itself contains only an infinitesimal proportion of ash; and if the refuse from the stems, after separation of the fibre, be burned and returned to the soil, the necessity for artificial manuring will be much reduced. The plant has long been cultivated in the countries where it is indigenous, and a knowledge of the methods adopted by the natives cannot fail to be of service to those who propose introducing it elsewhere.

Chinese plans.—The seeds are sown in sandy soil, near water; the ground is dug several times, and then watered in the evening; on the following morning, it is loosened with a small rake, and levelled; some seed is then mixed with moist earth, in the proportion of 1 pint of the former to 4½ pints of the latter; the seed is then sown with the earth, and is left uncovered; 1 oz. of seed suffices for 6–7 beds measuring 1 ft. by 4 ft. So soon as the sowing is done, a light framework is erected, in a slanting position, 2–3 ft. above the ground, and is covered with a thin mat. As the weather grows hotter, this awning is supplemented by a thick layer of straw, otherwise the young plants would be destroyed. Moisture is supplied by sprinkling water upon the roof; the latter is removed at night, in order that the plants may catch the dew. When the first leaves appear, weeding is begun; the roof is laid aside when the plants are 1–2 in. high, and the earth is kept moist to a depth of about 3 in. The young plants are next transferred to a stiffer soil. The beds are watered on the evening preceding the removal, and the new beds are watered in the morning, for the reception of the plants. The removal is effected by a spade, care being taken to keep a ball of earth around the roots. The young plants are pricked out at 4 in. apart; the ground is often hoed, and water is supplied at the end of 3, 5, 10, 15, and 20 days. The roots afford new shoots, which, at the end of 4–5 years, will be so numerous as to require thinning. This may be done either by taking cuttings 2–3 in. long from the roots, or by bending the stems down to produce layers, the latter plan being the quicker. Immediately the stems are cut, the ground is watered with a mixture of equal quantities of water and liquid manure, pigs' dung being avoided. Watering must be done at night or in cloudy weather. Root cuttings are placed by twos and threes in little trenches, about 18 in. apart; they are then surrounded with earth, and watered occasionally. In forming plantations with shoots, the new plants are placed at about 18 in. apart. In either case, choice is made of stiff land that has been well worked in the autumn, and manured. The stems are gathered for industrial purposes in the first year, when about 1 ft. high. In the tenth month of every year, before cutting the offsets, the ground is covered with a thick layer of horse or cow dung; in the second month, the manure is raked off, to allow the new shoots to come up freely. In the second year, the stems are again cut. At the end of three years, the roots are very strong, and send up many shoots. Cropping then takes place three times a year, the stems being cut when the suckers from the rootstock are about ½ in. high. The first harvest is got in at about the beginning of the fifth month; the second, in the middle of the sixth or beginning of the seventh month; and the third, in the middle of the eighth or beginning of the ninth month. The stems of the second crop grow the fastest, and yield the best fibre. After the crop, the stocks are covered with manure, and immediately watered. A well-cared-for plantation lasts for 80-100 years.

In Assam.—Here the plant is sparingly cultivated by the fishermen, to provide fibre for their nets. It is propagated entirely by root divisions, planted in garden plots, and well manured with cow-dung and wood-ashes. It often yields 5 crops in a year, after planting, or six from April to April; the first is cut in April, the second in June, the third in August, the fourth in November, the fifth in February, the sixth in April again, and so on. The most luxuriant crops are those of June and August, they receiving the most moisture; the February crop yields the strongest fibre. Between the crops, the ground is opened up around the roots, by means of a long-handled hoe. After the November crop, cattle are generally admitted into the plots, and the plants are thus kept down till February, when the ground is carefully loosened, and the roots are heaped up with earth, and well manured. The points claiming special attention are the manuring, the provision of abundant shade, and protection from storms; the last is often effected by walling-in the gardens with wattling. The common height of the plant is 8 ft., giving fibre 6 ft. long.

In Java and Sumatra.—The experiments undertaken here by the Dutch Government mostly failed, on account of the injudicious selection of open rice fields, instead of the much more suitable coffee lands. The natives propagate the plant by root divisions, set out at 3–4 ft. apart; the stems soon attain a height of 5–7 ft., and are cut when they have become brown for about 6 in. from the roots. Four crops are usually cut in a year; in the first year, the plants yield 4 stems at the first crop, 6–8 at the second, 10–12 at the third, and 16–20 at the fourth; more are obtained in subsequent years. The first crop is taken without waiting for the stems to ripen, as the fibre is so inferior as to be rejected.

Agricultural problems.—The principal points to be investigated, in order to determine the best methods of growing the plant on a commercial scale, are as follows:—(1) Influences of irrigation and manuring; especially the effect of returning to the soil the waste portions of the plant. (2) The variation of the amount and quality of the fibre according to the season. (3) The comparative quality of the fibre of short stems (3 ft.) and that of full-grown stems (5–8 ft.). (4) The effect of the density of growth upon the thickness, straightness, and branchiness of the stems, and upon the yield per acre, especially in connection with the prospect of a greater number of crops annually under the condition of limited height. (5) The best and cheapest methods of gathering, stripping, and sorting the stems. Experiments in France have proved the autumn crop to be much superior to that cut in summer. It seems to be an established fact that, for very fine purposes, the plant should be cut at 3–4 ft.; hence arises the question whether closer cropping, or enhanced value, will compensate for the diminished product. The proportion of waste will certainly be less in the shorter stems. The sorting of the stems is very necessary, as, from the variable nature of the plant, independently of external causes, the qualities, and therefore the applications, of several portions of the produce of the same plantation, may vary widely. The out-turn of clean marketable fibre per acre is variously estimated. One grower did not succeed in producing more than 720 lb. of green stems, yielding 45 lb. of fibre, or, reckoning 3 crops annually, 135 lb. From some experimental crops in the United States, 3 yearly harvests, of 700–800 lb. of clean fibre each, are anticipated. The safest official data from India, however, give 5200 lb. of green stems, yielding 208–312 lb. of clean fibre, or an average of 250 lb.; with 3 annual harvests, this would give 750 lb. an acre, with 4 harvests, 1000 lb.

Extraction and Preparation of the Fibre.—Before proceeding to a description of the various machines which have been designed for this purpose, the native methods deserve a brief notice.

Native methods.—In China, the gathered stems are (1) split longitudinally, with knives of iron or bamboo; the bark is first removed; then the lower layer, which is white, and covered with a shrivelled pellicle that comes off by itself, is scraped off; and the interior fibres are removed, and softened in boiling water. In winter, the stems require steeping in warm water, previous to splitting. The fibres are divided into three classes:—The first layer is coarse and hard, and fit only for common purposes; the second is more supple and fine; the third is available for extremely delicate textiles. The stems are bleached by tying them up in little sheaves, and exposing them on the roof to the sunshine by day, and dew by night. The process requires 5–7 days. In wet weather, they are put under cover in a draught; if rained upon, they turn black. (2) After peeling the fibres, they are tied in skeins, and steeped in water for a night; they are then spun on a wheel; and are again steeped in water containing the ashes of burnt mulberry wood. Next they are divided into packets of 5 oz., and placed for a night in a mixture of equal measures of pure water and powdered chalk; on the following day, they are boiled in water containing straw ashes, which renders them white and supple; after drying in the sun, they are reboiled in clean water; well washed; and finally dried in the sun. (3) The fibres are boiled in lime-water; well washed; and spread out on the surface of water during the day; at night, they are taken, and dried; the process is repeated daily till they are quite white. (4) The extracted fibres are simply softened in the steam of boiling water.

In Assam, the stems are gathered in the following way:—The top of the plant is taken in the left hand, and the right hand is passed down to the roots, stripping off all the leaves; the stem is then severed at 2–3 in. from the ground. The fibre is extracted, either at home or on the spot, by one of the following processes:—(1) The stem is broken in the middle, and, after a sharp movement of the right hand to either side, the thumb is passed up, and the fibre is ripped off with its adherent bark; the fibre is then steeped in water for a few hours, which removes much foreign matter; the small end of the fibre and bark is attached to a hook; taking one strand at a time, the operator holds the thick end in his left hand, while, with slight tension, he passes his right thumb along the inside of the strand, and thus disengages the bark. The latter falls off, and any remaining feculent matter is expressed by a blunt knife. The finished bundle is most carefully dried in the sun, or in a draught, and is then put aside. (2) The bark is scraped from the individual stems by a blunt knife, leaving the fibre on the woody portion of the stalks, which are then sun-dried for 2–3 days; on the third morning, after several hours' exposure to the dew, the fibre is removed by breaking the woody stalk towards its thick end, and drawing the fibre off towards the small end; the thick end is then similarly stripped. This process leaves about one-fifth of the fibre adhering to the stem.

In Java, the methods resemble those of China and Assam. In Borneo and Sumatra, the stems, tied in bundles, are subjected to a retting process before stripping; this usually lasts for 5–6 days, but is occasionally extended to 14 days. A day's work is variously estimated at $\frac{1}{2}$–$2\frac{1}{2}$ lb. of fibre.

Improved methods.—The tedious and expensive, though efficient, methods practised by the natives of the E. Indies are unsuited to the conditions attendant upon extensive operations. On this account, the Indian Government, represented especially by Dr. J. Forbes Watson, Reporter on the Products of India, has long been engaged in endeavours to solve the problem of the preparation of the fibre on a commercial scale. Despite the offer of large money prizes, no apparatus or process, fulfilling the condition of preparing a fibre worth 50*l.* a ton at a cost of 15*l.* a ton, seems as yet to have been invented. Before detailing the several machines which have been intended to satisfy the above condition, it will be convenient to notice the chief characteristics of the stem of the plant, as bearing upon the means suitable for extracting its fibres.

In length, thickness, and woodiness, the stems most nearly resemble hemp (*Cannabis sativa*); but they differ in being much more succulent, 100 lb. of fresh stems yielding only 17–25 lb. dry, as against 40–55 lb. The yield of fibre from the dried stems is about alike—15–17 lb. in 100; but calculated from the green stems, 100 lb. *Bœhmeria* give only 5 lb. raw fibre as brought to market, or $3\frac{1}{2}$–4 lb. when freed from gum, as against 9–12 lb. in the case of hemp. One of the greatest difficulties encountered in the treatment of *Bœhmeria* stems is the quantity and acridity of the gummy matters contained in them, and which, on exposure to the air, rapidly coagulate, and become insoluble in water. In the case of similar fibrous plants—as flax, hemp, jute,—the removal or destruction of this gum is effected by "retting," or subjecting the stems to partial fermentation by soaking them in water. The succulent nature of the plant under notice greatly increases the difficulty of controlling the fermentation, so as to avoid injury to the fibres. Retting the green stems would, probably, be quite impracticable; but if the stems were dried, assorted according to their development, and submitted to a preliminary crushing, to equalize the fermentation, the operation would be much simplified. Hitherto, every improved machine or process seems to have been destined for the treatment of the stems in a green state, and, indeed, the competition for the prizes offered by the Indian Government was limited to plans for extracting the fibre from the green stems. This is to be regretted, the more so as the fibre extracted from dried stems has proved to be at least as strong and lustrous as that procured from green stems. Moreover, the former plan presents several important practical advantages over the latter:—(1) The woody core and outer bark of the stem, when in a dry, friable condition, are much more easily separated from the fibre. (2) Dry stems might keep the machinery employed at all seasons; whereas green stems would be procurable only at intervals. (3) By using dry stems, the factory might be dissociated from the plantations, and form a central market for the crops grown at some distance around, by ryots, and others. Four tons of dried stems yield one ton of fibre, so that freight would not be expensive. To use green stems, the factory must be immediately at hand, as the supply must be daily, and the freight is multiplied fivefold. (4) The proportion of fibre extracted seems to be greatly in favour of acting upon the dry stems. (5) The possibility of producing uniform qualities of fibre would be much increased by sorting the large quantities of stems available for treatment in the dry. On the other hand, must be stated some possible drawbacks to treating the dry stems:—(1) The removal of the gummy matter may probably be less efficiently performed in the dry way, than by careful scraping and washing of the green stems. (2) In some localities there would be great difficulty in drying the stems during the rainy season; but where such were the case, the stems might be left to grow during that period, producing a coarser, but probably stronger, fibre.

Though several machines have been expressly designed for the treatment of this fibre, none appears as yet to have satisfied the requirements of the Indian Government.

The machine invented by C. C. Coleman, Honolulu, is shown in Fig. 635. The freshly cut ripe plants are passed through a series of rollers, being carried forward by moving wire screens;

hence they are dipped into tanks containing hot water and bleaching materials. The rollers crush the plant, and squeeze out the gummy matter, which is removed in the bath. The plants are taken through the operation as many times as may be necessary to cleanse and bleach the fibres, the squeezing between the rollers being repeated each time. The fibre is said to be neither broken nor weakened by the process, and to be cleaned at a cost of 4*l.*–6*l.* a ton.

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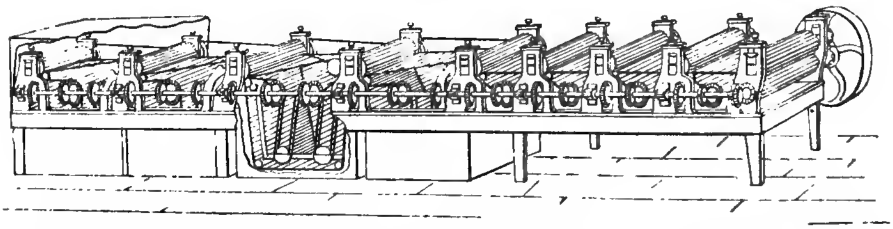

Lefranc and Nagoua's machine is seen in Figs. 636 and 637. The crushing and feeding rollers *a b* have their peripheries grooved correspondingly; *c* is a toothed support for the plant while moving into the rollers and the revolving beaters *d*; *e* are cylinders furnished with spiral, curved, or elliptical knives *f*, cushioned with rubber *h*. The plant is fed in between the rollers *b*, whence it passes between *a a′*, and under the knives *f*. The speed of *a a′* is a little less than that of *b b′*, to

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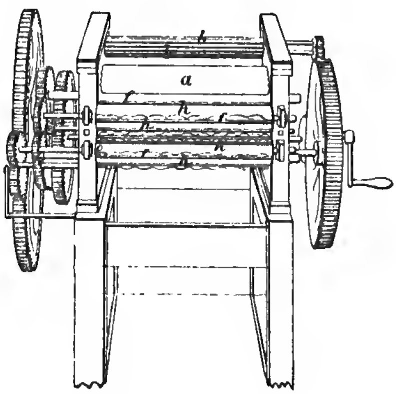

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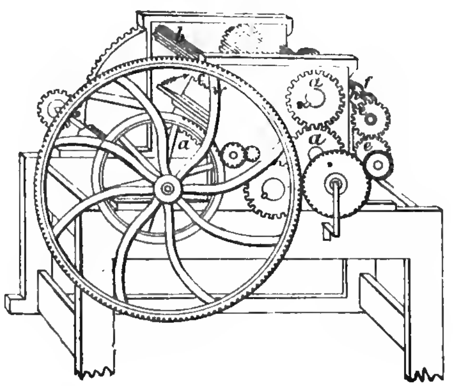

avoid tension of the plant; but the speed of the cylinders *c e′* is much higher than that of *a a′*, so that the knives *f* shall strip the bark and pith away from the crushed stalk, as delivered by the rollers *a a′*. To avoid the otherwise obvious fault that the end of the stem would thus pass out unstripped, revolving toothed beaters *d*, and a toothed support *c*, are provided. When the forward end of the stem reaches *a a′*, the after portion passes between *b b′*, and then falls on and between the arms of the beaters *d*, which, revolving rapidly in the direction of the arrow, bend the stem over the toothed support *c*, and strip the bark and pith off the end before it reaches *a a′*, so that the plant is cleaned from end to end.

Bouchard's machine is represented in Fig. 638. The plant is placed upon the table *a*, and introduced, by the lower end of the stem, between the rollers *b*; the small drum *d* effects the decortication of the stem, while the pipe *c* supplies water, which partially macerates the plant; the mass is projected by the lever *e* towards the large drum *f*, which disintegrates it, and passes it through the rollers *g* placed below.

Greig's machine is illustrated in Figs. 639 and 640. The green stems are spread on the travelling platform E, and are thus conveyed, small end foremost, between the fluted rollers B C D, by which their bark and internal pith is broken up. In this state, they pass down between the roller B and the pressure roller F, and are conducted thence between the revolving drums *g*, fitted with knives or scrapers *x*, by means of which, the short pieces of pith, broken by the action of the fluted rollers, are separated and threshed away, while the gummy and vegetable matters are scraped off the fibres. As the strips of fibre pass from the scrapers *x*, they are vertically suspended, and blown between the pressure roller I and travelling table K, by means of a revolving brush H. When the thick ends of the stems have passed through the fluted rollers, they fall down, and, being suspended by the small ends held between the pressure roller I and table K, they come into contact with the lower set of scrapers *r*, attached to the drums M, by which they are cleansed in the same manner as the small ends. The clean fibre is then drawn upward by the friction between the pressure roller I and the travelling table K, by which it is conducted away from the machine. In order to still further cleanse the fibre whilst it is being operated upon, a tank *v* is placed on the top of the frame A, and is provided with a tap *w*, and a rose *z* extending across the upper part of the machine, by which water may be discharged upon the fibre under treatment. To prevent the adhesion of the gummy and other matters to the scrapers *x r*, the latter revolve in contact with the brushes N. The speed of the principal parts are:—First motions, 65 rev. a minute; fluted rollers, 10·83; scraping-cylinders, 520; blower cylinders, 520; travelling webs, feed and outlet, 21·67 ft. a minute. Weight of machine, 30 cwt. The machine competed for the Indian Government prize in 1872; as an encouragement to others, it received an award of 1500*l*., though it did not fulfil the necessary conditions. It did not succeed in turning out the fibre, clean and fit for market, in one operation, and required the assistance of an ordinary scutcher. The action of the scutcher was considered too violent, and it broke up and injured the fibre to a great extent. The fluted rollers worked well in breaking the stems without injuring the

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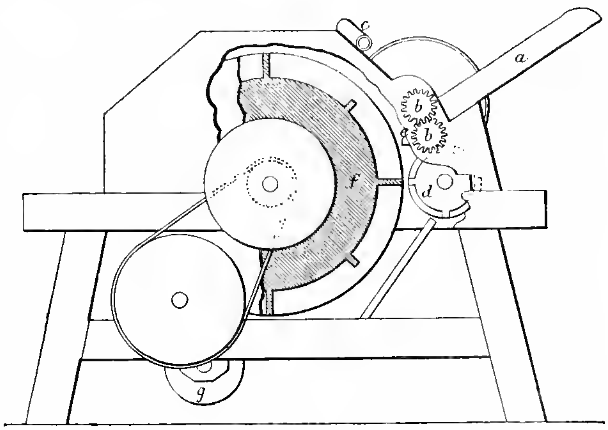

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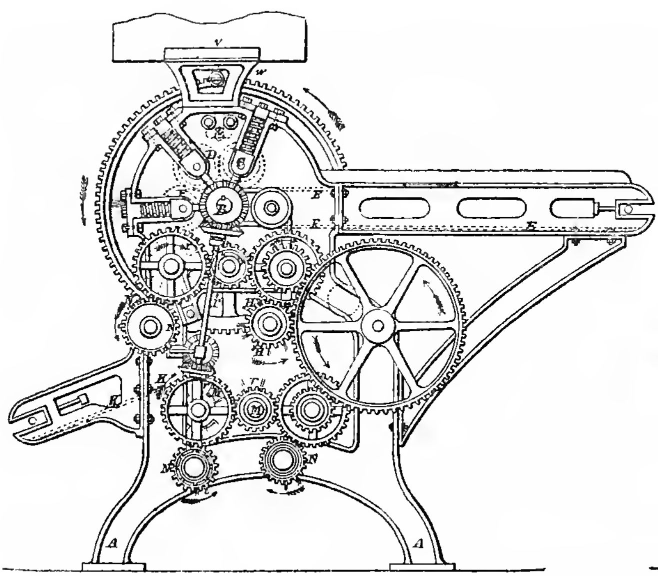

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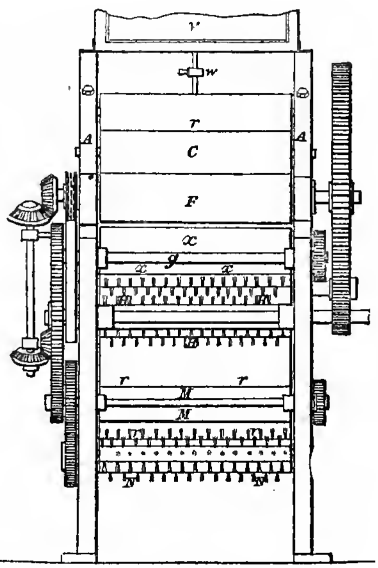

fibre; but the action of the scrapers was defective, especially when water was deficient. More than 40 gal. an hour were found necessary. The cost of preparation amounted to 35*l*. a ton, instead of 15*l*.; and the resultiog fibre, fit only for cordage purposes, was valued at 28*l*. a ton, instead of 50*l*.

Roessel's (of America) machine is simply an iron drum, with knives and breaking-bars arranged on its surface. The stems are delivered by hand against the drum, which moves at about 100 rev. a minute. The bars break the woody stems into short pieces, which fall out below; the knives separate the fibre into shreds. The latter operation is effectual, the out-turn is good, and there is no waste of fibre; but the work is done dry, and the fibre is not cleansed from bark. The umpire of the trials at Saharunpore, in 1872, was of opinion that this machine, if furnished with crushing-rollers in place of the breaking-bars, and if driven at less speed, might be supplied with water to remove the broken wood and bark from the fibre, and thus be made efficient.

Roland's machine, designed to convert the dried stems into raw fibre, is made in several sizes. The largest, driven by steam power, is shown in plan and longitudinal section in Figs. 641 and 642:—*a* is a table, on which the stems are placed; *b*, feeding-rollers, grooved longitudinally; *c*, driving-shaft; *d*, feeding-cylinders, provided with rings or circular grooves of triangular form,

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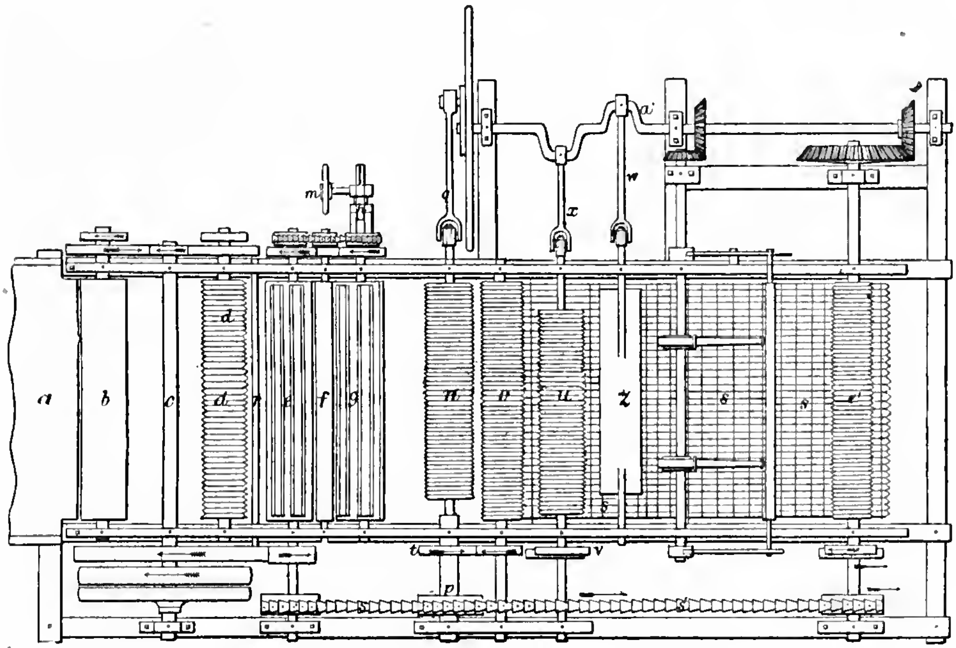

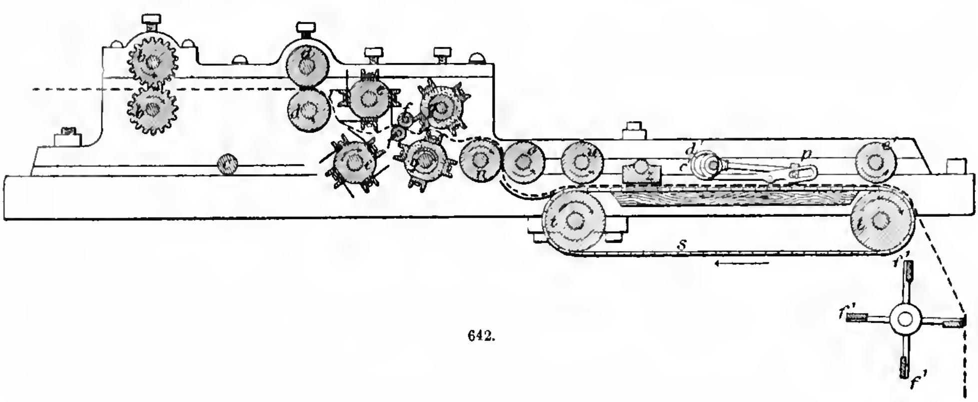

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perpendicular to the axis; these cylinders carry forward the stems, crushing, opening, and dividing them longitudinally, without damaging the fibres; *r*, beater placed direct at the back of the bottom cylinder *d*, consisting of a plate of iron as long as the cylinder, fixed upright, coated with indiarubber or leather, and having the effect of an anvil, on which the woody refuse of the stems is crushed and broken into fragments by means of the beaters; e, beating-cylinders provided with rakes, bars, or surfaces, arranged in pairs of U form, bolted to the shaft of the beater, and representing upright blades; the edges, being sharp, crush and crumble the refuse on the counter-beater, or on the cylinder provided with rings when the counter-beater is dispensed with. These beaters are provided with elastic blades, having the effect of springs, secured between the axis and the rakes or bars. Each blade forms an angle with the pair of rakes or bars under which the blades are fixed. The blades, made of steel, leather, or other elastic material, scrape and cleanse the bark of its epidermis, gum, and fragments of wood produced by the crushing of the stalks between the beating-cylinders. The beating-cylinders revolve at a greater speed than the feeding-cylinders, and, as they revolve, the rakes act against the spring-blades. The cleaning-cylinders *f*, coated with leather, or other suitable material, cleanse the beaters, and prevent the fibres from winding around them; *g*, scraping-cylinders or rollers, of similar construction to the beating-cylinders *e*, but not provided with elastic blades. The axes of the cylinders *g* are surrounded with a thick coating of leather, on which are fixed rakes, similar to those of the beaters, but having sharper edges. During the working, these rakes rub in pairs, in such manner that their sharp edges press on the coating of the axis. Clutch-boxes *h* are mounted on the axes of the scraping-cylinders *g*, in order to cause the latter to revolve in the direction of the beating-cylinders *e* or in an opposite direction. This is effected by winding a chain *l* on the toothed pinions *i j*. The latter are alternately fixed and loose, so that when *j* is thrown into gear, *i* runs loose, and the cylinders revolve in the same direction as the beaters; when *i* is thrown into gear, *j* runs loose, and the cylinders revolve in opposite directions to the beating-cylinders.

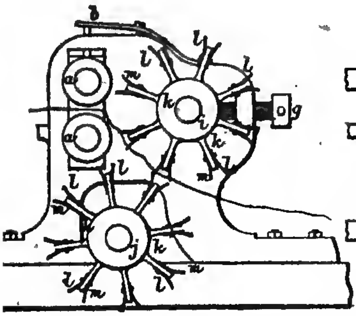
The direction of the scrapers is reversed by means of the double-ended lever and hand-wheel *m*, fixed on the axis of the clutch box *h*; *n o* reciprocating friction-cylinders, having rings or circular grooves perpendicular to the axis, or in a spiral line. The cylinder *n* has a double rotating movement and a lateral to-and-fro movement. The rotating movement is imparted by a toothed wheel *p*; and the to-and-fro lateral movement, by a connecting-rod *q* and an eccentric *r*; the endless table or apron *s*, grooved perpendicular to the axes, is composed of plates, joined together by hinges, the whole forming an endless chain, which revolves round the wheels or rollers *t*; *u*, friction-cylinder, fixed crossways above the endless table *s*, and having a double rotating movement and a lateral to-and-fro movement. The rotating movement is imparted by means of a toothed wheel *v*; and the lateral to-and-fro movement, by means of a connecting-rod *x*; *z*, cross friction-plate, grooved transversely, receiving a lateral to-and-fro movement by means of a connecting-rod *w* and shaft *a'*. The cylinder *u* and friction-plate *z* press and rub on the table *s* and come into contact with it by means of springs (not shown), which press them according to the thickness of the stems operated upon. The cylinder *e'* is provided with rings; its grooves gear with the grooves of the endless table *s* on which it rests. Having only one movement of rotation, it draws the fibre forward, and brings it under the influence of the fan *f'*, by which it is freed from wood, dirt, and any refuse which may still remain in it. The principal parts of the machine are driven by toothed gearing and endless chains *s'*. The friction-roller and friction-plate may be replaced by an endless grooved table, as stated above. This table will have a rotating motion and at the same time a to-and-fro movement. In that case the friction-roller will operate between two grooved endless tables.

The machine acts as follows:—The stems to be operated upon are placed on the table, and the top ends are first put between the grooved feeding-rollers, and thus crushed and divided longitudinally. As the stems pass between the grooved or fluted cylinders, they travel on to the counter-beater, where they are submitted to the action of the rakes of the top beater, which crushes the wood into fragments. The leaves, straw, and refuse become engaged between the two beaters; these, by means of their reciprocal gearing, and the combined action of the rakes and spring-blades, detach the fragments of wood, refuse of epidermis, and gummy matter, from the fibres. The stems, already in a fibrous state, still pass between the coated decorticating-cylinders. Travelling onward, between the scraping-cylinders, they are scraped above and below lengthwise; and passing between the friction-cylinders, and across the friction-plate and endless grooved table, they are cleansed, completely softened, and brought into a state ready for combing. Finally they are passed through a cylinder, and then fanned. The machine requires 1 H.-P., and turns out 500–600 lb. clean fibre daily.

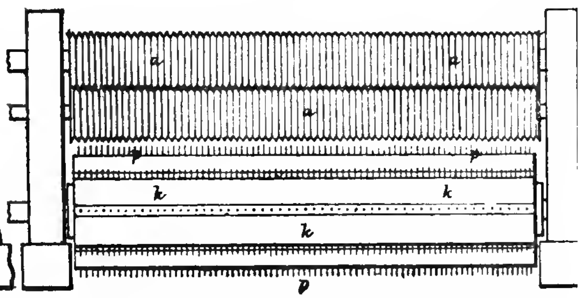
Figs. 643 and 644 show plan and longitudinal section of a Roland machine adapted to hand-power, and suited to operations on a small scale, the dried stems being dressed on the field. The stems are introduced between the fluted iron crushing-cylinders *a*, adjusted by springs *b* to suit the thickness of the stems. These cylinders *a* are provided with triangular rings of varying depth, and are put in motion by means of cog-wheels. From *a*, the stems pass between the wooden beating-rollers *ij*, provided with pointed iron bars *k*, to each of which are affixed two blades *l m*; blades *l*, being of iron or wood, are inflexible, and break the stems against the cylinders *a*; while blades *m*, of indiarubber covered with steel, or of steel alone, are flexible and elastic, and act as scrapers for the removal of the epidermis and woody refuse. The beating-rollers revolve 3–5 times faster than the crushing-cylinders, and may be adjusted by the set-screw *g*. Each rake of the beating-rollers carries a comb *p*, to assist in removing the fragments of refuse from the fibre. This machine is capable of turning out 150 lb. clean fibre daily.

Moerman-Laubuhr's system of retting, breaking, and cleaning has attracted some notice on the Continent. The cut plants are laid in retting-pits, measuring 2 cub. yd. in contents, and lined with cement; here they are kept down by pieces of timber, held by cramps at each end. With the object of hastening the operation, to every 1000 lb. of stems, are added 5 lb. flowers of sulphur, 5 lb. pounded and sifted coal, and 5 lb. ground chalk, carbonate of soda or potash, or clay. At the end of 5–6 days, the retting is finished; the bundles of stems are then taken out, partially opened, and set up in conical stacks to dry; when dry, they may be stored for any time, without injury.

643.

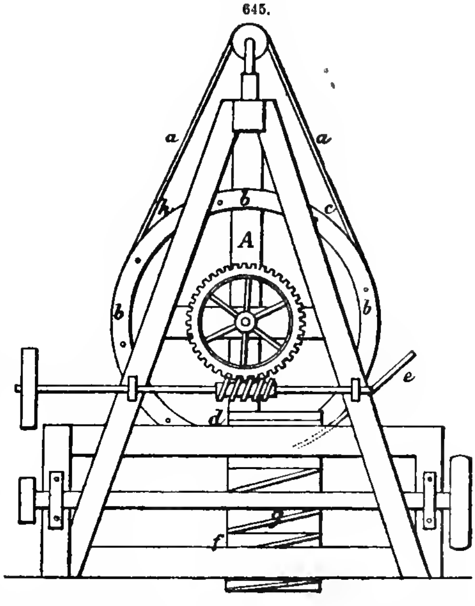


644.



The breaking and cleaning of the fibre are performed by three distinct apparatus. The first is a powerful crusher, with four pairs of heavy iron rollers; the second has two pairs of heavy fluted cylinders, to which a differential movement is given, thus breaking up the woody matter previously flattened and split by the crusher into atoms, three-fourths of which fall out below the cylinders. The third apparatus is a vat, 8 ft. in diameter, and more than 3 ft. deep. In the centre, revolves a vertical iron axis, supported by steel collars, and carrying 14 strong iron arms or beaters; these are driven at high speed, and strike with great force upon the fibre, which, in a partially charred state, is introduced by handfuls, through six slits or indentations in the side of the vat. The woody matter is thus effectually removed, while the suppleness of the fibre is increased, and no harm is done to it. A ventilating fan, fixed above, carries away all the dust. The complete apparatus is capable of dealing with 1–2 tons of stems daily, yielding 400–800 lb. of fibre ready for spinning.

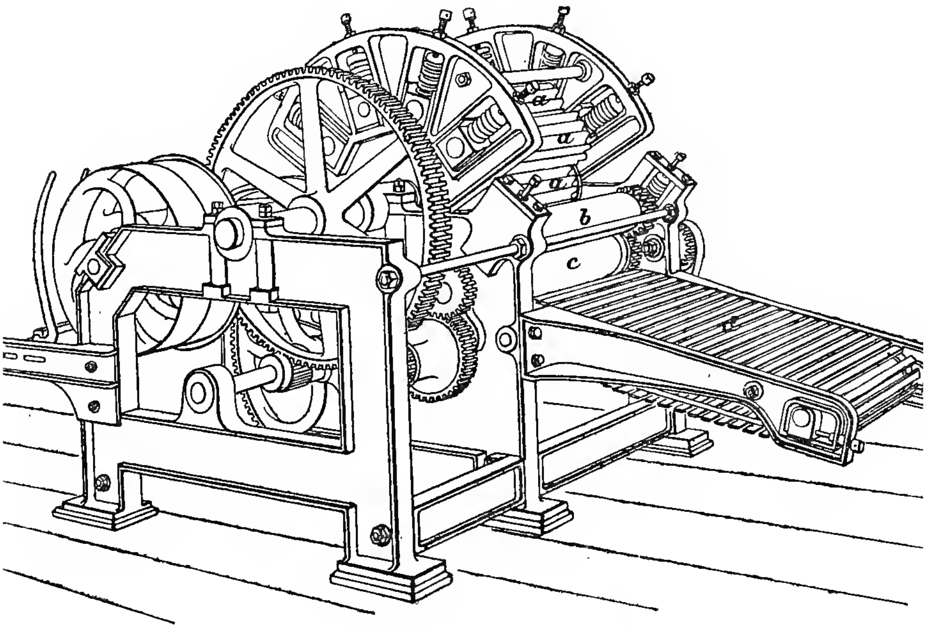
645.



Laberie and Berthet's machine for decorticating the green stems of *Bœhmeria* is shown in Fig. 645. The machine being set in motion, a workman takes the stems in both hands, and introduces them, top downwards, into the angle formed by the cord *a*, and the grooved wheel *b*, at the point *c*, where they are held by the cord. The stems, whose tops are brought to the concave cylinder *d*, by the iron rod *e*, are carried between the cylinder *f* armed with knives *g*, and that part of the cylinder *d* touching the knives *g*. The stems are here deprived of all the woody matter which is mingled with the fibres, and arrive cleansed at *h*, where the cord leaves the wheel. At the extreme end of the stems, there is always a non-decorticated patch, corresponding to the point at which they are held by the cord; this is usually cut off, or it may be passed again through the machine. Several of these machines are already being used in Algeria. Each machine is capable of decorticating 75,000–80,000 stems per diem. Before feeding the machine, it must be worked empty for some time, to bring the cylinders to the right adjustment for the reciprocal action of the knives. If the latter are too sharp, they must be rubbed down with a brick. The cord must always be kept strained tight.

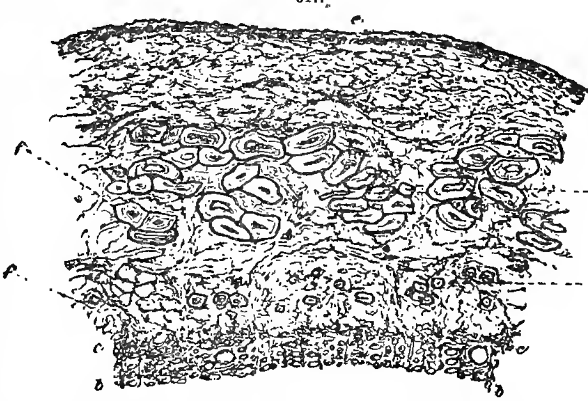
Dr. Collyer's new machine, as made by Sam. Lawson and Sons, Hope Foundry, Leeds, is shown in Fig. 646. It should be studied in comparison with the various forms of breaking-machine, illustrated further on in this article, under *Linum usitatissimum* (Flax). The four fluted rollers are in a rocking-frame, and oscillate over the cylinder, which has a constant slow movement forward, to determine the rate of delivery. The machine is powerful, and is reputed to be capable of dealing with 1 ton of green stems an hour, yielding 6½ per cent. of clean fibre.

646.



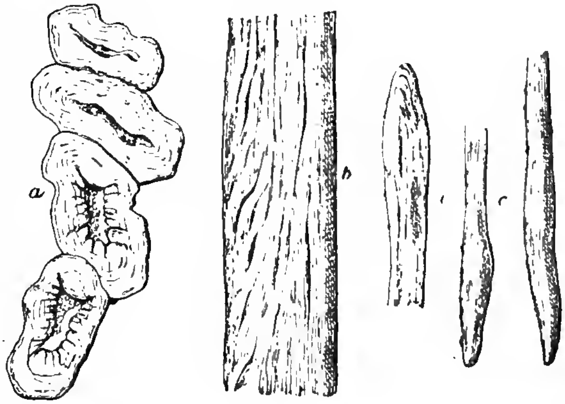
Characters and Uses of the Fibre.—The stems of the different varieties of the plant have the same outward appearance; their diameter varies from 0·39 in. to 0·78 in., they are covered with a brown epidermis, are very light, and contain a large proportion of pith. A section of the bark of the stem, magnified 100-fold, is seen in Fig. 647. The bark is relatively thin, and seems to consist of three layers:—The first includes the epidermis *e*, and a thin line of brown matter, representing the chlorophyl of the fresh plant; next comes a thicker layer, almost entirely composed of bast fibres *f*, associated in little independent groups; the third layer, resting on the cambium *c*, consists of parenchyma, often coloured brown, in which appears a second series of bast fibres *f*; the cells of this layer contain an abundance of crystals; *b*, woody fibre. The bast fibres are coloured blue by test H, the larger ones, in the second layer, exhibiting a bright yellow tint in the centre. The shape of the latter is well shown in the illustration.

647.



The length of the fibres varies from 2·36 in. to 7·87 in., and even 9·84 in.; the mean diameter is about 0·002 in., sometimes reaching 0·0028-0·0032 in. Examined under test F, they reveal very irregular forms and dimensions. One portion of a cell may be solid, smooth, or finely striated, showing an internal channel, empty, or partially filled with granulated matter; further on, the fibre enlarges, the walls appear thin, and the channel very large; elsewhere again, it occurs as a mere ribbon, flattened and very wide. The texture is fibrous, and the fibrils composing the walls have a very evident spiral disposition. Fig. 648 represents the appearance of the fibres, magnified 300-fold:—*a*, section of a bundle of fibres; *b*, a fibre seen longitudinally; *c*, ends. Examined under tests C D F, the fibres are coloured blue or violet, and appear clean and isolated. Some are solid, and their internal canal is filled with a granulated substance, coloured yellowish-brown. Others are wider, with relatively thin sides, the interior partially occupied by the granulated matter. Nearly all are covered with fine striations, disposed parallel to the axis, or spirally. On many fibres, are fine transverse lines of deeper colour, crossing each other in various directions, and giving a sort of marbled appearance.

648.



The inherent physical properties of the fibre place it in a pre-eminent position. In strength, it is second to no vegetable fibre, and in some trials it has proved to be more than twice as strong as Russian hemp (*Cannabis sativa*). It also presents unusual resistance to the effects of moisture and other climatic conditions, to judge by the slight action of high-pressure steam upon it. Samples of the fibre, exposed for 2 hours to steam at about 2 atmos. pressure, boiled in water for 3 hours, and again steamed for 4 hours, lost only 0·89–1·51 per cent.; while flax lost 3·50 per cent.; Manilla hemp, 6·07; New Zealand flax, 6·14; hemp, 6·18–8·44; and jute, 21·39 per cent. At the same time, the fineness of the fibre places it ordinarily before flax, though, according to the method of cultivation, it varies from an extreme degree of attenuation, equalled only by the pine-apple fibre. While in strength, resistance, and fineness, it equals or surpasses the best-known fibres, it possesses a silky lustre, shared only by jute, which is by far its inferior in strength and durability. On the other hand, must be mentioned the peculiar hairiness of the fibre, which, while enabling it to combine readily with wool, renders it difficult to spin, on account of its stiffness and brittleness interfering with the twist, and rendering the yarn rough, despite the silky smoothness of the individual filaments.

The combination of qualities exhibited by the fibre endow it with affinities to other fibres, both animal and vegetable, which favour a wide range of application. During the cotton famine, it was tried as a substitute, or for mixing purposes, being first cut into lengths of 2 in., and treated with alkalies and oil. Fabrics made with equal proportions of the fibre and Egyptian and Indian cotton gained in strength and gloss, and offered no difficulty in spinning and weaving; they also took dyes as well as Egyptian and American cotton, and better than Indian cotton, a little modification of the mordant, and of the strength of the vat, being necessary with a few colours. Such an application, however, permits no advantage to be taken of the prominent qualities of the fibre—length, strength, and lustre. Moreover, the relative prices of the two fibres now scarcely admit of such an admixture, especially when taking into consideration the cost of the treatment of the *Bœhmeria* fibre, and the loss of 25 per cent. by weight which occurs.

As a rival to the finest varieties of flax, it has perhaps a better prospect. Technical difficulties, however, arise in spinning the fibre on flax machinery, and owing to the stiffness of the fibre, the yarn produced is often very rough. A number of processes have been devised and patented, by J. H. Dickson (Godalming), Marshall (Leeds), Moerman (Ghent), Bonsor (Wakefield), for working up the fibre on flax machinery; but the real conditions of success, where it is attained, are kept jealously secret. In comparing the two fibres, account must be taken, not only of their relative market values, but also of the fact that the commercial *Bœhmeria* fibre still contains much of its natural gum, involving the cost of labour and chemicals for its removal, and consequent loss in weight, before it is ready for combing and spinning (see Linen Manufactures). The loss in weight amounts to 23–38 per cent., generally 30–34 per cent., so that the price of the available fibre is increased by 33–50 per cent., without including the cost of treatment. With the finest descriptions of flax, it might compete in price, but the demand for such is limited; that it will ever supplant ordinary flax, appears doubtful.

The hairy nature and length of the fibre point it out as likely to compete successfully with wool, especially long-shaped kinds, the market values of which are very high in comparison. Several manufacturers, e.g. Lister, Sangster, Wade and Sons, Whitaker (Bradford), China Grass Co. (Wakefield), have energetically followed up this promising outlet, though not always with success. The fibre is subjected to a chemical treatment, which causes the cells to separate, the longest varying from 4–9 in. The loss by chemical treatment generally amounts to $\frac{1}{3}$ the weight of the imported fibre; combing leaves about equal proportions of long fibre, and tow or "noils." Thus prepared, the fibre has been spun on worsted machinery (see Woollen Manufactures), and used like mohair, for glossy goods; as a rule, the warp was cotton, and the weft was *Bœhmeria* yarn of comparatively little twist. The success of the experiment was foiled by the ease with which the fabric took and retained creases; this evil has since been remedied by using very thick cotton warps, or by mixing with wool. A new effect in woollen goods is now obtained by mixing 10–20 per cent. of *Bœhmeria* fibre with 90–80 per cent. of wool, combining before spinning, say on the carding-engine or willow, and taking the former a little longer than the latter. The yarn is used for both warp and weft; the wool employed may be either carded or combed; and the cloth can be raised, milled, and woven, as usual. In dyeing the fabric, the advantage arises that the two fibres do not take the same dye. Moreover, the noils has been found very suitable for admixture with coarse wools, for blankets, shoddy, and other rough purposes.

Many experiments have been made in applying the fibre as a substitute for, or in admixture with, silk; but the cost of the fibre, and the difficulties encountered in its preparation, preclude it from competition with jute for this purpose. At the same time, it must be remembered that the study of the industrial applications of this beautiful fibre is yet in its infancy, and the inherent virtues of the fibre must ensure its extended use in textile fabrics, when the cultivation of the plant, and the extraction and preparation of the fibre, have received higher development. Even now, new uses are cropping up: Baker, Hill, and Sons (Nottingham) are employing it extensively for ladies' scarves; and the Yorkshire Fibre Co. (Wakefield) are converting it into handkerchiefs, umbrella and parasol covers, &c. The combined strength and lightness of the fibre, and its great durability, and resistance to water, favour its application to the manufacture of ropes, cordage, and nets. In all respects save price, it is much superior to ordinary hemp, and, even in the matter of price, it does not compare so very unfavourably, as the cost and loss in preparing hemp is very considerable. Its competitors on this ground will probably be Manilla hemp (*Musa textilis*), *Phormium tenax*, and the Agaves. For canvas and sailcloth, its superiority over flax seems undoubted. To the paper-maker, its price is prohibitive; but an admixture of a proportion of noils will impart strength and cohesion to very inferior materials. The average weight sustained by slips of sized paper, each weighing 39 gr., made of this fibre, was 60 lb., as against Bank of England note pulp, 47 lb., and "raw" *Agave americana* fibre, 89 lb.

The market values and supplies of this fibre have hitherto been subject to the greatest fluctuation. The former will depend upon the degrees of success with which the fibre may be made to replace others, as already indicated; and an important condition necessary to the welfare of the industry will be the possibility of obtaining constant supplies, of uniform quality or qualities, and at a figure not exceeding 40*l*. a ton.

B. frutescens [Maoutia puya] Pooa.—Flourishes in the north of India, at elevations up to 4000 ft. It is taller than the preceding, and furnishes a similar fibre. Another nettle, called *Villebrunia integrifolia*, is found in the Himálayas up to 5000 ft., and in Sikkim at elevations where the rainfall is 100–200 in. yearly. The plant is a small tree. The fibre is more easily separated than that of the preceding, and is considered one of the strongest in India. These, and some other species, have been selected as eligible for culture in Victoria, especially in moist forest tracks. Much remains yet to be done in identifying the various *Bœhmerias*, which cover a very wide range, and in deciding which species or varieties will yield the most and best fibre adapted to Western wants. Some allied plants are discussed further on in this article (see *Laportea pustulata; Urtica sp. div.*).

Bombax Ceiba—Silk-cotton.—A native of British Guiana, the W. Indies, and other portions of the western world. The seed capsules contain a silky down, used for stuffing purposes, and occasionally for making hats and bonnets.

B. malabaricum is indigenous to the E. Indies. The seed-down is locally used for stuffing purposes, and is suggested for conversion into paper, and for guncotton. Its elasticity and shortness of staple preclude its being spun on cotton machinery. It has, however, been successfully spun and woven; and has been felted for hat-making; but does not make a durable fabric. *B. villosum*: in Mexico; the purple down of this plant is spun and woven into cloth, which retains its natural colour. Other species are *B. hibiscifolium*, in Venezuela, *B. munguba*, *B. carolinum*, *B. pentandrum*, all affording cotton-like fibres.

Other silk-cottons are described under *Eriodendron*, *Chorisia*, and *Ochroma*.

Borassus flabelliformis—Palmyra palm.—Endogen; tree, 30–40 ft. Most extensively distributed throughout India, especially near the coasts; seems to thrive equally well in almost all soils and situations. The leaves of the tree have for ages been used as a local substitute for writing-paper. The petioles of the fronds yield a fibre about 2 ft. in length, strong and wiry; they are employed on the Madras side for making twine and small rope. In Bengal, they are scarcely used for any economic purpose, and the trees are there scattered too widely apart to enable the fibres to be collected at a low cost. Near the base of the leaves, occurs a fine down, used for straining liquids, and for staunching wounds.

Bromelia sp. div.—Endogen. The fibre yielded by the leaves of *B. Pigna* (*Pinguin*), a native of the Philippines, is woven into a most delicate textile fabric, known as "pigna cloth," from which the celebrated Manilla handkerchiefs are made. The cultivation of this plant offers great inducements. The same may be said also of *B. sagenaria*, known in Brazil as *Curratow*, or *Grawatha*.

Broussonetia papyrifera—Paper mulberry.—Exogen; tree. A native of the Pacific Islands, Burma, China, and Japan, perhaps only truly indigenous to the last-named. It has been recommended for culture in Victoria. It is a good coppicing plant, and may be propagated from cuttings. In Japan, it is very largely cultivated, after the manner adopted with osier beds.

A section of the bark is seen in Fig. 649; this shows two distinct layers of fibre: under the epidermis *e*, is a thick bed of parenchyma, full of green matter; then comes a stratum of coarse, solid fibres *f*, of very irregular form, sometimes having a large central channel, sometimes scarcely perceptible. These fibres are disposed in easily separated groups, divided by bands of parenchyma filled with chlorophyl. Within this belt, is a thin zone of parenchyma filled with green matter; then follow other groups of fibres *f*, smaller and less brilliant than the preceding. All the fibres are coloured blue by test H; *c* is the cambium; *b*, the woody fibre; mag., 100. The dimensions of the fibres are:—max. length, 0·984 in.; mean, 0·59 in.; mean diameter, 0·00075 in. In some of the Pacific Islands, this fibre is converted into fine white textile fabrics, which can be dressed with linseed oil, and then become quite waterproof. A more important use of the fibre is for paper-making, to which purpose it has been applied for ages past in Japan. With this object, the young shoots are cut down after the leaves have fallen, in December, and are boiled till the separation of the bark exposes the naked wood, from which latter the bark is easily removed by a longitudinal cut. The removed bark is dried, and soaked in water for a few hours, after which the outer cuticle and the internal green layer are scraped off; boiling in a lye of wood-ashes is continued till the fibres can be separated by a touch. The pulpy mass is then agitated in water, and beaten into a pulp, with a little mucilage from boiled rice. The paper produced is of excellent quality. The extensive cultivation of the plant in Burma is worthy of attention. Its leaves can be used as silk-worm food, and the bark of the shoots, which are periodically cut down to afford constant supplies of young leaves, produces very satisfactory half-stuff.

649.

The bark of *B. Kæmpferi* is also used for similar purposes in Japan.

Butea frondosa, and B. superba.—The bark and roots of both species yield a fibre which is locally used for cordage. The trees are, however, much more important as affording a valuable resin (see Resinous Substances—Butea kino). They also afford a dye (see Dye-stuffs—Kisso).

Calotropis gigantea—Yercum or Mudar.—Exogen; shrub, 6–10 ft. high. This plant is extremely common all over S. India, growing in waste places, and among rubbish and ruins, and often even encroaching upon cultivated ground, as a troublesome weed. It comes to maturity in a year, but is perennial, and, when once planted or sown, requires no further care. It thrives on soils where nothing else will grow, and needs neither culture nor water; hence it is admirably adapted for bringing waste land under tillage, and for protecting reclaimed desert from drifting sands. These reasons alone should suffice to encourage the cultivation of the plant, apart from its value as a fibre-producer. Its great abundance, in a wild state, may render cultivation unnecessary for a time. It is stated that an acre stocked with plants 4 ft. apart each way, will yield 10 tons of green stems, or 582 lb. of fibre, as prepared by the present native process, which wastes 25 per cent.; the cost of cultivation of the same area is placed at 2*l.* 9*s.* 8*d.*, after which, the only recurring expenditure would be for harvesting the plant. When raised from seed, it is said by some to require two years before being ready for cutting; but if cut close to the ground, it grows again rapidly, yielding a second crop within 12 months from the first.

The fibres afforded by the plant are of two distinct kinds:—(1) The seeds are coated with silky hairs, forming one of the so-called "vegetable silks," used occasionally for stuffing purposes, and said to be sometimes woven into shawls and handkerchiefs, and to form good paper-stock; (2) the stems contain a bast fibre, of great industrial value. The following remarks refer only to the latter. The native method of extracting the fibre is as follows:—The straightest branches, 12–18 in. long, are cut, and allowed to wither for at least 24 hours; after 2–3 days, the dried stems are gently beaten, especially at the joints, which permits the bark, and the fibre attached, to be peeled off, without breaking. The bark is then bitten through in the centre, and the fibre is drawn away from it, and dried in the sun. The process is necessarily very expensive, the cost of the fibre being estimated at 65*l.* a ton. Retting, it seems, cannot be adopted, as the fibre is discoloured and injured by it, owing to the solution of an acrid juice contained in the plant. The lack of a cheap, efficient machine for extracting the fibre appears to be the only obstacle to its extended use; yet little seems to have been done in the way of trying existing machines, or inventing new ones. Mr. Strettell's observations on this head are disappointingly meagre; his idea, that the machine used for dressing dry agave fibre (see p. 913–6) might be suitable, appears reasonable.

The fibre is said to possess many of the qualities of flax (*Linum usitatissimum*), though it is somewhat finer. Its fineness, tenacity, lustre, and softness, fit it for many industrial purposes. In Madras, the natives select it as the strongest material for bowstrings, gins, and tiger-traps; nevertheless, it is said to be better adapted for textiles than for cordage, and that it may readily be mixed with silk. Yet it shows a high degree of resistance to moisture; samples, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost only 5·47 per cent. by weight, as compared with flax, 3·50; Manilla hemp, 6·07; hemp, 6·18–8·44; coir, 8·13. The strength of the fibre is also considerable; according to Dr. Wight, it is the strongest fibre of the Madras side of India, bearing 552 lb., as compared with the next strongest, Sunn hemp (*Crotalaria juncea*), 407 lb.; and in Dr. Royle's experiments, it sustained 190 lb., as against Russian hemp, 160 lb. It can be spun into the finest thread, and has been pronounced equal to good flax, for making prime yarns. It is also said to possess all the qualities requisite to produce a compact felted first-class paper.

C. [procera] Hamiltonii—Ak.—This species replaces the foregoing in all the northern parts of India, and extends even to Persia and Syria. In N. India, it is quite as abundant as is *C. gigantea* in S. India, and the remarks upon the cultivation and utilization of the latter apply with equal propriety.

Both species yield a valuable viscid juice (see Resinous Substances).

Camelina sativa.—Exogen; annual herb. Cultivated in Middle and S. Europe, and in Temperate Asia, for its fibre, but especially for its oil (see Oils).

Cannabis sativa—Hemp (Fr. *Chanvre*; Ger. *Hanf*).—Exogen; annual, 4–6 ft. high. This plant is a native of Central and W. Asia, and is now found, either indigenous or naturalized, in almost all temperate and tropical countries. In Japan, it attains a height of 6 ft. and upwards; and it flourishes in N. and W. China. It is cultivated all over India, and attains a height of 10–12 ft. in the Himálayas, where it thrives best at 4000–7000 ft., but reaches even to 10,000 ft. It grows wild luxuriantly on the banks of the Lower Ural and the Volga, as well as all around the Caspian, and throughout Russia and Siberia, extending thence into the Altai range and Kashmir, and into Persia and the Caucasus; considerable quantities also are produced on the coast districts of the Black Sea, between Atino and Perchembé, particularly those of Oonié and Thermé. In continental Europe, the cultivation is carried on chiefly in Central and S. Russia, Hungary, Germany, France, and Italy; the last named produces the finest and best of all. In Tropical Africa, it is found on both the eastern and the western coasts, as well as in the interior districts watered by the Congo and Zambesi. In Natal, a hybrid has been produced between the native plant, found growing luxuriantly around the Kaffir kraals, and seed sent from Kew; the stems would doubtless yield good fibre, if the trouble were taken to extract it. The plant has also been naturalized in Brazil, to the north of Rio Janeiro; in Canada, in Venezuela, and in Victoria. The wide distribution of the plant is easily explained by the fact that it requires only a few months of summer temperature to bring it to perfection. In the East, it is grown by the natives chiefly, if not entirely, for the sake of the intoxicating properties of its products, *bhang*, *ganja*, and *churras*; these will be described under Narcotics. In Europe, it is grown for the valuable fibre yielded by the stems. The seeds of the plant also afford an oil (see Oils—Hempseed).

Cultivation.—The cultivation of hemp as a fibrous plant may be discussed under the following heads:—

Soil.—The best is a rich moist soil, 5–6 in. deep; alluvial lands, where sand and clay are intimately mixed, or friable loams, containing much vegetable matter, are well suited. Stiff, cold clays are to be avoided. Over-rich soils produce coarse but strong fibre; light, poor soils, when well manured, will bear the crop for several years in succession. The finest quality of fibre is obtained on soils of medium richness. The best hemp in the world is grown in the Romagna, of Italy, on rich, strong loams, made fine and friable, and well manured. Similarly, the plant thrives well in Lincolnshire, and in Holland. The chief producing districts of Russia, are Orel, Konrsk, Smolensk, and some of the neighbouring governments; the Polish provinces also contribute largely. The plains of Hungary seem peculiarly adapted to the crop. In India, the greatest success is obtained in the valleys and lower hills of the Himálayas, particularly on the Ghurwal and the Kumaon ranges; in Bengal, the plant is everywhere grown for its narcotic products, the fibre of the stem being discarded. The method of cultivation here pursued, however, renders the fibre worthless; and it is doubtful whether the plant can ever be economically raised as a fibre-producer in the plains of India.

Tillage and manure.—The land must, of course, be well ploughed and drained, harrowed and rolled, and cleansed from all weeds. The quantity of manure necessary will depend on the richness and warmth of the soil, and upon the climate. In England, 10–25 tons rotten dung to the acre is not considered too much; warm, moist climates require much less. The ash of the plant contains 42·05 per cent. of lime, 7·48 of potash, and 3·22 of phosphoric acid. Provided that abundance of chalk, gypsum, or gas-lime, be supplied, the crop should be much less exhausting than flax.

Seed.—That from Holland is most esteemed; it ripens soon, and yields abundant and fine crops. Well-grown English seed is, perhaps, equal to it. Seed from the plains of India, though of good outward appearance, yields poor fibre for the first crop or two; but Himálayan seed is inferior to none. Constant changes of seed are always beneficial. The seeds should be plump, and of bright-grey colour; they must not have been heated in any way, and should therefore have a sweet flavour. The quantity required may be 2–2½ or even 3 bush. an acre; the thicker the growth on suitable land, the finer the resulting fibre. Sowing takes place in May–June; frosts injure the young plant, but late sowing conduces to thinness and weakness. Sowing in drills produces coarse, strong fibre, fit for cordage; broadcast sowing is preferred when the fibre is to be used for textile purposes.

Culture.—As soon as the young plants appear, the ground is thoroughly weeded, and the plants are thinned out, according to the class of fibre required, and the capability of the ground. A second weeding is sometimes needed, but generally the plants grow so rapidly as to keep down weeds. Abundant moisture is requisite during growth, hence irrigation is practised in some localities.

Harvesting.—As the fibre afforded by the male plants is tougher and better than that yielded by the females, it is usual to divide the harvest. The males are gathered as soon as they have shed their pollen, about 13 weeks after the sowing; they are then recognized by their leaves being yellow, stems whitish, and flowers faded. Each is uprooted singly, care being taken not to injure the stem. The ripening of the females, which occurs about a month later, is indicated by similar signs, as well as by the grey tint of the seeds, and the opening of the capsules. If the plants are left for the seed to ripen thoroughly, the fibre becomes coarse and woody, and difficult of extraction; hence the full maturity of the seed should not be awaited. Plants which are to give sowing seed must have room to spread, and be left to ripen their seed. When it is not intended to preserve the seed (for the sake of its oil), and when the fibre alone is utilized, the plants may be pulled while in flower, and without any regard to sex. Under these circumstances, mowing would be a much more rapid method of harvesting the crop; yet a prize for a hemp-mowing machine, offered some years since by the Hungarian Government, did not attract a single competitor. As soon as the plants are pulled, they are held by the root, and carefully shorn of leaves and flowers, which help to manure the land.

Stooking.—When the stems are stripped, they are bound in small bundles, and the now dry soil adhering to the roots is knocked off. The stalks forming each bundle should be as nearly as possible of equal length, and the roots should be placed even. The bundles are then set on end in stooks like corn. If the crop is to be kept long, the bundles are made of larger size, and are stacked and thatched.

The female plants, after gathering, are allowed to stand in the air for 8–10 days, to allow the seed to dry and ripen; the heads are then cut off, and the seed is threshed out. Bundles of seeded stems are best conveyed by a rope fastened round under the heads, and suspended over the shoulder. The seed remaining after threshing is combed out; but it is inferior, and unfit for sowing. The female plants are generally stacked during the winter, and not retted till the spring. The length of time for which the pulled plants should remain in stook to dry before retting is a much debated point. Some authorities declare that 1–2 days' sun-drying is essential; while others state that it is unnecessary, and that ripe plants should be retted the moment they are pulled, the retting being then reduced from 8 days to 4.

Extraction and Preparation of the Fibre.—The extraction and preparation of the fibres of the plant may be divided into the following heads:—

Retting.—The term "retting" is applied to a modified process of fermentation, or rotting, to which the stalks are subjected, with the object of loosening the fibres, and facilitating their abstraction from the bark. The process is adopted with several other exogenous fibres, notably flax (*Linum usitatissimum*), and will be minutely described under that head (see p. 967). Meantime, it may be said that there are three ways of retting hemp, (1) "water-retting" or "watering," (2) "dew-retting," and (3) "snow-retting."

(1) Watering or steeping is often conducted in mere ditches, 3–4 ft. deep, and of varying length and breadth, dug on the margins of rivers. The bundles of hemp are laid at the bottom, covered with straw or sods, and weighed down by logs and stones. Putrid standing water makes softer fibres than running water; but the former engenders a disagreeable colour, which, however, is destroyed by bleaching. In some districts, retting is carried on in basins at different altitudes, a small stream constantly trickling from one to another. This seems to be the most satisfactory plan. The degree of retting greatly influences the strength and suppleness of the fibre; hence that intended for making fine textiles should be retted more than that for coarser goods, while fibre for cordage purposes should be retted least of all. The progress of the operation is readily ascertained, by taking out a stem by the root end, and drawing the thumb-nail along it to the top; when the fibre slips up the stem, the process has been carried sufficiently far.

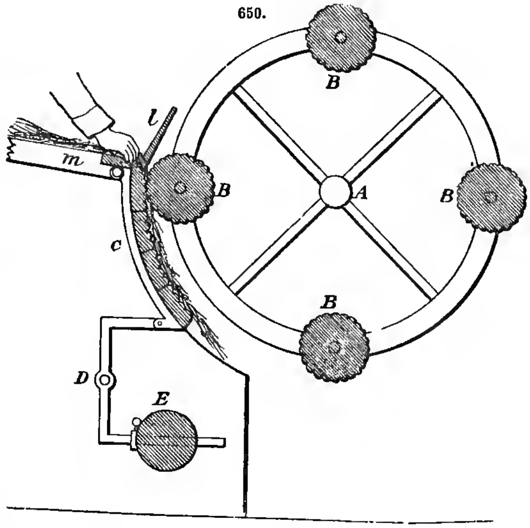
(2) Dew-retting is thus conducted. The pulled stems are allowed to stand in the stooks for 3–3 days, and are then spread out carefully on the grass. Here they are subjected to the effect of showers and dews, and an occasional watering if necessary, for a period which may extend to 6 weeks, care being taken to turn them constantly during the whole time. The appearance of pink spots on the stems must be watched for, whereupon the stems are gathered up, tied in bundles, and piled in stooks, to dry. By this method, the most valuable white hemp is produced; but the operation is very tedious, and entails great expenditure for labour.

(3) Snow-retting is sometimes practised in Russia and Sweden. After the first snow-fall, the dried hemp-stems are spread out, and left to be covered by subsequent falls, till the spring, when they are generally found to be sufficiently retted.

Grassing and Drying.—After water-retting, the hemp is removed from the water to a field of grass which is clean and unused by cattle. Here it is spread out evenly, and allowed to lie for 3 weeks or more, to bleach, and to enable the fibre to free itself; during this time, it is turned over, with long light poles, every 3–4 days. The process is considered complete when pink spots commence to appear on the stems. Drying is sometimes effected by exposure on walls or rocky ground, sometimes artificially in ovens. When dry, the stems are again tied up in bundles, and carried to a barn or rick.

Breaking and Scutching.—So close a resemblance exists between hemp and flax stems, that the machinery devised for the treatment of the latter is equally applicable to the former, always allowing sufficient strength to overcome the superior toughness of the hemp stems. Flax being of greater importance than hemp in our manufactures, breaking and scutching-machines suitable to both are described under the head of the former (see p. 969). A peculiar hemp-breaker, devised by G. M. Mure, of Turin, is shown in Fig. 650. Between two rims carried by the shaft A, are 4 grooved rotating rollers B; behind the table *m*, are placed a number of grooved boards or plates, loosely connected with each other, and made to follow the periphery of the arc C. While putting stems upon the feeding-board, the hand is protected by the grating *l*. The stems pass along the arc C, and are pressed against the grooves of the latter by the rollers B, through the rotation of A. A counter pressure by C against the beater B is produced by the lever D and weight E.

650.



Characters and Uses of the Fibre.—A section of a portion of the stem of the hemp plant, magnified 100 times, is shown in Fig. 651: *a* is the cortical portion; *b*, the ligneous; *e*, the epidermis; *f*, the bast fibres, which are divided into two zones, z^1 z^2. The fibres of the first zone are solid and polygonal, and bear some analogy to those of flax; those of the second zone are rounded, but irregular, contorted, and encroaching upon each other. Their walls too are relatively thinner, and the internal cavity is very large. The differences are more clearly seen in Fig. 652, *a*, *a*¹. Under test H, the fibres z^1 z^2 exhibit the remarkable characteristic of assuming a full blue colour, surrounded by a distinct yellow margin.

651.

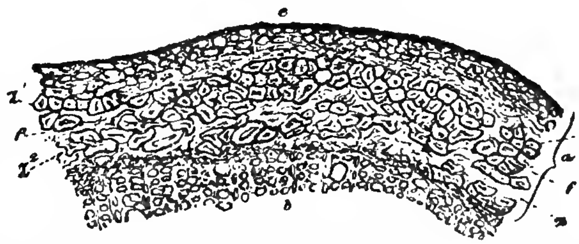
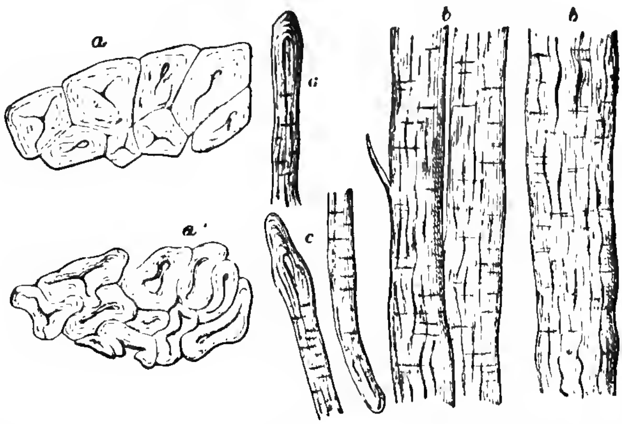


Fig. 652, mag. 300, represents the fibres: *a* *a*¹, sections of groups of fibres of the first and second zone respectively; *b*, fibres seen longitudinally; *c*, ends. Examined by test F, the fibrous bundles assume a blue or violet tint; often they approach a greenish hue, passing more or less to yellow at the edges. This last coloration arises from a yellow envelope, entirely covering the fibre, and disappearing only after complete bleaching. The isolated fibres are slightly transparent, and of very irregular diameter, even in short lengths; their surface is sometimes even and smooth, sometimes striated or corrugated longitudinally; they are often flat and ribbon-like. Numbers of nearly black, but extremely fine, transverse lines are visible; another peculiarity is an abundance of irregular fibrils, detached from the body of the fibre, after repeated friction. The dimensions of the fibres of hemp vary greatly; in the case of European hemp, the length may be set down at 0·196–2·165 in., mean, 0·866 in.; and the diameter at 0·00048–0·0015 in., mean, 0·00066 in. Hemp, as it occurs in the market, is longer, more rigid, and coarser than flax; it forms ribbons, more or less wide, and of varied colours—straw-tint, nearly white, green, brown, deep-grey, and nearly black, according to the manner in which it has been dressed and dried. Samples of the fibre, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost on the average as follows:—Italian hemp, 6·18 per cent.; Russian hemp, 8·44 per cent. Under similar conditions, flax lost 3·50; Manilla hemp, 6·07; Phormium, 6·14; coir, 8·13. Hemp is employed almost exclusively in the manufacture of ropes, twine, and nets (see Rope).

652.



Production, Exports, and Prices.—In the production of hemp for industrial purposes, Russia has undoubtedly the first place, her total annual yield of the fibre being estimated at 6 million poods (of 36 lb.). Italy has about 330,000 acres of land under hemp, producing 959,000 quintals (of 1·96 cwt.) of fibre. France produces annually about 600,000 quintals of fibre, from about 250,000 acres. Servia is recently reported to have 34,000 acres of land under hemp cultivation. The shipments of the fibre from Riga, the chief exporter of this staple, were:—in 1874, 20,108 tons; 1877, 18,155; 1878, 18,963. The German exports from Königsberg, in 1878, were 231,737 cwt.; 1879, 399,744 cwt. (including hemp yarn). British India exported 85,207 cwt., in 1877; and 55,312 cwt., in 1878. Samsoun, on the Black Sea, in 1878, exported 21,950 kilo., value 614*l.*, to France; and 12,000 kilo., value 240*l.*, to Turkey; in a good year, as much as 500,000 *okes* (of 2·83 lb.) are shipped. Considerable quantities of hemp are shipped from Chinese ports, chiefly for local consumption, though the length of staple of one of the varieties produced should make it valuable in European markets. The chief shipments were—from Amoy, 1818 *piculs* (of 133⅓ lb.) in 1877, 1694 in 1878; Hankow, 73,000 *piculs* in 1878; Kiukiang, 3,972,615 lb. in 1878; Kiungchow, 678 *piculs* in 1877, 214 in 1878. Our imports of the article, in 1878, were as follows:—(*a*) Dressed—from Italy, 24,786 cwt., value 61,914*l.*; France, 4004, 5006*l.*; other countries, 6120

10,553*l.*; (*b*) Undressed—Russia, 13,608 tons, 458,678*l.*; Italy, 10,141, 390,230*l.*; Germany, 7766, 257,448*l.*; (*c*) Tow or Codilla—Italy, 29,906 cwt., 41,556*l.*; Russia, 12,258, 16,139*l.*; Germany, 12,118, 14,310*l.* In 1879, the quantities were:—(*a*) Dressed—Italy, 18,710 cwt.; Russia, 10,663; Germany, 5579; other countries, 1110; (*b*) Undressed—Russia, 18,273 tons; Italy, 9331; Germany, 6217; British E. Indies, 1969; other countries, 1077; (*c*) Tow or Codilla—Russia, 26,087 cwt.; Germany, 25,589; Italy, 24,713; other countries, 2165.

Particular care must be taken to strip the fibre in fine dry weather; should it get wet, it is almost certain to heat, and become totally spoiled. As it arrives at the shipping port, it is assorted according to quality, and made up into bales. At Petersburg, the classification is—clean or firsts; outshot or seconds; half-cleaned or thirds; and codilla. At Riga—clean, outshot, and pass. More exactly, the labels are:—K S P, short black pass; L S P, long black pass; P P, Polish pass; P A, Polish outshot; P R, Polish clean; F P P, Polish fine pass; F P A, Polish fine outshot; F P R, Polish fine clean; S F P P, Polish superior fine pass; S F P A, Polish superior fine outshot; S F P R, Polish superior fine clean; M R, clean marine. The approximate relative prices in London markets are:—St. Petersburg—clean, 25*l.*–27*l.* a ton; outshot, 23*l.*–25*l.*; half-clean, 22*l.*–24*l.*; Polish, 26*l.*–33*l.*; E. Indian, 14*l.*–24*l.*

Carludovica palmata—Panama Screw-pine (C. Amer., *Jipijapa*, *Portorico*).—Endogen; leaves 6–14 ft. long. This plant is particularly common in Panama and Darien, especially in somewhat shady places; but its geographical range extends from 10° N. lat. to 2° S. lat., the grass being found all along the western shores of New Grenada and Ecuador, and even at Salango. From its unexpanded young leaves, are made the celebrated Panama hats, the plaiting of which can be conducted only at night or early morning, the leaves being rendered brittle by the heat of the day.

Caryota urens—Kittool, Indian gut.—Endogen; palm, 50–60 ft. This tree is a native of the jungles of Malabar, Bengal, Assam, Coromandel, Travancore, and Ceylon, and has been recommended for culture in Victoria. The leaves, measuring 18–20 ft. long, and 10–12 ft. wide, contain a quantity of fibre. This is strong and durable, and will resist the action of water for a long time; but it is liable to snap, if suddenly bent or knotted. In India, it is made into fishing-lines and bowstrings; and in Ceylon, into ropes for tying wild elephants. The woolly material found at the base of the leaves is used for caulking purposes. Since about 1860, it has been regularly shipped in increasing quantities from Colombo to this country, as a substitute for bristles in brush-making, to which purpose it seems well adapted, after being soaked in coconut- or rape-oil. It is prepared by the natives, in lengths of about 30 in., and is exported in small bundles of about 28 lb., packed in gunny-bags. The value of the article in London markets is about 3½*d.*–10*d.* a lb. Arthur Robottom, of 43, Mincing Lane, states that the true kittool comes only from Ceylon, and that parcels received from India are of inferior quality.

Cavanillesia platanifolia—Volandero.—Exogen. This plant is found abundantly in the eastern part of the State of Panama, and in New Carthagena. The inner bark affords a fibre, much resembling Cuba bast; it has been pointed out as a paper material, as it pulps well, bleaches readily, and makes a strong, white, opaque paper.

Celosia cristata.—Exogen; 6 ft. Common all over Bengal, and N. India generally. It yields a strong flexible fibre, so highly esteemed that rope made of it sells at 5 times the price of jute rope.

Celtis orientalis—Indian Nettle-tree.—Exogen; tree, 15 ft. It is common all over India. The nether bark consists of numerous reticulated fibres, which some of the tribes of Assam convert into coarse textile fabrics. *C. philippinensis*, in the Philippines, and *C. aspera* and *C. sinensis*, in Japan, also afford useful fibres.

Chamærops excelsa.—Endogen; palm. Common in Sindh, Afghanistan, and N. China, being largely cultivated in the province of Chekiang. The fibres of the leaves are locally used in the manufacture of matting and cordage, and occasionally for textile fabrics.

C. humilis—Palmetto (Fr., *Palmier de Nain*, *Crin végétal*).—Cultivated in some parts of S. Europe and N. Africa, notably by the French colonists in Algeria. The plant is particularly abundant in the Departments of Alger and Oran, especially in the dry portion of the alluvial plain of the littoral. It multiplies rapidly, and caused much trouble to agriculturists till its usefulness was recognized. The leaves furnish about 50 per cent. of fibre. A man can cut about 400 lb. of leaves per diem. The extraction of the fibre, which is a simple operation, requiring the most ordinary tools, is chiefly performed by women and children, a good day's work being 90–100 lb. of dry fibre. This is rough, coarse, woody, and brittle; yet it finds several applications. The "light" or "green" quality has been twisted or curled in its raw state; the "black" has been dyed with logwood and sulphate of iron. The fibre is consumed principally as a cheap substitute for hair, for upholstery purposes; with this object, it is largely exported to France, England, Germany, and the United States. Locally, it is occasionally applied to the manufacture of cordage. It has been tried, with rags and esparto, for paper-making; but it is reported as running a great deal to waste, and being expensive and troublesome to bleach. The exports, in 1872, were about 900 tons. The exports of "vegetable horsehair" from Algiers in 1877 were 9222 tons, and in 1878, 7678 tons; of palm-leaves, 400 tons in 1877, but only 1936 lb. in 1878.

China-grass—*See* **Bœhmeria nivea.**

Chlorogalum pomeridianum.—Endogen; 8 ft. Frequent on the mountains of California, and recommended for culture in Victoria. Its heavy bulb is covered with many coatings of fibres, which are employed for stuffing cushions, mattresses, &c.

Chorisia speciosa.—Found in Brazil and the W. Indies. The seed-down is used for stuffing purposes, and has been occasionally imported to this country, under the comprehensive term "silk-cotton" or "vegetable silk."

Cibotium Barometz—Pulu fibre.—Fern; 10–15 ft. Some uncertainty exists as to the species yielding Pulu fibre. It (or they) is a native of the Sandwich Islands and of the Indian Archipelago. It is found more or less on the five principal islands of the Sandwich group, but especially on Owyhee, in the districts of Hilo, Hamakua, and Puna. The plant grows on the high lands, commencing at an elevation of about 1000 ft., and extending upwards to about 4000 ft. The fibre, "vegetable silk" as it is called, is produced around the stalk, where the leaf or stem shoots out from the stock. Each plant yields only about 2–3 oz. of fibre, which occupies about 4 years in production. The gathering is a very slow and tedious operation. When picked, the fibre is wet, and has to be laid out on the rocks, or on mats, to dry. In favourable weather, this may be effected in a day or two; but in the habitat of the plant, rains prevail, so that the fibre is often brought in a wet state to market, even after several weeks' "drying." It is shipped closely packed in wool bales, principally to San Francisco, and, in a minor degree, to Australia and Vanconver's Island. The supplies are being exhausted. The application of the fibre is as a substitute for feathers and horsehair, for stuffing purposes. The exports from Honolulu in 1878 were 212,740 lb., of which, Australia and New Zealand took 181,070 lb., and the Pacific ports of the United States, 31,670 lb.

Cocos nucifera—Coconut fibre, Coir (Fr., *Cocotier;* Ger., *Cocosnuss, Kair*).—Endogen; tree, 60–90 ft. This palm is very widely distributed throughout the intertropical regions of both hemispheres, where the mean temperature is about 22° (72° F.). It is abundantly cultivated on the Malabar and Coromandel coasts of India, in Ceylon, and in all the islands of the E. Archipelago; also on the coasts of tropical E. and W. Africa; and in the W. Indies. It thrives best in low, sandy situations, within the influence of the sea-breeze, and never attains the same perfection when grown inland. This partiality for the sandy sea-shores, where no other plant will flourish, gives the tree an additional value.

Its cultivation is a very simple matter, the tree being prolific, and requiring little care or attention. The soil is cleared from weeds and undergrowth, and the thoroughly ripe nuts are placed in holes, and carelessly covered with earth. In 3–4 months, the nuts begin to germinate; if planted just before the rains, and not transplanted, the young plants will require no watering during the hot season. But after the first year, moisture must be supplied twice daily until the 4th–5th year, and the roots must be carefully protected from exposure to the air. According to the soil and situation, the trees begin to bear fruit at 5–8 years, and continue to the age of 70–80 years, being most productive between 25 and 30. The yield of nuts will vary from 30–50 to 80–100 per annum. The W. Indian plantations have recently been devastated by the attacks of a small beetle (*Passalus tridens*). A similar evil is reported from Zanzibar, in the shape of *Oryctes monoceros*, two other species of which are equally destructive in Bourbon and Penang. Trees may be saved by cutting out the larva, when the chewed leaf seen on the outside of the shoot shows that the plant has been attacked.

Besides other useful products, to be noticed under Nuts, and Oils, the tree affords a fibre known as "coir." This consists of a coarse fibrous rind which envelopes the nuts. The quality of this is much impaired by waiting for the nuts to arrive at maturity, consequently, for fibrous purposes, the latter are usually cut at about the 10th month. If cut earlier than this, the fibre is weak; if later, it becomes coarse and hard, requires a longer soaking, and is more difficult to manufacture. The removal of the fibre from the shells is effected by forcing the nut upon a pointed implement stuck into the ground; in this way, a man can clear about 1000 nuts a day. The fibrous husks are next submitted to a soaking, which is variously conducted. In some places, they are placed in pits of salt or brackish water, for 6–18 months; in other places, fresh water is used, but it becomes foul, and injures the colour of the fibre. The chief point to be considered is the duration of the soaking; if it be continued too long, the fibre will be weakened, if it be curtailed, the subsequent extraction and cleansing of the fibre will be rendered more difficult. The most approved plan of conducting the soaking is in tanks of stone, brick, iron, or wood; steam is admitted, to warm the water. By this means, the operation is rendered very much shorter, and the fibre is softened and improved. The further separation of the fibre from the husks is largely effected by hand, by the natives of the E. Archipelago. After thorough soaking, the husks are beaten with heavy wooden mallets, and then rubbed between the hands. Where our colonists have taken up the industry, machinery has been adopted in place of hand labour. The husks are crushed in a mill, consisting of two adjustable fluted iron rollers. The pressure here exerted flattens them, and prepares them for the "breaking down," or extraction of the fibre, performed in an "extractor," composed essentially of a drum or cylinder, whose periphery is coated with steel teeth that catch in the fibre, and tear it from the husk. The machine is covered in by a wooden case, to prevent the fibre being scattered. The last operation is "willowing," or the removal of all short or hard fibres, as well as dirt, from the good fibre. It is effected by the "dust-willow," a basket of galvanized iron wire. The proportion of clean fibre obtained from the nuts varies much; it may probably average 140–160 lb. fibre from every 1000 nuts.

The fibres are coarse, stiff, and very elastic, round, smooth, and very clean, like hair. Their tenacity is remarkable. Their dimensions are—length, max., 0·0393 in.; min., 0·0157 in.; mean, 0·0275 in.; diameter, max., 0·0094 in.; min., 0·0047 in. Samples of the fibre exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost 8·13 per cent. by weight, as compared with Manilla hemp, 6·07; Phormium, 6·14; Italian hemp, 6·18; Russian hemp, 8·44. In Dr. Wight's experiments, coir cordage broke at 224 lb. Though not superlatively strong, the elasticity of the fibre, and the capacity it exhibits of withstanding the action of sea-water, render it valuable for cordage purposes, to which it is widely applied locally, besides being less extensively imported into this country for a similar use. The adaptation of the fibre to textile fabrics is much impaired by the difficulty of spinning it into yarn. The native-dressed fibre is quite unfit for such an application, and only a small proportion of the machine-dressed can be so used. The yarn is now largely consumed for making press-bags, used in candle-making, oil-refining, sugar-making, and other mannfactures, and also for mats and matting. These latter are being extensively made by the Oriental Fibre Mat and Matting Co., Highworth, Wilts. Improved machinery for making figured fabrics from coir has been recently patented by W. J. Sly and T. Wilson, of Lancaster. The fibre not suited for ropes or textiles is utilized for brush-making, as well as for stuffing purposes. It would doubtless be useful in paper-making, being described as applicable to the production of all kinds of white paper for which esparto is used.

The shipments of this fibre from India were:—in 1876, 111,476 cwt.; 1877, 176,684 cwt.; 1878, 141,024 cwt. Hankow, in 1878, exported more than 3000 *piculs* (of 133⅓ lb.); Kiungchow shipped 379 *piculs* in 1877, and 889 in 1878. The coir produced at Zanzibar is said to be very fine, and much admired at Calcutta, but it is little utilized. The plantations in Jamaica have not yet commenced to export. The approximate market values of the fibre and yarn are as follows:—Fibre—Cochin, good to fine, 19*l*.–25*l*. a ton; coarse, 16*l*. 10*s*.–19*l*. 15*s*. Yarn—good to fine, 26*l*. 10*s*.–46*l*. a ton; medium, 21*l*. 5*s*.– 28*l*. 10*s*.; common, 14*l*.–22*l*. 10*s*.; roping, 18*l*.–24*l*.

Copernicia cerifera—Carnauba palm.—Endogen. A native of Brazil, and recommended for culture in Victoria, especially along the Murray River. It resists drought in a remarkable degree, and thrives on somewhat saline soil. The fibres of the leaves are converted into rope, which resists decay in water; they are also used for mats, hats, baskets, brooms, &c. The tree is, perhaps, more valuable for the wax it yields (see Wax—Carnauba).

Corchorus sp. div.—Jute (Fr., *Mauve des juifs*, *Corète textile;* Ger., *Jute;* Beng., and N.W. Prov., *Pát;* Orissa, *Kowria*, *Nálitá;* Burm., *Phetwoon*).—Exogen; annual, 5–10 ft. Several species of *Corchorus* are said to yield jute;—*C. capsularis*, *C. olitorius*, *C. acutangulus* (*fuscus*), *C. fascicularis*, *C. trilocularis*. Of these, only the two first are cultivated for their fibre; though botanically distinct, no difference can be discovered in the commercial qualities of their respective fibres, and they are universally grown as one plant; they will be treated of collectively in this article. The remaining species are not cultivated, though they yield valuable fibres, and grow in wild abundance in some districts; they will receive no further consideration here.

Jute is essentially an Indian fibre, and it is in India only that it is produced in any quantity, though attempts are being made to naturalize it in America. At present, Bengal almost monopolizes the culture of the plant. In most districts of Lower Bengal, both *C. capsularis* and *C. olitorius* are grown; in the central, and some of the eastern, districts, the former predominates; while in the localities near Calcutta, the latter is more largely cultivated, and affords the well-known Luckhipore jute. Generally speaking, jute is extensively cultivated in the districts of Pubna, Dinagepore, Rungpore, Mymensing, Tipperah, Purneah, Julpigoree, Bogra, Dacca, Hooghly, and the 24-Pergunnahs; moderately in Cooch Behar, Furreedpore, Goalparah, Rajshahye, and Backergunge; scantily in Midnapore, Burdwan, Nuddea, Moorshedabad, Maldah, Howrah, Tirhoot, and Bhaugulpore; and, in the Sunderbuns, Durrung, Nowgong, Seebsaugor, the Sonthal Pergunnahs, Maunbhoom, Singbhoom, and Cachar, whatever is grown is locally consumed, and the produce in some cases is insufficient. The future prospects of the cultivation may be judged of by the following facts. The present producing districts of Bengal comprise over 22 million acres of arable land, of which only about 1 million are under jute, so that should the demand be doubled, the culture would only absorb about $\frac{1}{11}$th of the arable land. This does not include the vast extent of reclaimable waste land. Many districts where the plant is now scantily grown offer opportunities for greatly increased operations. This is epecially the case with the alluvial soil of the Damoodar and Dalkishore, in Burdwan; the eastern portion of Beerbhoom; Bancoorah; the deep alluvium of the Bar Mehals, in Midnapore; the Bongong and Ranaghat sub-divisions of Nuddea; the large old *churs* in the eastern districts; the fine *dedrás* in the Ganges; the banks of the Kumar, Nobogonga, and Gorai or Modhoomati, in Jessore; the Gurjat estates, in Orissa; and the vast unreclaimed lands in the Sunderbuns. The province of Assam offers another wide field, as the districts of Nowgong, Kamroop, Durrung, Seebsaugor and Luckhimpore. The same may be said of the Garo Hills, Naga Hills, Khasi Hills, and Jynteah Hills, of Cachar, of the Hill Tracts of Chittagong, and of Hill Tipperah, as well as of many parts of Chota Nagpore. Leaving the Bengal Provinces, there are immense tracts of suitable rich land, now lying waste, in the Central Provinces. Throughout British Burma, the plants grow wild, and their cultivation might be developed to almost any extent. The Terai at the foot of the Kumaon Hills, in the North-west Provinces, appears to be a suitable field. In the plains of the Punjab, both species flourish in a wild state, and might be very widely grown. The cultivation of both species is also carried on in Bombay, and might be increased. Madras produces the plant in the northern districts, from Guntor in the Krista district, to Ganjam, but cannot yet supply its own needs. Two qualities of jute are grown in China; a coarse kind, principally in Sanhevi, near Canton; and a finer kind, raised in the Hankow districts. China, however, imports jute from India, in increasing quantity every year. Serious competition may be apprehended from some of the S. States of America; on the rich lands of Florida, Georgia, Louisiana, S. Carolina, Texas, and Mississippi, jute threatens to displace cotton, affording heavier crops, at less cost. The plant is recommended for culture in Victoria.

Cultivation.—The cultivation of the plant may be discussed under the following heads:—

Soil.—The plant grows luxuriantly in the Sunderbuns, where the land is more or less impregnated with salt; and thrives in the marshes of Furreedpore and Backergunge, in waist-deep water. The growing demand for it has caused all kinds of soil to be used, independently of their fitness for the cultivation, whenever other circumstances are favourable, and a crop can be anyhow raised. The bulk of the jute that comes from the central and some of the eastern districts is grown on *churs*, and on inferior soil; but in the *desi*, or the littoral districts, a larger proportion is grown inland than on the banks of the rivers. The balance of evidence is decidedly in favour of high or *súná* lands as the best for jute, provided all the other conditions necessary for its healthy growth be attainable; but low-lands and *churs* are not unsuited, *churs* ranking midway.

In Burdwan, the plant is grown on soil composed of rich clay and sand in nearly equal proportions; in Mymensing, on a mixture of clay and sand, or sand combined with alluvial deposit; in Backergunge, on loam mixed with a little sand; in Tipperah, on loamy and sandy soil; in Pubna, on land which is neither inundated, nor dry, the soil being loam, i. e. half clay and half sand. On the other hand, it is not averse to a clayey soil, which, in some districts, is considered to be best. It also thrives in ferruginous soil, as in Bhowal, Dacca, where it is pretty largely cultivated, and considered to be among the best descriptions which find their way to the markets of Dacca and Naraingunge. Laterite and gravelly soil are, however, not favourable; neither is a light sandy soil. Wherever tried in the rice-fields of S. Carolina, it has grown most luxuriantly.

Climate.—As regards climate, a hot, damp atmosphere is most favourable. Too much rain at the beginning of the season, and early floods, are equally destructive to the young plants, and injurious to the prospects of the crop. Except in low situations, seeds are never sown until after a shower of rain to help germination. Alternate rain and sunshine are found to be most congenial; but excessive rain, after the plant has attained a height of 2–3 ft., will not prove materially injurious, so long as no water lodges at the roots. The water so lodged does not kill the plant, for, as already stated, in some districts, jute grows even in waist-deep water; but it promotes the growth of suckers, which makes the fibre what is technically called "rooty," and it may be added that the jute produced in these districts is considered of comparatively little value. Frequent light showers at first, and heavier rains afterwards, with the gradual rise of the rivers, and a fair amount of sunshine, contribute very largely to the healthy growth of the plant. It suffers less injury from excess of rainfall than from the entire want of it. Drought always stunts its growth, and very often even destroys it, if not sufficiently developed. But heavy rains have no such destructive effect, so long as they do not drown the plants, and there is sufficient sunshine to afford the necessary warmth. In America, the plant resists a frost which will injure cotton.

Tillage.—The manner of preparing the land for sowing varies in different districts. It is commenced early (say September) in the case of the low lands, *churs*, *beels*, &c., where there is considerable risk of water rising high very early; but is deferred to a later period on high lands, where no such apprehension need be entertained. The number of ploughings required is dependent entirely on the nature of the soil, a clayey hard soil requiring a greater number of ploughings than a light sandy or loamy one. Under any circumstances, the land should be so ploughed as to render the soil finely pulverulent, and to expose every part of it repeatedly to the sun.

Seed.—Little attention is paid to the selection of seed. It is generally gathered in October, from the worst plants purposely left standing in the outskirts of the fields, after the harvest has been reaped. The reason for the preference of the bad plants for seed is that they are not good for fibre, and if not utilized for seed would be wasted; and the cultivator does not wish to lose the fibre to be obtained from well-grown plants by allowing them to remain standing till the seed-pods are matured. In limited districts, the best plants are left for seed; but in most instances, poor plants in corners of the field are left. These are out in September–November; the gathered pods are sun-dried for 4–5, or even 5–10 days, and are then threshed; the seed is stored in baskets, bags, or earthen pots. The average yield of seed (without husks) is about 370 lb. an acre.

Sowing.—In the period of sowing, there are great differences, according to situation and climate; in Bengal, the season extends from February to June, the most usual time being March–April. With one exception, the mode of sowing in Bengal is everywhere alike; the seed is thrown broadcast on a clear sunny day, and covered over with a thin coating of earth. But in some parts of Sylhet, the sowing is effected in seed-beds, and the seedlings are afterwards transplanted. The seed required is about 22–28 lb. an acre.

Weeding and Thinning.—Germination takes place in 3–4 to 7–8 days after sowing. The fields are then harrowed, or weeded, or both. The weeding is repeated 2–3 times, as needed. The crop is thinned by the removal of backward plants, leaving spaces of 6 in. to 8–10 in. between the plants.

Exhaustion and Manures.—Generally speaking, jute exhausts the soil to a much greater extent than other crops. Even virgin land, which has been broken up for a first crop of jute, will, in the 2nd year, lose about 25 per cent. of its productive power; and, even though afterwards heavily manured, its yield in the 3rd year will be about ½ of the 1st year's crop. So that except in the case of rich low lands flooded annually, it is rare that jute is grown in one field for more than 3 years consecutively. This exhaustion is remedied by manuring, rotation of crops, and fallows. The manures ordinarily used are:—cow-dung, ashes, house-sweepings, oil-cake, the ashes of burnt jute-roots, the stubble of rice-crops; cattle are often stalled upon the fields. An analysis of the plant would at once indicate what constituents were principally extracted from the soil. All refuse from the plant should be returned to the soil. Rotation of crops is practised in almost every district where jute is extensively grown, and is well understood by the cultivators, though no universal rules are current. The crops most frequently selected are mustard, rice, and pulses. Leaving the land fallow for 2–3 years is resorted to whenever found necessary.

Diseases and Pests.—Besides the injuries inflicted by unsuitable weather, the plants are subject to other serious evils. Entire fields are sometimes destroyed by a hairy caterpillar, which, in seasons of drought, eats the leaves and bark. An equally destructive insect is the cricket, which burrows into the ground, and either uproots the seedlings altogether, or cuts away the roots. During excessive rain when the plants are neck-high, a blight causes the leaves to shrivel, and the stem to shrink. Also during drought, a blight attacks the leaves, and stops the growth of the plants.

Harvesting.—The season of the harvest naturally depends upon the date of sowing. Plants sown in March–April are ready in June–July; those sown in May–June are not harvested till September–October. The time considered best for taking the crop is when the plant is in flower, and just before the appearance of the pods. The fibre is then of superior quality. But sometimes, to avoid an impending deluge of water on the fields, or from a wish to be early in the market, the cultivator gathers the plant even before it has flowered. The fibre from plants which have not flowered is weak, while that from plants in seed is harsh, woody, of bad colour, and wanting in gloss, though heavier and stronger than the fibre of plants cut in flower. Whenever practicable, the plant should be cut either during inflorescence, or when the flowering is just completed. The method of harvesting is usually to reap the plant with a bill-hook or sickle. It is generally cut at a few inches above the root, unless the lower end is overrun with suckers. The plants are pulled up, when grown on land under deep water.

Extraction and Preparation of the Fibre.—These operations are divided into the following branches:—

Stooking.—After the crop has been collected, the plants are in some districts stacked in the field, and exposed to the action of the dew and sunshine, till the leaves, which if steeped along with the stalks are said to discolour the fibre, have dropped off. In others, the leaves are said to add to the weight of the stalks, and make them sink readily, and therefore they are not removed. Elsewhere the process of stacking is said to bring on the rotting of the bark more quickly, and accordingly the plants, after reaping, are left in the field for a period, which varies from 2–3 to 7–8 days. But in the majority of places, stooking is not practised. The stalks, when cut, are made up into bundles, each of a weight sufficient for one man to carry; in some places, of two sizes—long and short; in other places, of three sizes—long, middling, and short. The swaths or bundles of stalks, except in the districts above named, are thrown into water at once after the plants have been reaped.

Retting.—There is great risk of the bundles being swept away by a sudden flood, if steeped in a stream; serious disadvantage is also apprehended of the fibre being impregnated with sand, which is always carried in suspension by river currents. Stagnant water, therefore, wherever accessible, is resorted to for this process. But where stagnant sheets of water are not accessible, or where a river is near at hand, the stalks are steeped in the still pools or bays of a tidal river, and sometimes also in running water. The recourse to stagnant pools is injurious to the colour of the fibre, and deprives it of glossiness and fineness; but in this case, especially when a large proportion of decomposing vegetation is present, the process is much expedited. In steeping the stalks in water, they are covered with a layer of refuse tops of the jute plant, or other jungly plants, or with clods of earth, sometimes with cow-dung, sometimes with the trunks of plantain trees, or logs of the date tree, and sometimes with straw smeared with mud. This is done partly with a view to protect the upper parts of the bundles from the action of the sun, and partly to keep the stalks sufficiently below the surface of the water; also, it is believed, to hasten the process of retting. In some places, the bundles are first sunk by the root end, which is harder, leaving the upper end exposed above the water, and then, after 10–12 days, the upper end is pressed down to the same level with the root end, so that the whole length of the stalks may ret uniformly. In some places, the bundles are turned over while steeping.

The duration of steeping is obviously regulated partly by the nature of the water used, that is, whether the water is of a stagnant pool, or of a running stream; and partly by the condition of the plant at the reaping time, that is, whether it was in flower, when the parenchyma of the bark would be tender, or whether it was in seed, when the parenchyma would be hard. Much also depends upon the temperature of the water while the steeping lasts. It is generally admitted that under-steeping leaves runners and pieces of bark adhering to the fibre, which is found to separate unequally, and to stop chiefly at the small knots which appear on the stem; thus causing the black specks so often seen in jute. On the other hand, opinion is unanimous that over-steeping impairs the strength and flexibility of the fibre, and gives it a dull muddy colour. The process occupies from 2–3 days to a month. While the bundles are under water, they are examined from time to time, to test how far the retting has progressed, and when it has gone so far that the fibres peel off readily, the bundles are taken out of the water, and at once put in hand for the separation of the fibre, according to the several methods prevailing in the different districts. In some places, however, the stalks are first dried in the sun.

Beating, Washing, and Drying.—The process of separation most generally followed is to beat or shake the stems in water till all the resinous substance in the bark is washed away. The operator, standing in the water, takes by either end as many stems as he can grasp, and, removing a small portion of the bark from the root ends, he strips off the whole from end to end, without breaking either fibre or stem. Having thus treated a certain quantity, he proceeds to wash off. This is done by taking a large handful of the fibre, dashing it repeatedly upon the surface of the water and drawing it towards him, so as to wash off the disengaged foreign particles; then he dexterously fans it out on the surface of the water, and carefully picks off all remaining black spots. The fibre is washed generally in the water in which the stems have been steeped; but the cleaner the water, and the more frequent the washings, the cleaner and whiter the fibre becomes. Whenever readily accessible, a running stream should be preferred for this process. After washing, the fibre is wrung out, and hung upon lines to dry in the sun for 1–5 days. Sometimes it is exposed alternately to sun and shade for a few days. When dry, it is made up into hanks, and is ready for the market.

Yield and Cost of Fibre.—The out-turn of fibre per acre varies exceedingly in the different districts of Bengal. The average, including all districts, is about 1332 lb. an acre; but this figure is not a true index of a fair crop on suitable soil, as it is affected by the scanty yield of a number of unfavourable localities. Taking only the large jute-growing districts, the average would be about 1500 lb. an acre. In the Southern States of America, a yield of 3500 lb. an acre is confidently expected, and may doubtless be obtained with due care and attention.

The estimated cost of the cultivation of 1 acre of jute, and the preparation of the fibre yielded by it, in Bengal, Assam, and Orissa, averages about 16*s*. This figure indicates what would be the cost if hired labour were employed, rather than the actual expense entailed. Indeed it is generally maintained that jute would not remunerate the Indian agriculturist, if the necessary labour were not furnished by the community without cost.

Suggested improvements.—Carelessness in tying the jute into bundles or drums before it is perfectly dry, causes much deterioration of the fibre. The season of cutting the jute determines the quality of its fibre, therefore that intended for cordage should be cut in seed; but for other purposes, such as gunnies, carpets, &c., it should be taken in flower. This fact demands especial attention. The practice of drying the stalks for 2 days before steeping is probably calculated to conduce to the strength of the fibre. Machinery for the cheap and effectual separation of the fibre has not yet been introduced into the industry. In the case of India, such a machine would have to be remarkably simple and cheap. Lefranc's ramie-dressing machine (see *Bœhmeria*, p. 925), is said to have been used successfully.

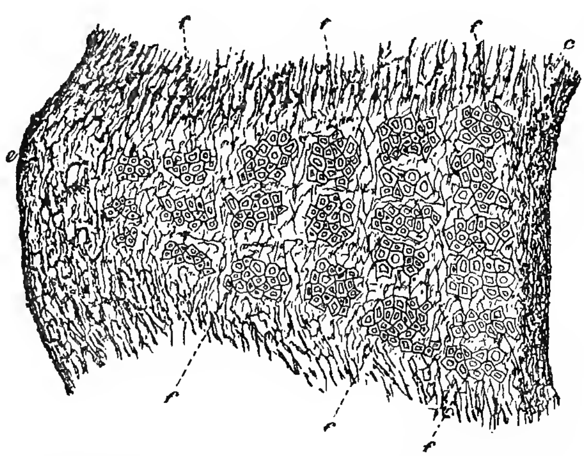
Transport and Trade.—The hanks of fibre are brought by boat, or on men's heads, to the nearest market, and there sold to the dealers who go into the interior. It is next put into small boats, and conveyed to the exporting marts—Serajgunge, Raygunge, Pangassi, Chunderkona, Oollaparah, and Shahajadpore. There the fibre is sold to the resident merchant, and is generally made up into drums, before forwarding to Calcutta. The great bulk of the jute brought into Calcutta finds its way by water, and is for export. As it arrives in drums or hanks, it is made up into bales in the different screw-houses. The best fibre is pressed into bales of 300 lb. and 350 lb. The lower portion of the stems, which is hard, and entangled with bark and woody matter, is cut off from the clean fibre, and made up into bales of 350 lb. and 400 lb., known as "butts," or "cuttings."

Adulterations.—A common plan for increasing the weight of the hanks is to pour water on them just before taking them to market; or to expose them to nightly dews; or to make up the hanks into bundles, before the fibre is dry from the washing process. The introduction of bad fibre into bundles of superior quality is frequently practised. Of the fibres of other plants substituted for jute there appear to be only two—*Hibiscus cannabinus* and *H. esculentus.* The former is brought in small quantities to some of the markets of the Mymensing and Dacca districts; it is very inferior, and is deliberately introduced with fraudulent intent. The latter grows extensively on some of the jute lands, and is often mixed with it without fraudulent motive. It is somewhat inferior. (See *Hibiscus.*)

Varieties and Qualities.—The marked differences noticed in the jute produced in distinct localities have led to the assignment of a variety of specific names, principally the following:—(1) *Uttariyá*, (2) *Deswál*, (3) *Desi*, (4) *Deorá*, (5) *Náráinganji*, (6) *Bákrábadí*, (7) *Bhátial*, (8) *Karimganji*, (9) *Mírganji*, (10) *Jangipuri.*

(1) The first is by far the best. It is called *Uttariyá*, or "northern jute," because it comes from the districts to the north of Serajgunge—Rungpore, Goalpara, Bogra, parts of Mymensing, Cooch Behar, and Julpigoori. This jute possesses to the greatest extent those properties which are essentially necessary in fibre intended for spinning—length, colour, and strength. It is, however, sometimes weak, and is never equal to the *Desi* and *Deswál* descriptions in softness. (2) Next in commercial value is the *Deswál*; it goes down fairly with the trade on account of fineness, softness, bright colour, and strength. Its name implies that it is the native jute of Serajgunge, and its neighbourhood. It first comes into the market in July–August. (3) The *Desi* jute is the produce of Hooghly, Burdwan, Jessore, and 24-Pergunnahs. It is a long, fine, and soft fibre. If its defects, which are stated to be fuzziness and bad colour, were removed, its market value would be very much improved. (4) The staple known under the name of *Deorá* comes from Furreedpore and Backergunge. Its name is due to a village in Furreedpore, where formerly there was a large mart. The bulk of the fibre of this class is strong, coarse, black, and rooty, and much overspread with runners. It is used for the manufacture of ropes. Its value would rise if the dealers would refrain from pouring water on the prepared fibre. Occasionally small batches are met with of a very superior quality. (5) The *Náráinganji* jute, which is brought from Aralia, Karimganji, and other centres of the Naraingunge mart, is mostly the produce of the district of Dacca. It is very good for spinning, being strong, soft, and long. But from some neglect in steeping, the fibre, by the time it reaches Calcutta, changes from its original colour to a brown or foxy tint, which detracts from its value. (6) The finest description of Dacca jute is the *Bákrábadí* fibre, which is raised on the *churs* of the river Megna. It excels particularly in colour and softness. (7) The *Bhátial* jute is also the produce of the district of Dacca, and comes to Calcutta from Naraingunge. It is grown on *churs*, and is called *Bhátial* because it is imported to Naraingunge from the south or tidal side of that place. It is very coarse, but strong, and is to a certain extent in demand in the British markets, for the manufacture of ropes. (8) Karimgunge, in the Mymensing district, gives its name to a very fine description of jute which is grown there. It is usually long, very strong, and of good colour,

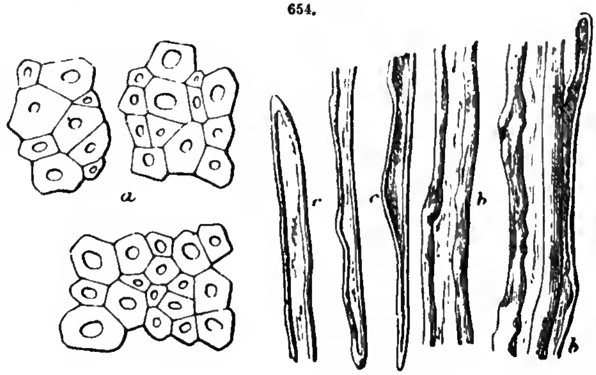
653.



partaking to some extent of the nature of the Naralngunge or Dacca jute. (9) The produce of Rungpore, though large, is generally of medium quality, and the worst kind of it comes from Mirgunge, on the Teesta, whence its name *Mirganji.* (10) The produce of a portion of the Pubna district is known by the name of *Jangipuri*, so called from a small village of that name. It is a short fibre, weak, and of a foxy colour, most objectionable for spinning.

In addition to their fortnightly circular, Ronaldson & Co., of 22, Mincing Lane, publish annually a very useful chart of the public and private marks and assortments of jute.

654.



Characters and Uses of the Fibre.—A section of a portion of the stem of this plant is seen in Fig. 653: *c*, cambium; *e*, epidermis; *f*, bast fibres; mag. 100. The bundles of fibres are arranged in lines forming a triangle. They are coloured distinctly yellow by test H.

The fibres, mag. 300, are seen in Fig. 654: *a*, section of bundles of fibres; *b*, fibres seen longitudinally; *c*, ends. The walls are somewhat thin in relation to the size of the central cavity. The latter is almost always apparent up to the extremity of the fibre. The ends vary much in shape. Under test F, the fibres assume a full yellow colour, which distinguishes them most readily from hemp and flax. The dimensions of the filaments are:—length: max., 0·196 in.; min., 0·057 in.; mean, 0·078 in.; diameter: mean, 0·0008 in. The shortness of the filaments explains their inability to withstand long exposure to water. The thinness of the walls, their rigidity, and their partial liguification, indicate their liability to break when sharply bent.

Samples of the fibre, exposed for 2 hours to steam at 2 atmos., followed by boiling in water for 3 hours, and again steamed for 4 hours, lost 21·39 per cent. by weight, being about 3 times as great a loss as that suffered by hemp, Manilla hemp, phormium, or coir. This indicates the comparative worthlessness of the fibre for ropes. Slips of sized paper, weighing 39 gr., made from this fibre, bore 60 lb., as against Bank of England note pulp, 47 lb. The pulp washes and works satisfactorily, making a firm paper that bears ink well. The "cuttings" and "rejections" seem well suited to the requirements of the paper-maker. Jute is most largely consumed in the manufacture of sacking, known as "gunnies"; also in a minor degree in mixed textiles; the preparation of these will be treated of in a separate article—Jute Manufactures.

Statistics and Prices.—The exports of raw jute from British India, in cwts., were as follows:—In 1874, 6,127,279; 1875, 5,493,957; 1876, 5,206,570; 1877, 4,533,255; 1878, 5,450,276. The average yearly shipment from Calcutta in the years 1868–1873, was 4,858,163 cwt. The destinations of the Calcutta exports in 1872–73, in cwts., were:—United Kingdom, 5,050,499, besides cuttings, 221,676, and rejections, 154,339; N. America, 307,718; cuttings, 1,039,953; rejections, 118,942; France, 137,126; cuttings, 10,715; rejections, 625; Trieste, 9139; Amsterdam, 5357; China, 3398; Ceylon, 1664; Straits Settlements, 452; Australia, 282; Italy, 45; Cape, 18. Also Bombay, 158,073; Madras, 21,898; Pegu, 13,767.

The London market values of the fibre are approximately as follows:—Good, 16*l.* 15*s.*–22*l.* a ton; medium, 13*l.* 15*s.*–19*l.* 10*s.*; common, 11*l.* 10*s.*–17*l.*; rejections, 10*l.*–11*l.*; cuttings, 9*l.* 5*s.*–9*l.* 10*s.*

Cordia angustifolia.—Exogen; tree, 12–15 ft. Found in Mysore, Bombay, and the Deccan. A fibre prepared from the bark is made into ropes, used in Malabar for dragging timber from the forests. It is very strong, and samples are said to have supported more than 600 lb.

C. latifolia and *C. Rothii* afford similar fibre, used for rope, coarse cloth, twine, and netting.

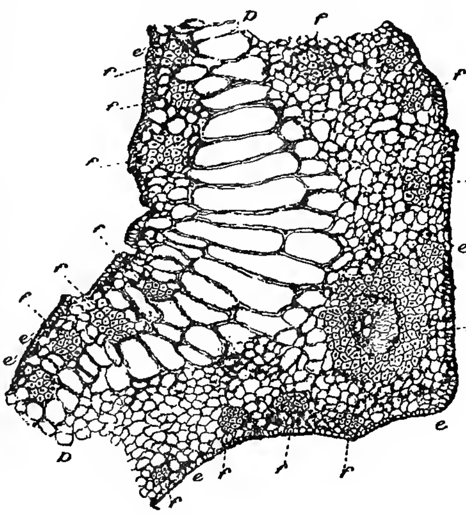
Cordyline australis—New Zealand Cabbage-tree.—Endogen; 10–20 ft. A native of Australia and New Zealand; found chiefly in swampy situations, but grows also on hill-sides. It may be readily propagated from seed, and grows rapidly. The stem is thickly fibrous, and the leaves, which are long and ribbon-like, about 2½ in. wide, contain much fibre. It is said that the whole plant might be made into paper-pulp.

C. [Dracæna] indivisa—Toi, Mountain flax.—Endogen; stem, 6 ft. A native of New Zealand, growing on the higher slopes of Mount Egmont, at altitudes of some 3000 ft., where the forest proper gives place to scrub. The leaves attain a length of 4 ft., and a breadth of 4–5 in., and contain an abundance of fibre, which diverges from the centre to the edge and top of the leaf. It is therefore shorter than the leaf, and not of the same strength throughout; but it is prepared with greater care than the New Zealand Flax (*Phormium tenax*), and is better for cordage purposes, as it does not contract in water. The natives use it in the manufacture of rough mats, employed as a cape to keep off the rain, it being more durable than phormium fibre. Though the fibre is coarse, it seems well adapted for ropes, and paper-making.

Other species in Australasia and China furnish from their leaves a superior fibre for ropes and other purposes. *C. terminalis*, *C. robusta*, *C. nutans*, found in Australia, China, India, the South Sea Islands, Norfolk Island, &c., contribute fibres closely resembling phormium. *C. indivisa* and *C. pumilio*, in New Zealand, are said to yield respectively the *toi* and *tirauriki* of the Maories.

Corypha [Livistona] australis — Australian Cabbage-palm. — Endogen. The leaves are of great size, and yield a fibre which is utilized by simply splitting the leaves longitudinally. They are then woven into hats, baskets, netting, clothing, &c. A section of a portion of a leaf of this species is shown in Fig. 655: *e e'*, epidermis, on each side of the leaf; *f*, fibro-vascular bundles, coloured yellow by test H; *p*, parenchyma; mag. 100.

655.



C. Gebanga, of Java, is similarly employed.

C. umbraculifera—Fan or Talipot Palm.—Trunk 60–70 ft. Very common in Ceylon; grows also in Malabar and on the Malay coast. The fibres resemble those of the preceding species, and are similarly employed. They are short, rigid, and with thick but irregular walls. Their dimensions are:—length: max., 0·196 in.; min., 0·058 in.; mean, 0·118 in.; diameter: max., 0·00112 in.; min., 0·00064 in.; mean, 0·00096 in. They possess remarkable strength. Tents are commonly made of the split leaves in Ceylon.

Cotton. *See* **Gossypium sp. div.**

Crotalaria juncea—Sunn Hemp.—Exogen; 4–8 ft. It is indigenous to S. Asia, and is widely dispersed throughout Tropical Australasia; it is common in every part of India, and is extensively cultivated, especially in the N.-W. Provinces, where it takes the place held by jute (*Corchorus*) in Bengal. Some 50,000 acres are occupied by it in the Punjab.

Cultivation.—The plant is grown in various kinds of soil. In Bengal, high, rich land is preferred, well ploughed, and freed from weeds; in the N. Circars, a strong clay suits it best; in the Deccan, any soil seems to suit it, and it kills out weeds. The season for sowing depends upon the rains. One crop, sown in June, is generally harvested about August–September; another, sown in October, is gathered in April. The quantity of seed used varies between 80 lb. and 125 lb. an acre. It is sown very thickly, during showery weather, and is covered by harrowing, or other rough means. It grows very rapidly, and, if sown thick enough, keeps down weeds. Scarcely any attention is necessary. The yield of fibre averages about 700 lb. an acre. When required for fine purposes, the plants are gathered in flower; when greater strength is sought, they are left till in seed, or even until the seed is ripe. The harvesting is effected by uprooting the plants, and reaping is very rarely resorted to. After the plants are gathered, they are laid in ridges for 5–12 days, which causes the leaves to decay and fall off.

Extraction and Preparation of the Fibre.—When the stems have been cleansed of leaves, &c., they are submitted to a retting process, of varying duration, according to the season. It is usual for the first day to submerge only the lower portion of the stems, which, being thicker, require longer maceration than the more tender parts. It has been suggested that the fibre would be improved by first sun-drying the stems for 2 days, and by reducing the term of retting. The latter is continued till the fibre separates easily from the stem, when it is cleansed almost exactly in the same manner as already described with jute (p. 943). After thorough washing, it is dried, and combed.

Characters and Uses of the Fibre.—The dimensions of the filaments are:—length: max., 0·472 in.; min., 0·157 in.; mean, 0·30 in.; diameter: max., 0·0020 in.; min., 0·001 in.; mean, 0·0015 in. The dressed fibre varies in length from 3 ft. 6 in. to 7 ft. Experiments made upon its strength gave a breaking strain of 407 lb. Samples of the fibre, exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost only 2·93 per cent. by weight, as against flax, 3·50; Manilla hemp, 6·07; hemp, 6·18–8·44. The average weight sustained by slips of sized paper, weighing 39 gr., made from the "raw" fibre, was 64 lb., as compared with Bank of England note pulp, 47 lb. One batch was reported to make a nice, clean, smooth paper, of good colour, but not taking ink well; another worked "wet" during pulping, but bore ink well. The fibre is remarkably well adapted for cordage and netting. Large quantities are shipped for the English market, and it forms the bulk of the so-called "hemp" exported from India.

C. tenuifolia—Jubbulpore Hemp.—Botanists now consider this a mere variety of the preceding. The plant is cultivated in precisely the same way, and the fibre it affords is similar in character and application.

Others of the many species of *Crotalaria* deserve attention for their fibre-yielding qualities. *C. dissitiflora*, *C. linifolia* and *C. crispata*, occur wild in Australia.

Cryptostegia grandiflora.—Exogen. Native of Malabar and Coromandel. Yields a fine strong fibre, resembling flax, and which may be spun into the finest yarn.

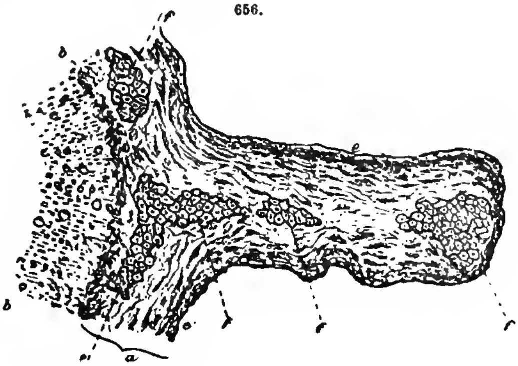
Cyperus Papyrus—Papyrus.—Endogen; sedge, 5–10 ft. Grows on the marshy banks of rivers in Abyssinia, Sicily, and Palestine; it formerly abounded on the Nile, but is now almost extinct in Egypt. The fibrous stem has been used for making sails, cordage, cloth, mats, and sandals. Strips of the stem, plaited, and treated with gum-water, constituted the papyrus of the ancients.

C. tegetum.—Very common in Bengal. The stems or culms are split, while green, into 3–10 pieces, and largely used for making mats.

C. textilis.—Widely dispersed over the Australian continent, but not yet noticed in Tasmania or New Zealand. Occurring also in South Africa. It is restricted to swampy localities. It is the best indigenous fibre-plant in Australia, and is likewise notable as being with ease converted into pulp for good writing-paper. Its perennial growth allows regular annual cutting.

Cytisus scoparium [Genista scoparia]—Broom.—Exogen. This plant is probably best known as affording a dye (see Dye-stuffs), yet it yields a fibre which may at least be used for paper-making, even if there be no truth in the statement that it was formerly employed for textile fabrics in Italy and S. France. A section of a portion of the stem of this plant is shown, mag. 100, in Fig. 656: *a*, bark; *b*, lignose; *e*, epidermis; *f*, bast fibres, coloured blue by tests F H. The fibres are short, uniform, fine, and supple. Their dimensions are:—length: max., 0·354 in.; min., 0·078 in.; mean, 0·2 in.; diameter: max., 0·001 in.; min., 0·0004 in.; mean, 0·0006 in. Paper-makers have hitherto found some difficulty in utilizing the plant, by reason of the presence of a small proportion of woody fibre in the branches, which has the effect of making little lumps in the pulp. The plant deserves attention, as it can be grown on arid and waste land.

656.



Dæmia extensa.—Exogen. Twining, shrubby. Found wild in Bengal and in the Himálayas (from Darjeeling to Nepal), and one of the commonest weeds in the Deccan. Its stem yields a fibre which has been recommended as a substitute for flax; it is said to be very fine and strong, and to have gained a medal at the Madras Exhibition, 1855.

Daphne papyracea [cannabina]—Nepal Paper-shrub.—Exogen; shrub, 5–6 ft. A native of the Himálayas—Nepal, Khasia, and Silhet—growing on the most elevated and exposed parts of the mountains, even where they are covered with snow. It seems to thrive luxuriantly only in the vicinity of the oak. The inner bark, prepared like hemp, affords a very superior paper material. The paper made from it is particularly suitable for cartridges, being strong, tough, and not liable to crack or break, however much bent or folded; it is proof against being moth-eaten, and is not affected by change in the weather; if drenched, or left in water for a considerable time, it will not rot. It is in universal request locally for writing deeds and records on, being quite smooth, and almost indestructible. Engravers say that it affords finer impressions than any English paper, and nearly as good as the fine Chinese paper. The fibre is also made into very strong cordage, which, when worn out, is still convertible into excellent paper.

D. aureola is utilized in Spain, where it is very common.

Debregeasia sp. div.—Exogen. Several species of this plant furnish a fibre resembling that afforded by the *Bœhmeria*, or China grass, and valuable for textile fabrics. They are chiefly: *D. edulis*, indigenous to Japan, and recommended for culture in Victoria; *D. hypoleuca*, on the Himálayas, and in Abyssinia, up to elevations of 8000 ft.; *D. velutina* and *D. Wallichiana*, ascend the Himálayas for several thousand feet. From the former, many of the Assam tribes obtain their cloth.

Diplarrhena Moræa.—Endogen. The native lily of Tasmania, occurring in abundance on the poorest lands. Fibre is extracted from the leaves.

Dolichos sp. div.—Exogen. *D. trilobus* is a very important fibre-plant in China, textiles made from it being termed "grass-cloth," like those from nettle-fibre. It has been utilized from the earliest times, and the manufacture is very extensive. From *D. umbellatus*, widely grown in Japan, no fibre is separated; but *D. tuberosus* and *D. bulbosus* (in China) are turned to account.

Dombeya [Astrapœa] cannabina.—Exogen. Native of Madagascar. The fibrous bark is locally made into rough but strong ropes.

Edgeworthia Gardneri.—Exogen. Native of the Himálayas. Affords a paper fibre resembling that yielded by *Daphne papyracea*.

Elæis guineensis—Oil palm.—Endogen. This W. African palm is very widely known for the valuable oil yielded by its fruits (see Oils). Its leaves contain a fibre which has not received the attention it seems to merit. The filaments are very fine, clean, and regular, like bundles of horse-hair; they are supple and very strong. Their dimensions are:—length: max., 0·137 in.; min. 0·058 in.; mean, 0·097 in.; diameter: max., 0·00052 in.; min., 0·0004 in.; mean, 0·00044 in.

Erechthites hieracifolia—Fireweed.—This plant springs up as a weed on recently cleared land in America. Its seed-pods yield a fibre much resembling cotton, but the seeds are smaller, and require no ginning to separate them from the boll. This fibre may be spun and woven, and wicks, ropes, yarn, and paper, are said to have been made from it. The application to paper-making was especially successful, the product comparing well with the silk-made papers of China and Japan.

Eriodendron anfractuosum.—Tree, 50–60 ft. One of the many "silk-cottons." Common in both E. and W. Africa, in India, and in the Sunda Islands. The silky seed-down is too short and brittle for weaving, but is used for stuffing.

E. Samauma, of Brazil, is similar. Also *E. gossypium* and *E. caribœum* (in Cuba and Porto Rico).

Eriophorum comosum—Cotton grass.—Endogen. This plant is very common in the N.-W. Provinces of India, growing abundantly in the ravines on the sides of the mountains, and is to be had for the cutting. Its seeds are clothed at the base with a cotton-like substance, which is used for stuffing and wick-making purposes, as well as for paper-makiug. The fibrous leaves are very extensively used locally for making rough, strong twine; and very thick cables of it are employed for rope-bridges in the Himálayas. Though pretty strong when newly made, the ropes are not durable. Reports on its paper-making qualities state it as being of about the same strength as esparto, and capable of making equally good paper. The yield is 42 per cent., and the consumption of "bleach" is small.

Eryngium ? sp.—Exogen. A native of the Argentine Republic. The leaves afford a fibre which is well spoken of by paper-makers.

Esparto.—*See* **Lygeum Spartum, Macrochloa tenacissima.**

Eucalyptus sp. div.—Exogen. *E. obliqua* (*nervosa*) has a very fibrous bark, applied to many purposes in Tasmania, Victoria, and S. Australia. *E. fissilis* is less fibrous.

Eugeissonia tristis.—Endogen. Native of Penang. The fibrous leaves are woven into mats.

Fitzroya Patagonica—Alerce.—Exogen; tree, 100 ft. A native of Chili, as far south as Chiloe. It grows in swampy places. The outer bark yields a strong fibre, used for caulking ships.

Flax.—*See* **Linum usitatissimum.**

Fourcroya longæva.—Endogen; trunk 50 ft. Inhabits the mountains of Gautemala and Mexico, at about 1000 ft. Dies after flowering. It is recorded as fibre-yielding.

Freycinetia Banksii—Kiekie.—Endogen. Native of New Zealand. It grows luxuriantly in swampy places in the forest, and could be obtained in great abundance. Its fibre will probably be found valuable for paper-making.

Gossypium sp. div.—Cotton (Fr., *Coton;* Ger., *Baumwolle*).—The number of species of the genus *Gossypium* has been variously stated at figures ranging from 7 to 20, with many additional varieties. Avoiding this botanical confusion, it will suffice to state that the species and varieties of the cotton plant affording fibre of any commercial importance may be divided into two typical sections: Indian or Oriental, which are different forms of *G. herbaceum;* and American or Occidental, which are of two distinct kinds—*G. barbadense*, and *G. hirsutum*. All cultivated kinds are naturally perennials, or become so in favourable climates.

Distribution.—The cotton plant is very widely distributed, and may in fact be considered as indigenous to all intertropical regions. The geographical parallels between which cotton culture is usually placed stretch in varying girdles between 36° N. lat. and 36° S. lat. Yet the area within which the cultivation is systematically pursued is comparatively limited, not so much by climatic and geological conditions, as by the question of labour supply.

United States.—It thus happens that, despite the efforts made to supplement, or even replace, the supplies of cotton from America during and immediately after the war, things have resumed their former state, and the world is still mainly dependent upon America for its most important textile fibre. On the other hand, increased labour difficulties, and impoverishment of the land by bad culture, temporarily reduced the production in many districts by fully two-thirds. This state of things seems now to have completely righted itself. According to the official returns of the Department of Agriculture at Washington, the average yield per acre has increased from 192 lb. of lint per acre in the years 1868–1871, to 200 lb. in 1872-1875, and 216 lb. in 1876–1879, there being a steady advance from 160 lb. in 1868 to 260 lb. in 1879. Moreover, the oldest cotton state, S. Carolina, shows a rise from 143 lb. in 1868 to 200 lb. in 1879. The cotton region of America is confined to the Gulf States—S. Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, Louisiana, Arkansas, and Texas. The culture is creeping away from the Atlantic sea-board, westwards to new lands. The cotton region may be roughly divided into four zones:—(1) A narrow belt of land, overlying Tertiary and Post-tertiary deposits, extending along the coasts of S. Carolina, Georgia, and part of Florida; this district produces the "Sea-Island" or "long-stapled" cotton, which excels in length, strength, and beauty of staple. (2) A broad tract, underlaid by Cretaceous rocks, sweeping round the S.W. extremity of the Alleghanies, extending over portions of Georgia, Alabama, Mississippi, and Tennessee, and reappearing in Texas. The predominating rock in this region is a soft, argillaceous limestone, called "prairie" or "rotten limestone," overlying which are the rich "prairie lands." (3) Light sandy soils occupy large portions of S. Carolina, Georgia, Alabama, and Mississippi, generally underlaid by metamorphic rocks—gneiss, and talc- and mica-schists,—and to some extent by Silurian and Carboniferous sandstones and limestones; these lands are much poorer than (2). (4) Rich alluvial deposits, or "river-bottoms," stretch along the lower Mississippi, and its tributaries, the Red River, the Arkansas, the White River, the Yazoo, &c., and along the Colorado, the Brazos, the Tennessee, &c.; these are very fertile, but subject to inundation. In the last three zones, are grown the "Georgian Uplands" or "Boweds" variety, the result of the cultivation of Sea-Island cotton on the interior uplands; and the two kinds of "New Orleans" or "Uplands." Boweds and New Orleans cottons form the great staple of production, and are commonly known in England and on the Continent as "American" simply. The culture is being energetically revived in California, where it was tried unsuccessfully, and abandoned, in 1877.

The production of the chief cotton states in the years 1859-60 and 1878–9 respectively, stated in bales, was as follows:—Mississippi, 1,202,507, 660,000; Alabama, 989,955, 650,000; Louisiana, 777,738, 610,000; Georgia, 701,840, 600,000; Texas, 431,463, 900,000; Arkansas, 367,390, 570,000; S. Carolina, 353,412, 350,000. The American cotton acreage in 1880 was as follows:—Alabama, 2,292,215 acres; Mississippi, 2,180,614; Texas, 1,886,786; Georgia, 1,883,571; Louisiana, 1,336,660; Arkansas, 1,212,188; S. Carolina, 1,054,345; Tennessee, 875,679; N. Carolina, 661,534; Florida, 229,386; total, 13,612,978 acres.

The area occupied by cotton, and the quantity of the staple produced in the United States, in the years 1875–8, were as follows:—1875—10,803,030 acres, 4,600,000 bales; 1876—11,677,250 acres, 4,438,000 bales; 1877—12,600,000 acres, 4,750,000 bales; 1878—12,266,800 acres, 5,216,603 bales. The greater portion of the crop of Louisiana, Mississippi, N. Alabama, Arkansas, and Florida, is taken to New Orleans, which receives about one-third of the entire produce of the country. The ever-increasing Texas crop is concentrated in a great measure at Galveston. The N. and S. Carolina exports, in bales, in 1878, were:—From Charleston: to Great Britain, 123,322; France, 70,355; N. Europe, 60,344; S. Europe, 43,420; American ports, 132,964. From Wilmington: to Great Britain, 35,007; France, 1780; N. Europe, 19,890; American ports, 88,530. The foreign exports from Mobile, during the year ending 31 Aug., 1879, were as follows: To Great Britain, 56,649 bales, or 27,753,535 lb.; France, 35,583 bales, 17,744,562 lb.; Germany, 8,940 bales, 4,463,398 lb.; Holland, 8428 bales, 4,210,240 lb.; Russia, 6612 bales, 3,309,286 lb.; Spain, 6442 bales, 3,229,246 lb.; Italy, 3058 bales, 1,520,760 lb.; Austria, 925 bales, 462,066 lb. The shipments to Great Britain in 1878 took place from the following ports:—New Orleans, 822,492 bales; New York, 342,384; Galveston, 173,481; Savannah, 163,099; Norfolk, 156,687; Charleston, 123,322; Mobile, 88,083; Wilmington, 35,007; other ports, 197,417. The New Orleans export of 1877–8 was thus distributed:—To Great Britain, 822,492 bales; France, 325,406; coastwise, 251,673; N. Europe, 238,271; S. Europe, Mexico, &c., 66,952. New York exported 442,577 bales to Great Britain in 1879. Savannah, in 1879, exported 458,208 bales of Uplands, and 1784 bales of Sea-Island; of the total, 202,625 bales came to British ports. Of the entire cotton-crop of 1875–6 (1 year), Great Britain took 45·08 per cent.; N. Europe, 10·80; France, 9·90; other ports, 4·70; leaving for consumption by American spinners in the north and south, 29·52 per cent.

The cost of raising cotton, upon a plot of 150 acres devoted exclusively to that culture, is thus estimated:—

Interest at 7 per cent. on value of land, $1500	$105.00
Interest on value of four mules, implements, &c., $550	38.50
Repairs of fencing at 13*c.* per acre	19.50
Wages of one white foreman and manager	200.00
Wages of three negro ploughmen	210.00
Provisions for four hands	100.00
Food for four mules (one year)	300.00
Salt and potash for manure, at $1 per acre	150.00
Twelve bushels of cotton-seed for manure and planting per acre, say 1800 at 10*c.*	180.00
Hire of eight extra hoe-hands, six weeks	120.00
Extra labour for picking cotton	120.00
Toll of 1-15th for ginning	195.00
Taxes at $1\frac{1}{4}$ per cent. on $2050	25.12
Add for sundry incidental expenses	100.00
Interest on outlay ef $1700, at 12 per cent. per annum, average time four months	68.00
Total expenses	$1,831.12

150 acres, at an average yield of 216 lb., produce 32,400 lb., equal to a cost of about $5\frac{11}{16}$*c.* a lb., delivered at the railway stations. The expenses, from the interior to the shipping ports, average about $\frac{3}{4}$*c.* a lb., making the cost at the ports about $6\frac{7}{16}$*c.*, equal to about $3\frac{3}{16}$*d.*, to which about $1\frac{1}{4}$*d.* are added in expenses of shipment and delivery at Liverpool, making the total cost of the production of cotton delivered at Liverpool about $4\frac{7}{16}$*d.* a lb., for average strict good ordinary.

W. Indies.—Before the present century, England obtained her chief supply of cotton from the W. Indies. The sort there grown was the Sea-Island, known also as Anguilla, and said to be indigenous to Honduras. The product was highly esteemed, aud has probably never been surpassed in quality; but the cultivation has had to give way before the sugar-cane, and the production is now trifling. The exports from the Spanish island of Puerto Rico have declined from 2506 *quintals* (of $101\frac{1}{2}$ lb.) in 1874, to 150 *quintals* in 1878.

Central and S. America.—Several of the countries of Central and S. America figure as cotton producers. A variety of the plant largely grown is *G. peruvianum* (*acuminatum*), the "tree-cotton" of Peru, an arborescent kind, attaining a height of 10-15 ft., yielding large crops for 4–5 years, lasting for 8–10 years without renewal, and, in the Andes, bearing cotton while frosts whiten the ground; it furnishes the cottons known in the market as "Pernams," "Maranhams," &c.

In Brazil, where the plant thrives well from Pará to Rio Grande, much cotton is now raised from New Orleans seed, and is known as "Santos." The cultivation in the province of Bahia is falling off, owing to the excessive cost of carriage from the interior; the little that comes to market is taken up by local mills. During the financial year 1877–8, Bahia exported 34,177 kilo. of raw cotton, of which more than half came to Great Britain, and the remainder went to Portugal. In 1878–9, the quantity was 37,371 kilo., and the proportion to Great Britain was increased to over $\frac{2}{3}$. Ceará, in 1878, exported 468,051 kilo. to England, 3217 to Hamburg, and 1420 to Havre. Maceio, in 1877, shipped 58,801 bags (of 75 kilo. each) to Great Britain, and 155 to New York and Lisbon; in 1878, the figures were 37,384 to Great Britain, and 3590 to Russia. In Paraiba, the crop of 1877–8 was only 1150 bags. Cotton is one of the staple productions of the province of Pernambuco. The shipments from the port, in the year 1877–8, were :—to Great Britain, 2,443,505 kilo.; Spain, 1,236,929; Portugal, 589,426; France, 363,277; Russia, 198,026. In 1878–9, the figures were:—Great Britain, 2,060,607; Spain, 1,046,061; Portugal, 511,545; France, 284,573; Russia, 176,742.

Ecuador is a small producer of cotton. The exports from Guayaquil, in 1877, were 2489 *quintals* (of $101\frac{1}{2}$ lb.); in 1878, 142; and in 1879, 200. This decrease was caused by continued heavy rains.

Surinam, in 1821, exported 1,500,000 kilo. of cotton; in 1850, the figure had fallen to 500,000. Since the emancipation of the slaves, the cultivation has not been lucrative, and the 14 estates of 1863 are now reduced to 6, with a cotton area of about 1800 acres. In 1877, the production was 202,659 kilo.; and the exports, 95,073 kilo. The latter, in 1878, were only 84,600 kilo.

Europe.—Of European countries, Italy alone seems to possess the conditions requisite for successful cotton culture. The American war gave the industry a new impetus, and quantities of New Orleans seed were supplied to the peasants in place of the short, weak, and ill-coloured staple they were then growing. In 1864, 217,557 acres were planted with cotton; but 10 years later, this figure had fallen to 85,388, the production decreasing in the same period from 1,225,770 cwt., to 354,827 cwt. The present centres are around Bari and Barletta, on the Adriatic; in the neighbourhood of Salerno, Saron, and Castellamare, S. of Naples; and in the provinces of Caltanissetta and Girgenti, on the S. shores of Sicily. The products are known respectively as "Pugliar," "Castellamare," "Biancavilla," and "Terranova." Sardinia also grows a little.

Africa.—Several portions of the African continent promise to afford considerable supplies of cotton. Foremost among them is Egypt, which is perhaps entitled to be considered the finest cotton-growing country in the world, not even excepting the S. States of America. The indigenous plant has been grown from very remote times, but cotton cultivation may be said to date from the introduction of American seed in the present century. The industry has spread widely in Lower Egypt, where soil and climate are specially suitable, but labour is scarce. A still more likely district is to be found in the rich alluvia of the Soudan, where hundreds of thousands of acres await systematic husbandry. Experiments have recently been made to test whether the sowing-season of the ordinary plant might not be deferred from February-March to July, so as to bring the picking-season into June, instead of September–October. In this way, the dangers of fogs, heavy dews, and inundations, to which the plants are now liable, would be greatly reduced. On the other hand, the production from the soil would be limited to one crop annually, instead of two; but it is thought that the one crop would then be equal to two of the present. The weight of the crop obtained in the years 1871–8, stated in *cantars* (of 98 lb.) was as follows:—1871–2, 2,044, 254; 1872–3, 2,298,942; 1873–4, 2,538,351; 1874–5, 2,106,691; 1875–6, 2,928,498; 1876–7, 2,773,258; 1877–8, 2,593,670. Owing to the very high Nile of 1878, and a favourable season, the crop of 1879 was the heaviest on record. It was estimated at 3,250,000 *cantars* (of 98 lb.), or 500,000 bales (of 5¾ cwt.); and the quality was correspondingly good. The exports of this crop, from Oct. 1879 to Mar. 1880, have been in the proportion of 67½ per cent. to England, 14½ per cent. to Russia, and the remainder to Austria, France, and Italy. There is a noteworthy growth in the export to Russia of late years. Early in 1877, a new variety of Sea-Island cotton, which had appeared in the Menoufieh district, attracted much attention. Its chief peculiarity lies in its fastigiate form of growth, 2–3 branches rising straight up from the main stem to 8–10 ft., without any secondary offshoot. It was called "Bamia," from its resemblance to *Hibiscus esculentus*, and the erroneous supposition that it was a hybrid between cotton and that plant. It bears an average of 50 pods, and its mode of growth allows much closer planting than with ordinary cotton, so that the yield is nearly doubled, while the quality is excellent; but the plant requires much more water, which is a great drawback to its extended culture in Egypt, and it has not as a rule maintained its reputation when grown elsewhere—India, Fiji, &c. Nevertheless it is advancing in public favour both with growers and consumers.

Algiers exported 33,244 kilo. in 1877, and 27,335 kilo. in 1878. In Natal, the plant grows to perfection, and has yielded Sea-Island staple nearly 3 in. long, and of silk-like quality, without any attention. In the Umkomas valley, an acre yielded 300 lb. clean cotton. Several of the W. African States possess equally suitable soil and climate, but lack labour.

Turkey, Levant, Persia, &c.—Much of the Ottoman Empire is unsurpassed in natural conditions for cotton-growing, and might contribute very largely; but the energy displayed during the "cotton-famine" has not long survived. The country around Smyrna is most noted, the plantations being chiefly situated on the plains and slopes bordering the Meander, and other streams draining the Sultan Dagh range. The Roumelian coast, from the Gulf of Saros to the Gulf of Salonica, might produce large crops. Turkish cottons are named after the districts where they are grown, which are chiefly Cassaba, Aidin, Denizli, Kirgagatch, and Danidir. It is classed as *Tchikrik* or unginned, and *Subutcha* or ginned, and finds its way into the Smyrna market. The Adana cotton comes from Tarsus, and is shipped at Messina. Turkey cotton is carelessly grown, badly gathered, of mixed staple, and imperfectly cleaned. Its position in the market shows what might be done with it. The 75,000 bales annually exported go chiefly to S. European ports. Adana, in 1878, exported 18,760 bales, or 5,913,820 lb., value 94,870*l.*

Cyprus grows cotton, chiefly in the Messaorea, on the plains of Morpho and Nicosia, and in the districts of Larnaka, Buffo, Famagusta, and Karpas. The best staple, however, comes from Lefka and Kythrea. In ordinary years, the production is perhaps 10,000 cwt., a trifle only of what might be raised.

In different parts of Syria, cotton has been cultivated for ages, but inattention has caused the staple to deteriorate. Consul Moore enumerates the following localities where water is abundant, and cotton culture might be successfully maintained:—The sources of the Jordan, the valley of the Bekaa and Baalbec, the sources and banks of the Orontes, the plains beyond Damascus, that part of Mesopotamia on both sides of the Euphrates, chiefly waste lands. The plains in the vicinity of Alexandretta and Tarsous, and the Nablous and Anagreath mountain districts, produce cotton without irrigation, water being scarce.

A large quantity of cotton is grown about Erivan and the frontier of Persia, as also in Ghilan and the interior. The export trade amounted at one time to 100,000 bales yearly; and, though it is now much crippled by duties, still continues to flourish, and shows what might be done.

Increasing quantities are being sent to India, from Bushire. The exports of raw cotton from Gez and Casvin to Russia were valued at 55,760*l.* in 1878, and 34,615*l.* in 1879. The exports from the province of Asterabad, in 1879, were 19,580 bales, value 37,306*l.*

Central Asia.—The Central Asian countries of Bokhara and Turkestan, notably the former, produce annually about a million cwt. of very inferior cotton, much of which finds its way to Nishni-Novgorod and Moscow. The culture is increasing. It is hoped that the duty levied on imports of raw cotton will develop the culture in Central Asia and the Caucasus. Hitherto, Central Asian cotton has been used only in mixtures with American cotton; but it is said that at Turfan, in E. Turkestan, a little to the south of the Tian-shan Mountains, cotton equal to American is grown, and it is believed that by protecting this, Russia may be ultimately rendered independent of American cotton. There is more cotton raised now in this district than in all Central Asia besides. The climate is favourable; the plant attains a height of 9 ft., and a thickness of stem of 2½ in. The crop is gathered in early August.

India.—India now ranks second only to the United States as a source of cotton. Owing to climatic and other influences, the staple is short, and not so well adapted for spinning as some other varieties. Until the American war, the demand for "Surats," as Indian cottons were called, was small in Europe, though cotton had always been cultivated on a large scale, for home consumption and export to China, &c. The crop is well suited to the soil of many parts of India, and is understood by the peasants, hence the stimulus of high prices has attracted science and capital to the industry, and has resulted in a greatly increased production. The subjoined Table, prepared in 1872, shows approximately the extent of cotton cultivation (in acres), the average produce per acre (in lbs.), and the total estimated yield (in bales of 400 lb.), of the several provinces and presidencies of India:—

Political Divisions.	Cultivation.	Produce per Acre.	Total Produce.
	Acres.	lb.	Bales.
Bombay Presidency and Sindh	2,200,000	80	440,000
Bombay Feudatories	2,000,000	80	400,000
Central Provinces and the Berars	750,000 1,250,000	80 80	150,000 250,000
Nizam's Territories Central India Rajpootana, &c.	2,000,000	50	250,000
Punjab sends to Kurachee	800,000	50	100,000
Total country drained by Bombay	9,000,000	80	1,590,000
Madras	1,320,000	80	264,000
Mysore	30,000	80	6,000
Total Madras	1,350,000	..	270,000
Lower Bengal	400,000	50	50,000
N.-W. Provinces	1,600,000	80	320,000
Oudh	80,000	50	10,000
Punjab (see above)	..	..	..
Total Bengal	2,080,000	..	380,000
British Burmah (Total)	60,000	50	7,500
Sundry Cultivation in the Interior in Native States (produce not exported)	400,000	50	50,000
Grand Total	12,890,000	75	2,297,500

As will be noticed, the average production from an acre of land varies much. This variation is chiefly due to difference of soil. The sort most common throughout the cotton-growing tracts of W. India, and on which the best cotton is produced, is the "regur," or "black cotton soil," of the Deccan, which stretches from the W. Coast to the centre of India, near Nagpore, where it meets the lighter soil which covers the sandstone formation. The "regur" is of a bluish-black, greenish, or dark-grey colour. It forms into a paste with water, and gives a clayey odour. It absorbs moisture rapidly, and parts with it in dry and hot weather. Its thickness varies from 3 ft. to about 20 ft. It is cultivated very easily, yielding a rotation of crops, consisting of cotton and two kinds of corn. It rarely requires to be left fallow, and demands but little husbandry; for the last 2000 years, it has continued in cultivation without manure, retaining the utmost fertility. An analysis of it shows:—Silica, 48·20; alumina, 20·30; carbonate of lime, 16·00; carbonate of magnesia, 10·20; oxide of iron, 1·00; water and organic matter, 4·30. The subsoils vary from rich black mould to hard basaltic rock. Very little natural manure is available, and artificial fertilizers have only recently been introduced. A good composition is said to be formed of 10 parts soluble phosphate of lime, 3 parts sulphate of ammonia, 3 parts nitrate of soda, 4 parts Peruvian guano. Apart from the heavy cost of such a manure, there arises the serious drawback that it can only be used with a liberal supply of water, not to be obtained in India except by irrigation, which is quite undeveloped in the cotton districts.

The several varieties of Indian, Asiatic, or Oriental cotton belong, with one exception, to *G. herbaceum.* This exception is the purple-blossomed tree-cotton, *G. arboreum* (*religiosum*), held sacred, and grown about the Hindu temples; its staple is silky, and efforts have been made to improve it by hybridizing, and to bring it into general culture, but it remains almost unknown to commerce. Indian cottons, known collectively as "Surats," are distinguished chiefly as "Hingunghât," "Oomrawuttee," "Broach," "Dhollera," and "Dharwar." The first, possessing the highest qualities, is at the head of the sorts grown in the Central Provinces and the Berars; the staple is moderately long and strong, soft, white, and silky. Great efforts have been made to improve the Indian cottons by the introduction of exotic seed, the chief object being to increase the length of staple. The only case in which any success has been achieved is with New Orleans cotton (*G. hirsutum*), in the Dharwar country, in the south of the Bombay Presidency. All experience elsewhere in India points to the fact that exotic cottons rapidly deteriorate, and that efforts to improve the best indigenous kinds are more likely to be successful. With these latter, the object sought is increased production rather than augmented length of staple, and it remains to be proved whether the additional care and expense will be warranted by the result. Meantime, the researches of Col. Trevor Clarke on hybridization may open up a new line for improvement.

Every step in the culture of the plant, and preparation of the fibre, is in India marked by extreme rudeness, not to say carelessness. The picking of the bolls, and separation of the fibre from the seed, are especially capable of much improvement, the introduction of which would materially raise the value of the article.

The Table, p. 954, compiled for the Exhibition of 1872, exhibits the proportionate quantity of each sort of cotton produced in the various provinces, the season of coming to market, the local consumption, and the ports of shipment and destination of the exports, as nearly as could be ascertained.

The exports for the last five years have been as follows:—1873–4, 4,499,698 cwt.; 1874–5, 5,600,086; 1875–6, 5,009,788; 1876–7, 4,557,914; 1877–8, 3,459,077. The shipments to the United Kingdom have been falling off annually since 1871–2, and England no longer remains a large customer for Indian cotton, much less than half the total export now coming to us. Continental Europe maintains a steadily increasing demand: in 1877–8, France took about 611,000 cwt.; Italy, 434,000; Austria, 407,000; and Germany, 109,000; China also took 209,000 cwt. Russia in the same year took 49,000 cwt., which was last year (1878–9) reduced to less than 2000 cwt. In the matter of production, the Bombay Presidency is steadily declining, while Bengal and Madras, especially the former, manifest a decided increase.

China.—The Chinese or Nankin cotton is a variety of *G. herbaceum.* It is cultivated chiefly on the level ground around Shanghai, forming the principal summer crop. The soil here is a strong rich loam, which is manured with the scrapings of the ponds and ditches—rich mud, full of rotten vegetable matters. In April–May, the seed is sown broadcast, and trodden in. Thinning and weeding are attended to during the summer, and the earth is loosened. The plants flower in August–October. When the pods begin to burst, they are gathered with great care, and taken home, and spread on hurdles 4 ft. above the ground to be sun-dried. When dry, the seeds are extracted by the old-fashioned Indian rolls, and the fibre is bowed. This last process renders it particularly clean and soft. Chinese cotton is reckoned much superior to Indian, thanks to the greater care bestowed upon it. None is exported.

The French Colony of Saigon, in 1879, had about 2114 acres under cotton cultivation, distributed among the following provinces:—Vinhlong, 1475; Saigon, 360; Bassac, 182; Mytho, 97 The exports in 1879 were 11,569 *piculs* (of 144 lb.); the crop was partially destroyed by heavy rains. In 1878, about 34,384 *piculs* came to market. Egyptian seed sown in Cambodia promises well.

Japan, Java, &c.—In Japan, an indigenous variety of *G. herbaceum* is largely cultivated, and develops different characteristics according to the locality where it is grown. It thrives in a much colder and moister climate than the best known varieties, but its product is inferior to American, Egyptian, or even South Sea cotton. The seed, having been soaked in water, is sown in early May, and the plants appear about 7–8 days later. Fish-manure is then applied. From mid-June to mid-July, the plants are thinned out, and the larger ones are pruned. Watering is then most carefully attended to till the pods begin to expand in early September. A light well-drained soil is best. About 1000 lb. uncleaned cotton is obtained from an acre in good seasons.

Political Divisions.	Sort of Cotton.	Quantity exported: Bales.	Season of coming to Market.	Retained for Home Consumption.	Exports in Detail, in Bales of 400 lb.				
					Port.	To Great Britain.	To the Continent direct.	To China.	Total.
Bombay Presidency and Sindh	Dharwar .. Compta ..	200,000	Mar.						
	Broach .. Surat ..	150,000	Jan.		Bombay ..	991,000	135,000	53,000	1,179,000
	Kandeah .. Sindh ..	75,000 20,000	Jan.						
Bombay Feudatories ..	Dhollerah ..	375,000	Jan.						
Central Provinces and the Berars	Hingunghat..	60,000	Dec. and Jan.	360,000	Karwar ..	25,000	..	..	25,000
	Oomrawuttee Akote ..	225,000							
Nizam's Territories .. .. Central India .. .. .. Rajpootana, &c.	Barsee .. Bengal .. Oomrawuttee	125,000	Jan. and Mar.						
Punjab sends to Kurrachee	Bengal .. Sindh ..	5,000	Jan.		Kurrachee ..	26,000	..	..	26,000
Total of country drained by Bombay	..	1,230,000	..	360,000	Total Bombay	1,042,000	135,000	53,000	1,230,000
Madras .. Madras .. Mysore ..	Western .. Northern	240,000 ..	Mar. ..	.. 30,000 ..	Cocoanada .. Madras .. Tuticorin ..	32,000 94,000 84,000	30,000	..	32,000 124,000 84,000
Total Madras.. ..	..	..	..	30,000	Total Madras	210,000	30,000	..	240,000
Bengal (Lower Bengal, N.-W. Prov., Oudh .. .., Punjab (see above))	Bengal	200,000	Feb.	180,000	Calcutta ..	116,000	2,000	82,000	200,000
Total Bengal	..	..	..	..	Total Bengal	116,000	2,000	82,000	200,000
British Burmah	..	..	..	1,500	Rangoon ..	3,000	3,000	..	6,000
Total Burmah ..	..	..	..	..	Total Rangoon	3,000	3,000	..	6,000
Sundry Cultivation in the interior in Native States, Produce not exported				60,000	Not exported.				
	Grand Total			621,500		1,371,000	170,000	135,000	1,676,000

Java also produces three kinds of cotton, the principal of which is a local variety of *G. herbaceum*, which yields the sole textile fibre employed by the natives, and is cultivated in almost every part of the island. It is generally planted on the declivities of the hills, after reaping the rice crop, and yields its cotton in less than 3 months. It is a very hardy plant, but its product is coarser and less in quantity than that of the Indian plant. The latter, however, is much more delicate.

The Laos district in Siam produces small quantities, and the climate seems to be favourable, but labour is wanting.

None of these countries afford commercial supplies.

Australasia.—There can be no doubt of the adaptability of many portions of our Australian colonies to the culture of cotton. Sea-Island cotton of fine texture and quality can be grown on many of the elevated tablelands of Queensland; and samples grown 200 miles from the sea are as good as those raised on the coast. Remarkably fine specimens of Uplands also have been obtained from the coast country of Queensland, an acre yielding over 300 lb. of clean fibre. There is here a fine field for this important industry, yet the exports of raw cotton have fallen from 2,602,100 lb. (value 79,317*l.*) in 1871, to 221,689 lb. (value 6940*l.*) in 1877.

The South Sea Islands seem admirably adapted, both in soil and climate, to cotton-growing. Fiji cotton received three prize medals at the last Exhibition (Paris), and the crop is said to be as heavy as in the S. States. The exports from Tahiti in 1878 were 733,475 lb. of clean baled cotton, valued locally at 30,561*l.* Only a small proportion of this was grown at Tahiti, the greater part having been obtained from neighbouring independent groups of islands.

Cultivation of the Plant.—The following remarks upon the cultivation of the cotton plant have reference specially to the methods practised with the short-staple or Upland variety in the S. States of America, and to modifications or improvements suitable to India. Colonial planters will easily deduce from them what plan is best adapted to their particular case. The main heads of the subject are as follows:—

Soil.—Generally speaking, assuming the presence of favourable climatic conditions, any light soil, as loams and sands, is suited for cotton-growing. Stiff clays, and wet soils, are objectionable, as any liability to retain stagnant water is fatally injurious to the plant. Very rich soil in a tropical region is apt to make the plants run to stalk and leaf, while the same would be advantageous in a colder situation. Free drainage, with abundant facility for irrigation where rain is insufficient, may be taken as primary essentials.

Tillage.—Deep ploughing of the ground is absolutely necessary, to allow the tap-root of the plant to penetrate it to the utmost. In India, the limit to the depth of ploughing is commonly about 6 in., in America, 12 in., and in Guiana, 18 in. It is certain that great benefit would arise from stirring the soil to a depth of even 30 in., the increased penetration of the roots rendering the plant much more independent of drought, and other external influences. In the S. States, the preparation of the land commences in November, and continues until March–April, when the sowings take place. The land having been ploughed and harrowed down, is then again ploughed, and thrown into ridges or beds, about 10 in. high, and 2–2½ ft. broad, the tops being neatly levelled or smoothed by a one-horse implement, termed a "sweep."

Sowing.—The sowings are made as early in the season as the frosts will allow, in order to get all the land planted in good time, and to have the crop in as forward a state as possible. In this, however, there is always more or less risk, for late spring frosts may come, and all the young plants may be cut off in a single night, entailing the necessity of resowing the whole of the fields. The best sowing season in Western India appears to be after the first heavy rains of the S.W. monsoon.

The manner of sowing varies according to soil and locality, and according to personal ideas. Thus, the distance of the rows, from centre to centre, ranges from 5 to 7 ft. in America, and averages about 3 ft. in India; and whilst some deposit the seed in furrows opened by a light plough, others carefully dibble in the seed at exact distances apart. This latter method is considered much superior. The beds having been formed, a gang of men (each taking a row) proceed rapidly along them, striking their dibbles into the centre of each, at exact distances of 12–24 in. apart. A second gang (generally women) deposit 4–6 seeds in each hole or indentation made by the dibbles, and a third gang (generally young boys and girls) follow with light hoes, and cover the seed with soil, thus completing the operation.

The seeds should be soaked in a mixture of cow-dung and water, or in a dilute solution of saltpetre, and then be sun-dried for about an hour, before sowing. Upland seeds are not only furred by the cotton lint still remaining on them, but they stick so together, that their delivery by drilling-machine is uncertain and unsatisfactory.

Weeding and Thinning.—The seed being sown, the greatest possible care is taken to prevent the growth of weeds, for these may seriously injure, perhaps entirely destroy, the crop. The weeding gangs, with light sharp hoes, also from time to time cut out the weakly plants, until at length only two, and these the strongest, are left in each hole. Supplying, or resowing the holes that have failed to produce plants, likewise occupies attention; and the soil washed down from the ridges should occasionally be drawn up round the plants, as before. It is always the object of the planter to do as much work as possible by horses, mules, ploughs, sweeps, &c., and as little as he can by hand-labour; but the weeding of the very young and tender plants is too delicate an operation to be performed with any safety or nicety altogether by ploughs or sweeps; although some never use a hoe in the cotton-fields.

Topping.—When the plants exhibit an inclination to produce wood and leaves, at the expense of flowers and seeds, their tops should be nipped off when the podding commences.

Picking.—The whole cultivation of the cotton-plant, up to the period of its first "picking," is termed "making the crop." If the season has been forward and favourable, the picking may begin (in America) in August; but if backward, the first general picking may be delayed until September; in uncommon cases, in some districts it may begin as early as July. Whenever it does commence, the chief dread of the American planter is an early frost; for until a killing frost does occur, the plants continue to produce and ripen their bolls. Each picker takes a bag (tied round the breast or waist) and a good-sized cotton sheet; the former he fills with the cotton he picks, which he then lays out on the latter to dry, whilst he is refilling his bag, and so on until the sheet will hold no more, when it is carried to the weighing-house.

A good careful hand will pick in a fair field 200 lb. of seed cotton in a day; to accomplish a greater quantity, the cotton must be unusually thick on the bushes. On most plantations, the average does not exceed 100 lb. a hand.

Successive pickings, each being less in quantity, at length so exhaust the cotton on the bushes, that there is no longer any left to pay for further picking; the cattle are then turned in, and speedily destroy the bushes, and the land is left in this condition until required again.

Produce.—In the valley of the Mississippi, the common average yield per acre of ginned cotton is one bale of 400 lb., whereas in S. Carolina, Georgia, &c., 200 lb. is considered an excellent return, much of the land not giving 100 lb. an acre. There is, however, abundance of rich land in all these states, which will yield 400 lb. an acre; but being low lying, the cotton is liable to mildew, to be injured by wet, and to be killed by early frosts; hence such lands are preferred for corn and rice. Some Upland cotton-plants, under favourable circumstances, are wonderfully prolific, producing 300–400 bolls a tree, weighing 4½ lb. of seed cotton, equal to about 1½ lb. of ginned cotton. Indeed, the produce per acre may be much increased by a good selection of seed, and by a careful attention to the due preparation and manuring of the land.

The average yield from native cultivation in India is about 50–60 lb. of ginned cotton to the acre; yet the result of careful scientific experiment has been an average of 267 lb. an acre.

To pick cotton properly is a very nice and delicate business, inasmuch as it is essential to withdraw every particle of cotton from the boll at one pull, without getting any leaf, scraps of leaves, or other foreign matter clinging to it. By dexterous management, so as to grasp lightly with the fingers the five sections comprising the boll, and withdraw all at once the cotton in it, the rapidity of the picking is ensured; whereas, by making two, three, or four efforts, but a small quantity would be gathered in the day's work. By obtaining it free from fragments of leaves, and of the boll itself, the cotton is clean, and consequently entails little or no trouble in getting rid of extraneous matters prior to being ginned.

A comparatively dry season, with only a few showers now and then, is most favourable for cotton-picking. The wetness of the bushes, from the nightly dews, causes much sickness among the workpeople; and the cotton picked in a damp state deteriorates greatly in value.

Long-Staple or Sea-Island.—The preparation of the land, and the throwing up of the beds for the plants, very much depend upon the situation of the fields and the nature of the soil. The land may lie low, and be very much impregnated with salt, from the influx of high tides, or it may be swampy from fresh water; again, it may be very light and sandy, or it may be stiff clay, or a nice warm loam, lying high and dry, above the influence both of tides and freshets. According as these conditions vary, so, to a certain extent, does the practice of the planter. In low-lying lands, very light drainage alone is practicable, hence a clay soil is liable to be cold and trying to the plants, keeping them sickly in appearance and backward in growth. In such cases, it is usual to ridge very high, to plant thinly, and to give the warmest manures available. The spaces between the ridges act as drains to carry off the superfluous water. These ridges are mostly thrown up in the first place by means of ploughs, and are finished off by the hoe; and throughout the whole culture there is a great deal more hand-labour than on Upland plantations, and infinitely more care is bestowed. On higher and drier lands, such heavy ridging is not required, although the system is, to a certain extent, universal on all Sea-Island plantations.

In all operations, horse or mule labour is availed of, as far as possible; but the nature of this cultivation necessitates a constant recurrence to manual labour. The produce is so much more valuable than Upland cotton, that the Sea-Island planter can afford more time, and more expensive labour.

Great numbers of these island plantations have large stores of vegetable manure, brought by intersecting rivers, creeks, &c., besides the quantities of rich saline mud, intermingled with small shells, which they likewise furnish. It is not uncommon to see large tracts of land, which, but a year or two previously, were quite covered by salt water, and which still retain so much saline matter as to be apparent to the eye, covered with the most luxuriant growth of bearing cotton.

There is no difficulty in sowing this description of cotton-seed by means of a drilling-machine, for the seeds are perfectly smooth, and consequently easy of delivery. The sowings being effected, the after-operations of weeding, moulding, and banking, or ridging, are performed. About July or August, the picking commences, and continues generally until November, unless severe frosts occur earlier. If rapidity and care are required in picking the short-staple variety, extreme care and attention are demanded in gathering in the delicate and valuable "Sea-Island." Rapidity of work is by no means so essential as great cleanness, for the aim is to preserve the quality.

When it has been picked, the first object is to get rid of any superfluous moisture it may contain, without drying it too much. It is then picked over, to get rid of all motes, and discoloured particles of cotton, which sometimes, from insects boring into the bolls, and from other causes, get mixed up with the mass. This being performed, it is kept in heaps, sometimes 5 ft. high, 4–5 ft. broad, and 20 ft. long, and covered over with cloths. The object of this is to preserve the oiliness, strength, and gloss of the fibre (which a lengthened exposure to the air would destroy) until it is sent to market. But the liability to heat must be attentively watched and guarded against, and whenever it gets too warm, the heaps must be immediately opened out, and the cotton be carefully spread on the clean-swept floor of the cotton-house, to be again replaced in heaps as soon as it has become perfectly cool. If the heaps become hot, in a very short time the oil contained in the seeds oozes out on the fibre, and imparts to it a dirty-yellow colour, which rapidly changes to a brown, and destroys its commercial value; but many planters do not object to its becoming very slightly heated, esteeming it an advantage rather than otherwise, inasmuch as they consider that the fibre gradually extracts some of the oil from the seeds, and thereby becomes stronger, softer, and more silky, whilst at the same time it acquires a very delicate shade of yellow, such as experienced buyers admire.

Manures.—The object of cotton-culture is to develop the quantity and quality of the down which envelops the seeds of the plants, hence manuring must be conducted with the aim primarily of supplying such constituents as are extracted from the soil by the fructificatory parts of the plant. An analysis of the ash obtained from the incineration of cotton fibre shows that the principal mineral ingredients are potash (31·05 per cent.), lime (17·09), and phosphoric acid (12·32); in other words, 10,000 lb. of cotton fibre abstract from the soil, 31 lb. of potash, 17 lb. of lime, and 12 lb. of phosphoric acid. Examinations of different samples of cotton fibre have shown that while New Orleans cotton contains 0·079 per cent. of phosphoric acid, Surat contains only 0·027 per cent.; this fact has suggested the important question, whether the inferiority of Indian cotton is not due to deficiency of phosphoric acid in the soil.

Analysis of the ash of cotton-seed reveals the presence of 45·35 per cent. of phosphoric acid, 29·79 per cent. of lime, and 19·40 per cent. of potash. The seed is thus much more exhaustive than the fibre, and when its much greater proportion is taken into account, it is probably not an exaggeration to say that while the cotton fibre (or "lint," as it is called) alone takes no more than 4 lb. of soil ingredients for every bale of cotton, the seed accompanying it takes about 38 lb. If the seed, therefore, after expression of the oil (see Oils), be made into cattle-food, and be returned in the form of cattle-dung to the ground, the crop will be one of the least exhaustive known; but if the seed be permanently removed from the land, heavy manuring will be necessary to maintain fertility.

The analyses indicate that the manures best adapted to the end in view are superphosphate of lime (supplying both phosphoric acid and lime), and potash (either wood-ashes, or natural potash salts); and that nitrogenous manures—guano, nitrate of soda, sewage, &c.—should be avoided, as forcing the plant to produce wood and leaf, rather than flower and fruit. Salt appears to be peculiarly beneficial.

All refuse from the plant should be returned to the soil, either by being burnt, and the ashes ploughed in, or by allowing cattle to feed upon it on the ground. The stems contain a fibre, about which extravagant ideas have been current. It is probable that any attempt to improve this fibre would be at the expense of the seed-down, or it would entail so much extra manuring that the end would not warrant the means.

Diseases and Enemies.— The cotton plantations of America have long been infested by two most destructive insects—the cotton-worm (*Aletia argillacea*) and the boll-worm (*Heliothis armigera*). The former has been credited with the ruin of 38–98 per cent. of the whole crop on some estates. The highest average of loss is in the southern portion of the cotton-belt, as in Florida and S. Texas; it increases also in a westerly direction, commencing with Georgia at 16 per cent., and ending with Texas at 28 per cent.; in the northern portion of the belt, the averages are low, ranging from 5 to 8 per cent., while in many parts, notably N. Carolina, the caterpillar appears so late as to generally do more good than harm, by destroying the top foliage, and admitting the sun.

The moth from which this caterpillar originates appears either to hibernate in the cotton-districts in the moth state, or to emigrate annually from warmer regions, as the Bahamas. Its predilection for sweets affords the most likely means of arresting its ravages. Arseniate of copper, mixed with honey, and applied to tree-stems, &c., about the estate, may kill the first moths, and check the pest at once. When the worms are hatched, they feed on the under side of the leaves, and can then only be reached by an upward sprinkling of a poisonous solution, generally arsenical.

Separation of the Fibre.—Cotton-ginning, or the separation of the fibre from the seed, is always performed in the vicinity of its growth. Seed cotton only yields 15–30 per cent. of fibre, but the separated seed possesses valuable qualities, and is carefully preserved.

Ginning is the first process to which the fibre is subjected; without the gin, or its equivalent, the cultivation and manufacture of cotton on its present extended scale would have been an impossibility. The important inventions that took place in Lancashire during the 18th century led to the introduction and extended cultivation of cotton in the S. States of America, and, towards the close of the century, the want of a ready and facile instrument for separating the lint from the seed was becoming severely felt. Picking by hand, which was the method in vogue, was a slow and costly process, a good worker not being able to clean more than 4 lb. of seed cotton, yielding about 1 lb. of fibre, per diem. The want being general, the attention of several individuals was directed to, and their efforts were engaged upon, the invention of some suitable mechanical appliance. As might be expected, several inventions were brought forward so nearly simultaneously that it is now difficult to award priority to the deserving one. Eve, Bull, and Whitney are competitors for the honour, and it is not easy to say which was first, or which invention was the most practically successful. Public opinion, however, seems to have decided that it is to Whitney that the world is indebted for the saw-gin.

In Eastern countries, where cotton has been cultivated and manufactured for ages, the methods in use in remote districts, particularly in India, are still of the most primitive character. Previously to the occurrence of the American Civil War, which caused a great amount of attention to be directed to that country as a source of cotton supply, these methods were almost general. The first was simply hand-picking, the second was by the foot-roller, and the third by the *churka.*

The foot-roller may be termed the first mechanical appliance for cleansing cotton. The operator procures a flat smooth stone, 1–2 ft. square, which is covered with a layer of seed cotton. An iron roller is next placed upon it, and worked backward and forward by the feet of the operator, who sits upon a stool while at work. As the Indian cottons are mostly of the smooth-seeded varieties, the lateral pressure exerted pushes the seed over the edge of the stone, leaving the clean cotton upon its surface. The product of a day's work by this method is 4–6 lb. It is altogether ineffective when applied to the green-seeded American varieties, the fibres adhering very tenaciously.

Previous to the introduction of European gins into India, the *churka* was the instrument most generally in use. It is a rude roller-gin, containing two rollers, fixed in upright posts borne in a rail at their base, and rendered firm by a cross-piece. Sometimes both rollers are of wood, sometimes the upper one is of iron. The Guzerat *churka* may be taken as the representative of this class of machines; the upper roller is of iron, ½ in. in diameter, the lower, of wood, 2 in. in diameter. The rollers are not geared together, and there is a slight space left between them. When working, their surface velocities are not alike, the iron one revolving most quickly. The cotton is presented to the rollers, and the fibre is dragged from the seed, and carried to the other side, the seed being kept back until cleared, when it falls in front of the rollers. It is sometimes worked by one person, sometimes by two. The yield is 6–8 lb. of clean cotton a day for each person engaged. When the *churka* is in good repair, the quality of the work is very good, no violence being done to the fibre. But the machine is liable to frequent derangement, and considerable wear and tear, owing to the rudeness of its construction.

Eli Whitney's saw-gin consists of a drum carrying a number of circular plates, the periphery of which is cut so as to form teeth, or rather hooks. The plates are 9–12 in. in diameter; above the cylinder is placed an inclined grid, which forms the bottom of a box or hopper, into which the seed cotton is placed. The bars of this grid are set sufficiently close to prevent the passage of the seed. When working, the plates upon the cylinder pass between the bars of the grid, to the depth of about one-third of their diameter, and the teeth, laying hold of the fibre, drag it through the bars, leaving the seed behind. The latter is subjected to this action as long as any fibre remains upon it; when thoroughly stripped, it falls through a narrow slit in the bottom of the box, into a receptacle provided for it. The cotton, as it is drawn through the grid by the saws, is stripped from them by means of a swiftly revolving brush, which throws it through an aperture into another apartment, called the "lint-room."

It will be obvious from this description, that the filaments of cotton, being thus torn from the seed, are liable to serious damage from this action. A great amount of skill has, therefore, been spent in the endeavour to make the saws as harmless as possible in their action, and to diminish the acuteness of the stroke, by which the fibre might be broken. The striking edges are therefore rounded, made perfectly smooth, and curved in such a form as to avoid any sudden jerk or pull after the teeth have laid hold of the fibre; whilst the increasing drag is such as to strip the lint from the seed, as speedily as possible, with a minimum of violence. There are numerous varieties of the saw-gin, but the differences between them are only in points of detail.

The Macarthy gin, so named from the inventor, is constructed on a different principle, and is admirably suited for long-stapled cottons. It is also capable of doing good work with the short-stapled varieties. The production from it is not equal in amount to that from the saw-gin, but the quality is far better.

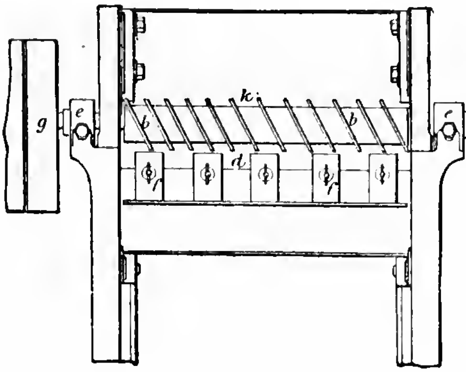
This gin, in its original and simplest form, consists of a leather roller and two steel blades. One of the latter is pressed tightly against the revolving leather roller. The fibre is drawn in by the rough surface of the roller, and, as the latter revolves, the lint is stripped from the seed, which falls into a receptacle beneath. To assist in the detachment of the seed from the fibre, the second blade is adjusted a little in front of the fixed one, and has imparted to it a rapid vibratory motion, by means of which the seed is struck from the fibre. From this action the vibrating blade has been termed the "beater," the fixed one being called the "doctor." The machine is provided with a grid, upon which the seed cotton is placed, the bars being so arranged that the seed cannot pass through them, until it has been stripped of all fibre. There are many varieties of the Macarthy gin, all constructed upon this principle, but differing in detail.

In construction, the double-action knife-roller gin, made by Dobson and Barlow, differs more widely from the original Macarthy than most others made on that principle. It has been subjected to severe test trials with other gins, at the competitions instituted by the Government of India at Manchester and Broach. The results of these trials have recently been issued, and an examination of them will show that this gin emerged from the tests with great credit to its makers.

Figs. 657, 658, 659 show it in front and end elevations, and in section. The roller *a* is solid, and composed of discs of walrus leather, compactly pressed together upon a square shaft. The knife-roller *b* is made up of a number of discs, fitted obliquely upon a wrought-iron shaft, as seen in

Fig. 657. Objection has been taken to this form of the disc that it was liable to work all the cotton to one side of the gin. In order to provide against this, an alternative form of the knife-roller has been constructed, which is shown in Fig. 661. The box or hopper *c* is for the reception of the seed cotton; the knife *d* extends across the frame, and its functions are those of a "doctor"; two set-screws *e*, one at each end of the rollers, are for the purpose of adjusting the distances between them.

657.



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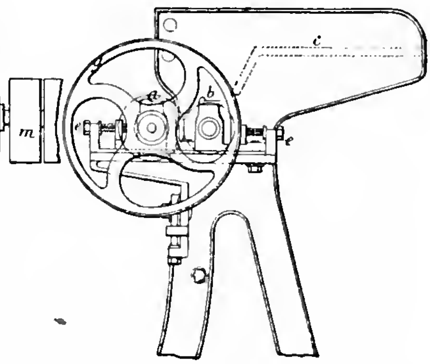

The knife *d* is carried by the springs *f*, capable of adjustment by thumb-screws attached. The gin has a fast and loose driving-pulley for each roller, shown at *g* and *m*; these being of different diameters, indicate different speeds of their respective rollers. A semicircular grid half encloses the knife-roller *b*, as can be seen in the section. This grid, according to choice, may be perforated with holes as at A, or have transverse or longitudinal bars as in B C (Fig. 660).

The process is as follows:—The seed cotton, being placed in the hopper *c*, descends upon the knife, and fills in the interstices *k* between the blades. By the revolution of the rollers it is brought into contact with the surface of *a*, which lays hold of the fibre, drawing it down. The doctor-knife *d* prevents the seed being drawn along with the fibre, and the revolution of the roller *b*, carrying oblique blades, causes the latter to disengage the seed from the fibre, which then drops through the grid into a receptacle beneath. The bars of the grid are so arranged that no seed to which fibre adheres can pass through, but is carried round by the roller, and again subjected to the action of the stripping-roller, until quite cleared. The cleaned cotton is discharged upon the floor, or it may be formed into a rough sort of "lap." The disc-roller revolves at the rate of about 350 rev. a minute. A 40″ gin on this principle is capable of cleaning 300–800 lb. of seed cotton in an hour, according to the description. The yield of clean cotton is 75–150 lb. At higher speeds this is increased proportionately.

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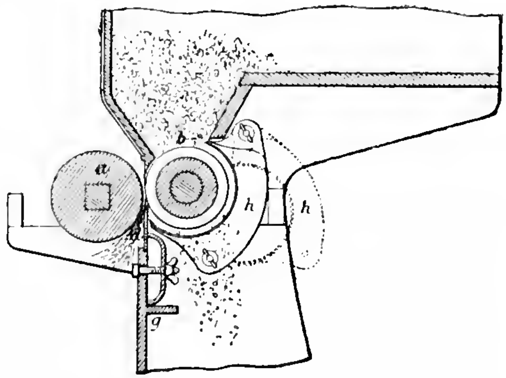
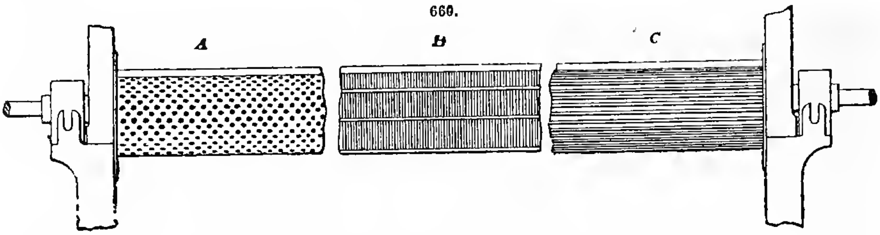


The "lint" or "wool," when thoroughly cleansed, is packed in bales by hydraulic pressure, for export. The bales are covered with coarse jute or cotton canvas, bound with ropes or iron bands. The seed yields a valuable oil (see Oils—Cotton-seed), and is made into cakes for feeding cattle.

Characters and Uses of the Fibre.—Seen longitudinally, the fibres of cotton appear quite independent of each other; they are flat, and always more or less twisted, like a cork-screw, as shown in Fig. 662. This last feature is quite characteristic. The length of the fibres varies from 1 to $1\frac{1}{2}$ in. for long-stapled, and from $\frac{3}{8}$ to $\frac{3}{4}$ in. for short-stapled. The parts indicated in Fig. 662, are —*a*, sections; *b*, longitudinal views; *c*, ends; mag. 300. The manufacturing capacity of the fibre is discussed at length in the article on Cotton Manufactures (pp. 730–733). Its uses are further described under Hosiery, Lace, and Small Wares.

Imports and Values.—From the 14th to the 16th centuries, the cottons of Candia, Lemnos, Cyprus, Malta, Sicily, S. Italy, and the district between Jerusalem and Damascus, were those chiefly imported into Europe by the Genoese and Venetian merchants. Our imports of raw cotton in 1870 were contributed (in cwts.), as follows:—United States, 6,495,045; British India, 3,040,550; Egypt, 1,283,037; Brazil, 573,331; France, 330,653; Anatolia (Asia Minor), 51,581; Chili, 36,119; sundry European countries, 35,271; New Granada, 34,295; European Turkey, 33,278; Peru, 21,216; British W. Indies, 18,851; Foreign W. Indies, 14,660; W. Coast Africa, 12,503;

660.



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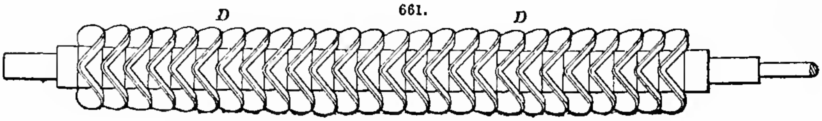
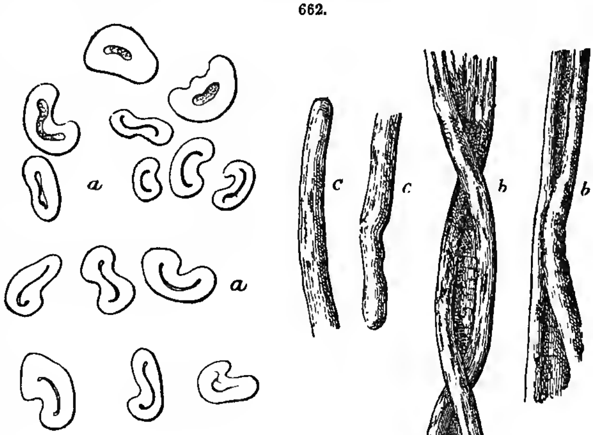


Ceylon, 8269; Venezuela, 8268; Queensland, 8201; New South Wales, 7928; Syria and Palestine, 7326; Natal, 4368; Nova Scotia, 4317; New Zealand, 3348; Gold Coast, 2721; French India, 2348; Illyria and Dalmatia, 2114; British Guiana, 1812; Argentine Confederation, 1478; Euphrates and Persian Gulf, 1060; Malta, 832; Italy, 611; Greece, 571; Cape of Good Hope, 561; Persia, 527; Sierra Leone, 493; Siam, 135; Gambia, 120; China, 94; Ecuador, 28; Algeria, 20; Mexico, 18; Mauritius, 6.

662.



The quantities (in cwts.) and values of imports of our raw cotton, in 1879, were:—Atlantic Ports of U.S.A., 9,664,167: 25,945,174*l.*; Egyptian ports, 1,412,786: 5,088,109*l.*; Bombay and Scinde, 896,691: 2,210,883*l.*; Bengal and Brit. Burmah, 427,230: 993,704*l.*; Madras, 292,712: 709,714*l.*; Brazil, 152,185: 427,964*l.*; New Granada, 84,622: 255,166*l.*; Peru, 70,473: 222,466*l.*; France, 52,823: 140,521*l.*; Denmark, 12,363: 24,590*l.*; Belgium, 11,623: 30,547*l.*; Chili, 3924: 11,571*l.*; Germany, 3834: 13,024*l.*; Australia, 3626: 20,403*l.*; Turkey and Cyprus, 3316: 9682*l.*; British N. America, 3314: 9137*l.*; Ceylon, 2542: 6332*l.*; Pacific Ports of United States, 673: 4793*l.*; other countries, 20,368: 56,408*l.*; total, 13,119,272: 36,180,548*l.*

The quantities and values for the four preceding years were as follows:—1875, 13,324,564 cwt., 46,259,822*l.*; 1876, 13,284,454 cwt., 40,180,880*l.*; 1877, 12,100,725 cwt., 35,420,852*l.*; 1878, 11,967,679 cwt., 33,519,549*l.*

Grewia oppositifolia.—Exogen. Native of India, chiefly in the Himálayas. The inner bark is employed by the natives for making ropes and coarse cloth. A fairly good paper has also been made from it. *G. occidentalis*, in S. Africa, affords a so-called "Kaffir hemp," a white fibre of great strength extracted by retting, and much used by the Kaffirs.

Guazuma tomentosa—Bastard Cedar.—Exogen; tree, 40–60 ft. Introduced from the W. Indies, but now commonly cultivated in India. A fibre prepared from the young shoots was submitted to experiments by Dr. Roxburgh, and found to be of considerable strength, breaking at 100 lb. dry and 140 lb. wet.

Hardwickia binata.—Exogen; tree, 100 ft. Found in India, on the banks of the Cauvery, in Salem and Coimbatore, on the western slopes of the Neilgherries, in Mysore, in the Godavery forests, and in Bombay. It is recommended for culture in Victoria. It is easily raised from seed, readily pollarded, and flourishes up to an elevation of 3500 ft. in India. The bark yields without difficulty a valuable fibre for cordage purposes.

Helianthus annuus—Sunflower—Exogen. Native of Peru, and selected for culture in Victoria. In these climates, the plant would repay culture for the fibre yielded by its stems. About 6 lb. of seed are required for an acre; the plant likes calcareous soil; and a return is obtained in a few months.

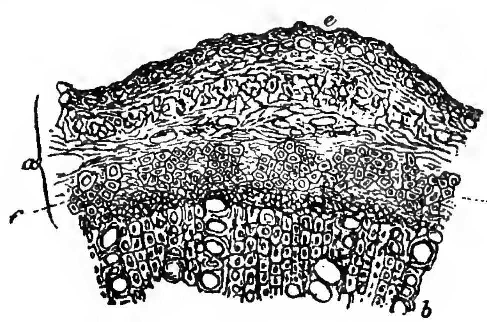
H. tuberosus—Artichoke.—Attains to perfection in Brazil. The stem is rich in textile fibre. The plant can only be fully developed in a soil rich in potash.

Helicteres Isora.—Exogen; shrub, 12 ft. Native of India, growing at the foot of the Himálayas, and at the base of the hills in Travancore. It is a common plant. Its bark yields a fibre well adapted to cordage purposes, and extracted by retting the stems in water, and then beating them. It is strong and white, and is used locally for making gunny bags, and for the curtain blinds of verandahs of native houses.

Hemp.—*See* **Cannabis sativa.**

Hibiscus cannabinus—Ambaree, Deckanee Hemp.—Exogen; 5–12 ft. This plant is common in almost every part of India. It is usually cultivated in the cold season, but, with sufficient moisture, it will thrive throughout the year. It prefers a rich loose soil. The seed is sown about as thick as hemp, but generally mixed with that of a grain crop; the sowing must be thin, to prevent shading the latter too much. It occupies the ground for about three months, from the sowing to the harvesting. In some districts, it is sown alone. In the districts of Furreedpore and Backergunge, it thrives well in marshes, and even in waist-deep water, and contributes largely towards the *deorá* jute of those localities. Rich soil has yielded over 3000 lb. clean fibre per acre. It is readily cultivated, and, with more attention, might compete with jute. The bark of the stem is full of strong fibre, which is extracted and prepared like the fibre of the jute plant (*Corchorus*), or that of the sunn (*Crotalaria*). A section of the stem is seen in Fig. 663: *a*, bark; *b*, lignose; *e*, epidermis; *f*, bast fibres, coloured distinctly yellow by test H; mag. 160. The dimensions of the filaments are:—length: max., 0·236 in.; min., 0·078 in.; mean, 0·196 in.; diameter: max., 0·00132 in.; min., 0·00056 in.; mean, 0·00084 in. The length of the extracted fibre varies between 5 ft. and 10 ft. The fibre is somewhat stiff and brittle, and though used as a substitute for hemp and jute, it is inferior to both. The breaking strain has been variously stated at 115–190 lb. It is bright and glossy, but coarse and harsh. It is sold with and as jute, and is employed in Bengal for the purposes of jute, including fishing-nets and paper. Samples of the fibre exposed for 2 hours to steam at 2 atmos., followed by boiling in water for 3 hours, and again steamed for 4 hours, lost only 3·63 per cent. by weight, as against flax, 3·50; Manilla hemp, 6·07; hemp, 6·18–8·44; jute, 21·39. The average weight sustained by slips of sized paper weighing 39 gr., made from this fibre, was 71 lb., as compared with Bank of England note pulp, 47 lb. It worked satisfactorily, and took ink well.

663.



H. [Abelmoschus] esculentus—Okro (Fr. *Gombo*). — Exogen; herbaceous annual; 2–10 ft. A native of the W. Indies, notably Cuba, where it grows freely in almost all soils; indigenous also to Africa, wild and abundant on the White Nile, and near the Victoria Nyanza; long naturalized in India, and commonly cultivated in gardens. The plant is grown in India, for its edible pods, chiefly in Jessore, Rungpore, Bogra, Hooghly, the 24-Pergunnahs, Nuddea, Moorshedabad, and Cuttack; the culture might be much extended in Bancoorah, Beerbhoom, and Nowgong. It is very common in Burmah; and is being introduced into Algeria.

The fibre is long and silky, and generally strong and pliant; its breaking strain, according to Roxburgh, is 79 lb. dry, and 95 lb. wet. When well prepared, as in the Southern Presidency, it is adapted for the manufacture of rope, twine, sacking, and paper. In Bengal, its fibre is reputed harsh and brittle, owing doubtless to improper treatment, and it is but little manufactured there. In Dacca and Mymensing, it is used to adulterate jute. It resembles hemp, and, under this name, is exported, to the amount of a few thousand cwt. yearly. In France, the manufacture of paper from this fibre is the subject of a patent; the fibre receives only mechanical treatment, and affords a paper, called *banda*, equal to that from pure rags.

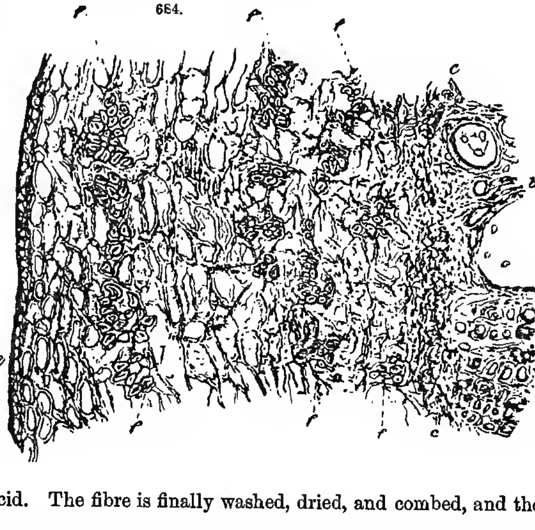
H. abelmoschus [*A. moschatus*], grows in Bengal, Travancore, Coromandel, and Burmah. Produces a strong fibre. Plants, cut in flower and immediately steeped, broke at 107 lb. wet and dry. *H. furcatus* is found in the S. Provinces of India, and in the interior of Bengal. The bark yields an abundance of strong white fibres; a line broke at 89 lb. dry, and 92 lb. wet. The stems are cut when the plant is flowering, and steeped at once. *H. Ludwigii*, native of S. Africa, is a tall and shrubby species, yielding fibre of great strength and toughness. *H. ficulneus*, native of Bengal, with a straight stem 6–14 ft. high, and very smooth bark, thrives luxuriantly with little or no care, yet is very little cultivated for its fibre. The seed is sown in beds in May, and when the plants are 6 in. high, they are set out in rows, 9 in. apart each way. The luxuriant growth and habits of the plant commend it to serious attention. The bark abounds in flaxen fibres, long, glossy, white, fine, and strong, and easy of extraction. *H. Sabdariffa* is a native of Tropical Asia and Africa, common in Indian gardens, abundant in the W. Indies, and selected for culture in the warmest parts of Victoria. The plant is cut while in flower, and a fine, silky fibre is extracted from the stem, by retting in fresh water. The staple is long and uniform, and said to be adapted to cordage. The tow yielded by it is valuable for paper-making. *H. tiliaceus*, native of India, Tropical Australia, and the Pacific groups, is extensively used by the natives for making fishing-nets, cordage, &c. *H. vitifolius*, common all over India, is a wild plant yielding a very white, fine and strong fibre, extracted by retting. *H. elatus*, the "Cuba bast" of the W. Indies, is employed in making cigarette wrappers. There are probably several other fibre-yielding species of *Hibiscus* awaiting research and utilization.

Holoptelea integrifolia—Wawla bast.—Exogen. Native of the W. Indies. The fibre is not strong.

Holostemma Rheedianum.—Exogen. Native of India, from the southernmost province to the base of the Himálayas. It yields a fair fibre, said to be in best condition after the rains.

Humulus Lupulus—Hop (Fr., *Houblon*; Ger., *Hopfen*).—Exogen. Native of the temperate zone of Europe, Asia, and N. America. The bine of this well-known plant contains a quantity of useful fibre—70–75 per cent. of the dry weight—which is generally thrown away. A section of the bine is shown in Fig. 664: *b*, lignose; *c*, cambium; *e*, epidermis; *f*, bast fibres, coloured blue by test H; mag., 100. The fibres are very supple. Their dimensions are:—length: max., 0·748 in.; min., 0·157 in.; mean, 0·393 in.; diameter: max., 0·00072 in.; min., 0·00048 in.; mean, 0·00064 in. The fibre is well suited for paper-making, especially unbleached paper and cardboard. In Sweden, it has long been applied to textile manufactures. It is extracted from the plant by steeping for 24 hours in cold water containing 5 per cent. of sulphuric acid, or for 20 minutes in boiling water with 3 per cent. of the acid. Another plan is to boil for $\frac{3}{4}$ hour in water containing soap or soda, then to wash, and boil in very dilute acetic acid. The fibre is finally washed, dried, and combed, and then resembles flax.

664.



Iris pseudacorus—Yellow water-iris.—Endogen. A common weed in England and Ireland. The leaves yield when dry about 60 per cent. of available fibre for "half-stuff," which makes a fairly good paper.

Jubæa spectabilis—Coquita.—Endogen; palm. Plentiful in Colombia, Chili, and other parts of S. America. The bark of the tree yields a fibre of great strength, which is commonly used locally for the manufacture of ropes, which are very durable, and sold at a trifling rate. Cables made of it are found to last longer than hempen ones.

Jute.—*See* **Corchorus.**

Kittool.—*See* **Caryota urens.**

Kydia calycina.—Warang bast.—Exogen. Native of the Tropical Himálayas, W. Ghâts, and Burmah. The fibre resembles lime-tree bast (*Tilia europæa*).

Lagetta lintearia.—Lace-bark tree.—Exogen; tree, 25–30 ft. Native of Jamaica, growing in rocky places. The inner bark of the tree consists of numerous layers of fibre, interlaced in every direction, and forming fine meshes. On soaking it in water, it is easily separated. A section across the internal bark is shown in Fig. 665: *p*, parenchyma; *f*, bast fibres, coloured distinctly yellow by test H; mag.. 300. The fibres are very fine, full, smooth, and stiff. Their dimensions are:—length: max., 0·236 in.; min., 0·118 in.; mean, 0·196 in.; diameter: mean, 0·0004 in. They are much used locally for making lace articles, and other delicate textile fabrics. It is suggested that the bark might be used for paper-making, if sufficiently plentiful.

665.

Laportea pustulata.—The only foreign nettle which will withstand the cold of the European winter. (*See Urtica sp. div.*)

Lardizabala biternata.—Native of Chili, and selected for culture in Victoria. A climber, with stems of enormous length, which, in Chili, are dried, and used as ropes. It would probably yield good tough cordage fibre.

Lasiosiphon speciosus—Rameta bast.—Exogen. Found in the Deccan. The fibres are very strong, and almost colourless.

Lavatera arborea—Tree-mallow.—Exogen. Native of Middle Europe and the countries of the Mediterranean; recommended for culture in Victoria. Has long been an inhabitant of some of the sea-cliffs and coasts of the United Kingdom; also grows in Madeira. It requires no care for cultivation, and is of quick growth; it probably would not withstand the cold of high inland districts. The inner bark yields a strong fibre, which is somewhat coarse, but is capable of manufacture into cords, ropes, and mats, and may probably be used for paper-making.

L. plebeja—Australian Mallow.—Grows luxuriantly in the barren country beyond the Darling River, and extends from S. Australia, through Victoria, into New South Wales. It may be obtained in considerable quantity along the Murray River and many of its tributaries. It is a perennial, and will probably admit of an annual crop being removed. It has been successfully tried for rope and paper-making. In the latter case, it is pulled up by the roots and hung up to dry; when dry, it is chopped up small, treated with alkali, to remove the gummy matter, and, after ordinary bleaching, may be used like rags. It is employed by the natives for baskets and fishing-lines.

Leopoldinia Piassaba—Para Piassava.—Endogen; palm, 20–30 ft. This tree grows abundantly near the White River, that flows into the Barra de Rio Negro, as well as on some of the tributaries of the Orinoco; it is also found in the Amazon basin; but the bulk of its fibre comes from the Barra de Rio Negro. Its habitat is low sandy flats, where water may stand a little in rainy weather; but it avoids swamps. The dilated base of the petioles separates into a long coarse fringe, which is collected by the natives, and tied in bundles several feet long, weighing about 1 *arroba* (32 lb.). The fibre is not interlaced with the bark of the leaf. Hitherto the fibre was despatched in boats by the natives on the White River, to Para, whence the fibre takes its name. The irregular arrival of these vessels caused great fluctuations of price at the port. Latterly steamers ascend as far as Manaos, at the junction of the Amazon and Barra de Rio Negro, and bring the fibre direct to England. It absorbs much more water than the Bahia kinds, and each tree yields a larger quantity. This description, however, only forms about 4–5 per cent. of the total production of Piassava fibre. Locally it is much used for making rough but durable ropes, which resist the destructive effects of alternate wetting and sun-drying better than any other native fibre. Its consumption in this country is chiefly for brush-making. The prices in the London market fluctuate exceedingly—from 25*l.* to 45*l.* a ton. (See *Attalea funifera.*)

Arthur Robottom, of Mincing Lane, who is well known in connection with this fibre, states that parcels of a so-called "piassaba" have recently been collected in Peru, and shipped, viâ Manaos and Para, to this market. He describes it as tender, dark-coloured, and very fine, being quite different from either the Para or the Bahia kind. The first arrival brought 6–7*l.* a ton (not enough to pay freight and charges), while later ones have found no bidder at even 5*l.* a ton. Its market value is spoiled solely by carelessness in collecting it.

Lepidosperma gladiata—Sword-sedge.—Endogen. Native of Australia and Tasmania, found in great abundance on the coast lands. May be cut annually from the bottom of the stem, and the roots will throw up fresh shoots. When cut, it is partially bleached by alternate exposure to the sun and nightly dews. It is used by the natives for baskets and fishing-lines. Its only industrial use will probably be paper-making, for which purpose it is considered equal to esparto.

Linum usitatissimum—Flax (Fr., *Lin;* Ger., *Flachs*).—Exogen; 20–40 in. Central Asia has been pointed out as the original home of the flax-plant, which, as now cultivated, is an annual, supposed to be a variety induced from the anciently grown *L. angustifolium* of the Mediterranean basin. Almost the whole of the flax now grown is produced by *L. usitatissimum*, and the very trifling quantities contributed by *L. catharticum*, *L. crepitans*, and *L. perenne*, do not merit separate mention. The cultivation of flax has now almost a world-wide distribution, the temperate zone appearing to be best suited to its growth as a fibre-yielding plant. Belts of coast-land subject to moisture-laden winds possess the climate in which the plant attains greatest perfection; and the littoral, from the south of Spain, northwards by France, Belgium, Holland, Scandinavia, the Baltic, and the White Sea, embracing also Great Britain and Ireland, comprise all the principal flax-growing districts.

The approximate area under flax, and the yield per acre and total yield, of the chief countries which grow it as a fibre-plant, in the order of their importance, are as follows:—

(1) Russia: 2,000,000 acres, at 20 stones an acre, total, 250,000 tons. Flax is largely raised in three widely distant portions of the Russian Empire—the north-west, the centre, and the south. The first is by far the most important, especially in the provinces of Pskov, Livonia, and Witepsk; the second is much less productive; and in the third, the plant is raised chiefly for seed. (2) Germany: 329,362 acres at 27·9 stones, 57,432 tons. E. Prussia, Saxony, Westphalia, and Hanover are the principal contributors. (3) Austria: 232,494 acres, at 27·78 stones, 40,367 tons; chiefly in Bohemia and Moravia. (4) Italy: 201,023 acres, at 18·14 stones, 22,791 tons; more than half of this total is contributed by Lombardy, the best coming from Avellino, Caltanissetta, and Trapani. (5) France: 187,451 acres, at 36·34 stones, 42,575 tons. The following Departments are the chief producers, in the order stated:—Nord, Pas de Calais, Somme, Finisterre, Haute Garonne, Côtes du Nord, Manche, Landes, Loire Inférieure, Mayenne, and Gers. Others produce a good quality, but in small quantity. (6) Belgium: 140,901 acres, at 33·59 stones, 29,580 tons. The Belgian flax, particularly the Courtrai product, is unequalled by any in quality. (7) Ireland: 128,004 acres, at 24·51 stones, 19,611 tons. Almost the whole Irish growth is in the province of Ulster, the following counties being conspicuous—Down, Tyrone, Londonderry, Antrim, Monaghan, Armagh, Donegal. (8) Holland: 46,700 acres, at 31·77 stones, 9273 tons. The chief districts are Groningue, Rozenburg Island, Rotterdam, Pingjum, Werkendam, S. Holland, and Schöwen Island. The white-flowered flax is produced in Brielle, Zealand, and Friesland; the blue-flowered variety comes from a portion of the provinces of S. Holland, Guelder, and Brabant. (9) Sweden: 37,500 acres, at 20 stones, 4688 tons. (10) Hungary: 24,888 acres, at 20 stones, 3111 tons. (11) Denmark: 17,686 acres, at 20 stones, 2211 tons. (12) Egypt: 15,000 acres, at 20 stones, 1875 tons. (13) Great Britain: 7055 acres, at 24·51 stones, 1081 tons. The English counties having more than 100 acres under flax in 1879 were:—Yorkshire, 3129; Lincoln, 818; Somerset, 616; Suffolk, 608; Cambridge, 506; Norfolk, 436; Essex, 361; Dorset, 272. Scotland, in the same year, had a total of 73 acres; Wales, a total of 12. The total area for Great Britain in 1879 was 7055 acres; in 1870, it was 23,957 acres. (14) Greece: 957 acres, at 20 stones, 119 tons. The return just issued by the Registrar-General shows the Irish flax acreage in 1880 to be:—Ulster, 152,996 acres; Leinster, 2157 acres; Connaught, 1239 acres; Munster, 1142 acres. This is equal to an increase of 29,513 acres, or 23·1 per cent, over the figures for 1879.

The countries above enumerated by no means exhaust the list. America grows very large quantities of flax, principally for the sake of the oil-yielding seed (see Oils—Linseed), but also for the manufacture of coarse fabrics from the fibre. Canada had 8000–10,000 acres of flax in 1864, and promises to furnish a considerable amount of the fibre; some samples attracted attention at the Paris Exhibition. The plant has also been introduced into the French Colonies of Algeria and New Caledonia. In the former, about 14,000 acres of flax are cultivated, but the seed is the chief object. Natal also is encouraging the industry. In the Australian colonies, flax culture is destined to assume great importance; there is a wide range of soil and climate suited to the plant, and samples of the fibre, particularly from W. Australia, have proved so good that buyers in this country are enquiring anxiously for it. In India, flax has been grown and manufactured from very early times; but within the last 200 years, it has entirely lost its ground as a fibre-plant, being reduced to a stature of nowhere more than 18 in., and sown and cultivated in such a manner as to produce bushy, dwarfish plants, the sole object being the oleaginous seeds. The plant is grown very largely in Bengal, Behar, Oude, Bombay, the Punjáb, the N.W. Provinces, and Madras. There is an abundance of land available; but it is doubtful whether the heat of the climate would favour the production of fine fibre, and it is certain that the natives would not relinquish their present modes of culture for the sake of the seed, without assurance that the fibre would be equally remunerative. Portugal grows four varieties of flax: (1) *Gallego*, cultivated mostly in Braganza, Braga, Aveiro, Castello, Guarda, Coimbra, and especially Guimareas and d'Amarante; receives special care, and produces the fine *cambraia* linen. (2) *Mourisco*, grows chiefly in Alemtejo and d'Algarve, and yields a coarse thread. (3) *Coimbrao*, very common in Feira, Celorico, and other districts of Vianna;

valued next to Gallego. (4) *Riga*, cultivated especially in the neighbourhood of Oporto. Servia is reported to have about 3000 acres under flax.

Cultivation of the Plant.—The cultivation of the flax-plant for the sake of its fibre may be discussed under the following heads:—

Soil.—Assuming that the situation be in accordance with the remarks made above on the subject of climatic influence, land in "good heart" will produce the largest yield of fibre, and of the best quality; poor land will give weak fibre. Heavy land, with favourable weather for pulverizing the soil, will give rich crops. The land must always be in good condition, and clean. Peaty land without a clay subsoil, as well as sandy land with a gravelly bottom, is unsuited, and will give but a poor yield of fibre. Medium and alluvial soils are the best—a nice dry loam, neither too light, nor too clayey. In the polders of Holland, the vegetable mould of the Bocages, the peat of Connaught, the limestone of central Ireland, and the clay-slate of Ulster, good flax is grown; but the soils best suited for it are alluvial deposits. In all cases, perfect drainage is an essential condition. Five examples of celebrated flax soils from Russia, Belgium, Holland, and Ireland contained respectively:—Silica, 82·21, 83·93, 60·94, 69·32, 79·36 per cent.; lime, 0·45, 0·35, 0·36, 2·36, 1·19 per cent.; alumina, 6·93, 1·29, 5·66, 7·81, 3·31 per cent.; iron, traces, traces, 6·04, 0·45, 7·49 per cent. The average composition of three highly favourable soils was found to be:—Silica and sand, 69·0; oxide of iron, 5·4; alumina, 7·0; phosphate of iron, 0·2; carbonate of lime, 1·7; magnesia, &c., 0·3; organic matters, 6·9; water, 9·2 per cent. The organic matter was rich in nitrogen. Land selected for flax should be as flat as possible, so as to produce plants of uniform length, this condition having an important bearing upon the value of the crop.

Tillage.—This will depend upon the nature of the soil. Stubble land should be ploughed deep in the autumn, and if light, be allowed to remain till seed time; medium may need a second ploughing, not less than 2 months before sowing; heavy land must certainly have a second ploughing, and may even require grubbing. The second ploughing should be shallow—3–4 in. Potato ground must only have one shallow ploughing—3–4 in., and, if the soil be light, this should be done only 4–6 weeks before sowing; if heavy, it may be done earlier, so as to expose the ground to the frost. When the sowing-season arrives, all weeds should be removed, previously to harrowing, by men with spades or grapes, and children to gather. After this, the ground is harrowed fine: if in ridges, up and down only; if flat, across also. Ground in ridges is not cross-harrowed, because that would draw mould into the furrows, and leave too loose a bed in the furrows and brows. If the land is sufficiently dry, either naturally or by drainage, the flatter it is the better. The extent of the pulverizing depends on circumstances: on light and medium soil, excessive pulverizing is injurious; with a deep ploughing in the autumn, and, if necessary, a shallow winter ploughing, moderate harrowing will leave sufficient fine surface mould to give a good bed for the seed; deep pulverizing on such land would ruin the crop, unless the season were unusually wet. Heavy land, on the contrary, cannot be pulverized too much. After each harrowing, the land is picked clear of weeds and large stones; previous to sowing, it is rolled once.

Sowing.—This is said to be done best on the rolled surface, though some farmers first give a single stroke of a seed harrow. A dry, calm day must be chosen. Flat ground needs tracking out, to guide the sower, by poles, or measured and traced by a man's foot. The best time for sowing depends upon the situation: land near the sea may be sown early; inland, too early sowing may encounter late spring frosts, which injure the young plants, and make them branch—the worst evil that can befall the crop. Early sowing is done in the hope of having an early harvest, but this is often prevented by the weather. The best authority on flax growing in Ireland, Michael Andrews, Secretary of the Flax Supply Association, advises the sowing in that country to be completed before the last week in April, so that the flax may be "abraird," or well above ground, by the 1st May. When it is intended to lay down land in clover and perennial rye-grass, these should be sown immediately after the flax, and before it is harrowed in. Italian rye-grass should be sown only on the surface, after pulling, in wet weather.

The kind of seed most suitable is subject to variation: on heavy land, or after a green crop, Dutch seed is best; on light and medium soils, Riga seed is preferable. The quantity of seed used depends upon the kind sown, and upon the quality of seed and fibre required. Dutch seed produces finer fibre than Riga; but this point is influenced by the thickness or thinness of the sowing, the fineness of fibre increasing in direct proportion to the thickness of the sowing. In Ireland, where the moist climate does not admit of such thick sowing as on the Continent, 2 bush. an acre ($3\frac{1}{4}$ bush. an Irish acre) is the usual quantity; but a trained sower should be able to regulate his seed so as to produce exactly the class of crop required, without reference to the measure of seed used. Riga seed contains many weed-seeds, which should be removed by passing it through specially prepared flax-sieves of perforated zinc. Dutch seed seldom needs this cleansing.

After sowing, the seed is harrowed in by two strokes of the seed-harrow, once up and down, and once across. If dry, rolling may at once follow, across the field; on potato land, extra rolling will be needed. The prospect of the crop is best when rain falls immediately after the sowing, as this makes a strong and even sprout; but where weak spots appear, a dressing of soot or stimulating artificial manure may be applied in wet weather.

Weeding.—Weeding should begin as soon as the flax is up, and weeds appear, and should continue at intervals till the crop has reached a height not exceeding 7 in. Seed-weeds should be pulled; larger ones with strong roots may be cut. The weeders should work bare-footed, and must tread with the utmost gentleness, placing the feet flat upon the ground, and never twisting them. They should also work facing the wind, to assist the flattened plants in regaining an upright position. The crop soon recovers from careful weeding, but carelessness may ruin it utterly. Weeding must only be done when the ground is so moist that the weeds can be eradicated without disturbing the roots of the neighbouring plants; in long continued dry weather, it must be foregone.

Rotation and Manuring.—Sufficient attention has not been paid to the subject of rotation when growing flax, and to this is due, in a great measure, the diminution of the yield per acre. The system recommended by Andrews, as being best calculated to maintain the fertility of the soil, is to include flax in the "four-course" rotation; but, instead of putting wheat into all the land that carried a green crop in the preceding year, to have $\frac{2}{5}$ in flax and $\frac{3}{5}$ in wheat. By adopting the following rotation, flax is not repeated on the same land till the 9th year, while the space allowed to it does not exceed 10 per cent. of the whole, which is considered to be the most appropriate ratio. Thus:—1st year: turnips, potatoes; 2nd year: wheat or oats, flax; 3rd year: clover and grass; 4th year: oats; 5th year: potatoes, turnips; 6th year: flax, wheat or oats; 7th year: clover and grass; 8th year: oats; 9th year: turnips, potatoes; 10th year: wheat or oats, flax. When growing turnips and potatoes, the flax crop succeeding them is shifted from side to side, so that it may never follow turnips, as this is very objectionable. After potatoes, or old pasture, off which one white crop has been taken, flax grows admirably. Lea-land, though often yielding a heavy crop of flax, is objectionable, on account of the troublesome tillage, and the probability of attacks from cut-worm, at least in S. Ireland. On no land should flax be repeated oftener than once in 7 years.

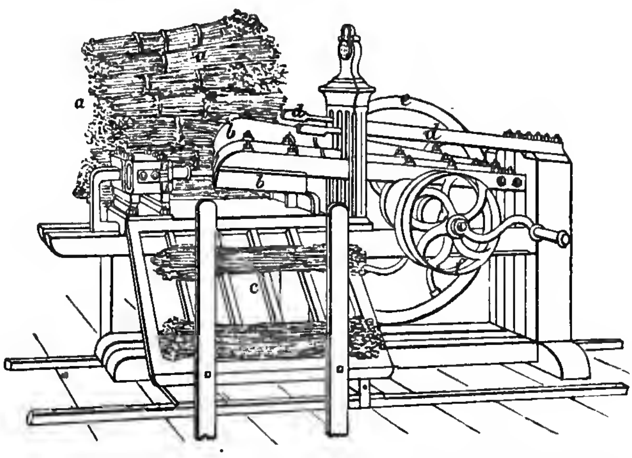
It is generally considered in Ireland that the use of artificial manure is objectionable in the case of flax, except to invigorate a crop whose growth has been retarded by bad weather. The selection of land that will yield a fair crop without manuring, is deemed preferable. This is secured by good tillage, judicious rotation, and the thorough manuring of the previous crops. On the other hand, the finest specimens of flax shown at the Paris Exhibition, 1878, were grown by the aid of direct manuring. Analysis of the flax-plant dried at 100° (212° F.) shows 3·2 per cent. of ash; this ash contains 20·32 per cent. of potash, 19·88 of lime, 10·24 of phosphoric acid. It is estimated that the flax grown on 1 acre of land extracts from the soil about 50 lb. of alkalies (chiefly potash), and 24 lb. of phosphoric acid. Almost the whole of this might be returned immediately to the soil, if the refuse of the plants, and the retting water, were utilized. Where this is not done, manuring must be an expensive matter. Some eminent flax growers, in the French Department of Seine-Inférieure, prefer to employ a manure composed as follows:—$1\frac{1}{2}$ cwt. nitrate of potash, 3 cwt. superphosphate of lime, and 3 cwt. gypsum per acre. In the first year's trial, the result was eminently satisfactory, and it is believed that by using such a compound, rotation might be dispensed with; at least Loisel Méry, of Goderville, has obtained three successive flax crops off the same land by its use.

Diseases.—The worst evil that attacks the flax-plant is the appearance of dark-brown coloured blotches on the stems, known as "firing" or "burning," from their resemblance to the effect created by fire. The crop is most liable to it as it approaches maturity, and if the spots make rapid progress, the crop must be gathered at once, and steeped immediately, whether it be ready or not. The disease is usually considered incurable, but the recent researches of a French agriculturist go to show that the firing takes place only on poor soils, and especially those destitute of potash; and that where this valuable and most necessary ingredient is supplied, the plant flourishes remarkably, while an adjoining plot, not so manured, may be completely destroyed. The flax crops in N.-E. Russia have been attacked by a caterpillar, especially those on high ground. Three or four caterpillars are usually found on a plant, feeding upon the upper branches and flowers. They are said to be proof against smoke and lime, but are driven away by deep ploughing. There is certainly abundant room for improvement in Russian agriculture.

Harvesting.—The time for harvesting the crop must be judged with great care; the plant is ready when the portion of its stalk nearest the ground commences to assume a yellow tint, the leaves at 8–10 in. from the ground fall off, and the top seed-bolls begin to show a very slight brownish hue. Pulling too early entails a tender fine fibre, which will waste much in scutching; by allowing the plant to become too ripe, the fibre is rendered dry and coarse, and the additional weight does not compensate for the inferior quality. When any of the crop is lying, and suffering from wet, it should be gathered as soon as possible, and kept apart.. Dry clear weather must be chosen for the harvest. Neither scythe, sickle, nor reaping-machine is employed, though the last-mentioned has been tried unsuccessfully in Ohio. The plant is up-rooted by hand, by experienced persons, and never by children. The proper method is to seize the plant just below the seed-bolls, and to remove it perpendicularly by a dexterous jerk of the arm. When the ground is uneven, the stems will vary in length ; in such cases, each length should be pulled separately, and kept apart throughout the subsequent processes. Every care is necessary to keep a uniform length of stem, and to exclude weeds ; hence the non-success of the ordinary harvesting implements. The flax as pulled is laid down in handfuls of a size that can be conveniently grasped, and crossed so as to avoid entanglement, scrupulous attention being paid to keeping the "butts" or root-ends exactly even.

Seeding or Rippling.—The next step is the removal of the seed, for which purpose, the handfuls are carried by children to the "ripplers." The "rippling-comb" consists of a row of round iron teeth, screwed into a slab of wood : the teeth are about $\frac{3}{16}$ in. apart at bottom, $\frac{1}{2}$ in. at top, 18 in. long, and begin to taper at about 3 in. from the top. The comb is bolted to a plank, lashed to the body of an unmounted cart, or to a frame surrounded by a sheet, either being placed in the pulling field. Each handful of stems is taken very tightly in both hands, and slightly spread out like a fan ; the extreme ends are brought down upon the teeth of the comb, and carefully drawn through, repeating the stroke, and increasing the length of stem acted upon, until all the bolls have been removed ; 3–4 strokes generally suffice. A more modern implement for this purpose is the seeding-machine, which simply consists of two heavy cast-iron cylinders, revolving within a cast-iron frame, the lower cylinder being driven from pulleys, and the upper one turning in contact with the lower, and releasing the seeds by the pressure of its weight upon the seed-bolls. Ernest Legris, of Pontrieux, Côtes du Nord, has recently introduced a more complicated machine, shown in Fig. 666. The beets *a* are spread on a table, with their seed-ends turned towards the beaters *b* ; they are pressed down on an endless chain, furnished with corrugations, which passes them slowly and regularly under the blows of the beaters. Each beet receives the successive blows of the three beaters, and arrives, completely seeded, at the end of the table, where it passes down a screen *c*, to be piled in order. At the end of each stroke of the beaters, the elastic shakers *d* come into play, and shake out the seeds, which fall into a receptacle placed beneath. The machine is driven by the fly-wheel *e* and pulley *f*, and requires three attendants. As fast as the flax is rippled, it is tied in "beets" or bundles of small size, and loose in the band. The best bands are rushes, but tying may also be done with short flax. The beets are then ready to undergo the various processes for extracting the fibre. It should be added that whereas rippling is only performed immediately the flax is pulled, machine seeding is confined to flax-straw which has been dried in the field, and held over till the following spring.

668.



The further treatment of the seed will be described under Oils—Linseed.

Extraction and Preparation of the Fibre.—The extraction and preparation of flax may be divided into the following sections :—

Retting.—This is the most important step in the extraction of the fibre from the "boon" or woody portion of the stem, and consists in subjecting the latter to a certain degree of fermentation, in order to decompose the gummy matter which binds the filaments together. It is performed in a variety of ways, which may be classified under dew-retting, simply water-retting, and water-retting with the aid of heat, chemicals, &c.

"Dew-retting" is employed on all the Archangel flax, and on most of that from St. Petersburg. The flax, as soon as pulled, is spread on the grass, under the influence of air, light, dew, and rain, for a lengthened period. The fibre assumes a brown colour, and is more liable than any other kind to "heat," if exposed to damp, and closely packed. It is, however, of soft and silky quality. Outside Russia, dew-retting is scarcely ever employed.

"Water-retting," "watering," or "steeping," is the process most generally in vogue. The two essential conditions are suitable water, and suitable "dams" or ponds. Soft water is by far the best; hard water improves much by exposure to the atmosphere. The presence of iron, unless in such proportion as to cause rust, should not condemn the water, unless better can be had; the only effect of iron is to discolour the fibre somewhat, and thus lower its value. Water containing lime must not on any account be used. As an easy test of the suitability of water for retting purposes, it may be stated that any water in which soap will not curdle is sufficiently soft; but the softer it is, the better.

Artificial dams should be made long before they are required, and be dug in clay if possible. Dimensions will vary, but a depth of 4 ft. should not be exceeded, and the area should be divided among several, rather than restricted to a few of large size. The average crop of 1 acre will require a dam of about the following capacity:—Length, 50 ft.; breadth, 9 ft.; depth, 4 ft. The situation should be sheltered from wind, with a sunny aspect. Soundness is essential in a dam; flax-water will escape more readily than clean water. Peat-bog holes may be extemporized as dams, but they must be of old formation. New dams should be dug during winter, and old ones repaired at the same season; either should be filled by surface drainage, and kept full till steeping time. Where the dams are so situated as to allow the water to be run off, a pipe may be fixed in the bottom or side for that purpose; the same water should never be used twice.

Dams and water being suitably provided, the retting commences. The beets, tied as described, are taken to the dam. The flax pulled each day should be put into the dam on the same evening if possible; and one day's pulling should never be mixed with that of another. Beginning at one end of the dam, the beets are laid closely side by side in rows, with the root end down; when one row is finished, a second is commenced, placing the tops of these beets level with the bands of the first, and so on, row after row, till the dam is full; a final layer may be placed flat on the top. The whole is then covered with ragweeds, rushes, or straw, then preferably with boards; and finally stones, or turf-sods with the grass downwards, are piled on to sink the flax beneath the surface of the water. Where a stock dam is available, by far the best plan is to fill the dam while dry, and then let in the water. Fermentation ensues, the sooner the better; in continued warm weather, it will set in immediately. This process causes the flax to rise above the water; it must be forced down, and more heavily weighted. When the fermentation decreases, the flax will sink in the water; the weight must then be partially removed, so as to allow the flax to rise to the heat, but never so far as to reach above the water. After a few days,—the duration of the retting varies exceedingly, according to the nature of the weather, of the water, and of the crop,—the flax is examined, and the greatest judgment is demanded to decide when the watering has proceeded sufficiently far. One or two beets are removed from different portions of the dam, opened, and tested. The conditions which indicate that the flax is ready to leave the dam are as follows:—If "glit" appears in the middle of the beet, and it feels soft when grasped in the hand; if the "reeds" or stems taken out are covered with a greenish slimy substance, and if this can be removed by delicately passing the reed between the finger and thumb; and if, when gently bent over the forefinger, the woody "shive" or core freely separates from the fibre, and starts up. The stem must be examined throughout its length; it will be found softer at the root-end, but if it yields to these tests in the middle, it may safely be considered ready. Both coarse and fine stems must be selected; the former will be ready first, so the average condition must be determined. The Dutch test is to hold the middle of a stem in both hands, and twist in opposite directions; if the fibre separates freely from the core, the operation is considered complete. It is common to ret flax too little, trusting to finish the process on the grass; but this is not advisable, and the grassing should amount to little more than drying. At first, examination should be repeated daily, then at intervals of six hours, as the change may be rapid towards the end. When the retting is complete, the burden is removed, and the beets are taken out very carefully by men standing in the water. The flax is then allowed to drain for a few hours, either by laying the bundles down on an incline, or by standing them together on their root ends, taking care not to place too many together, or heating may result.

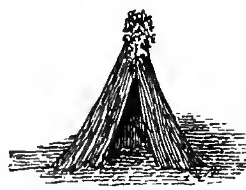
Many plans have been devised for avoiding the retting process altogether, but none has yet met with even partial success. Later investigations have been prosecuted rather in the direction of reducing the time occupied in the operation as ordinarily conducted, and rendering it more constant and uniform. The only successful modifications are the following:—(1) R. B. Schenk's warm-water system. Open pools and dams are replaced by large, covered, wooden vats, in which the flax is tightly packed in a vertical position. The water admitted is raised to a temperature of 24°–35° (75°–95° F.), and is maintained at that heat during the whole period of steeping. The fermentation is very brisk, and the operation is concluded in 50–60 hours. (2) Pownall supplements this by passing the stems, immediately on their removal from the vat, between heavy rollers, over which a stream of clean water is kept flowing, this effectually washing away the adherent gummy matters, and much facilitating subsequent processes. (3) Michael Andrews suggests, as an improvement upon Schenk's method, to admit the water at the proper temperature, and then to maintain it so by keeping the air of the chamber containing the vat at the correct degree, uniformity being by this means much more easily ensured. The ordinary Irish method of retting in open pools of stagnant water is unequalled by any in simplicity, and cheapness of plant; but some of the Continental methods are more elaborate, and produce better fibre. These will be alluded to below, under the section treating of local modifications.

Spreading or Grassing.—When the flax has drained sufficiently, after removal from the retting-dam, it is conveyed to the spread-ground. This should be a field of clean, short, thick pasture, any tall weeds or grass being carefully mowed down. The beets are distributed at convenient distances; the spreaders follow, and shake the flax out in a thin layer in even rows across the field. When turning is not intended, the top of one row should overlap the butt of the preceding, to the extent of about 2 in. This is done to prevent the scattering effect of a high wind; but it is objected to by some that it tends to cause entanglement in the subsequent lifting. The flax is sometimes turned by a pole 2–3 times while lying on the grass, in which case, it must not be allowed to lap. Turning doubtless produces a fibre of more uniform colour and quality; but it loosens it on the grass, and thus exposes it to the wind, which is a serious drawback in some districts. It is best done when rain threatens, as in that event the flax would be beaten down. After the first day's exposure, the stems will be found quite "tight," and the fibre will be most difficult to separate from the woody core, except with much rubbing. But in a day or two, if the retting has been properly conducted, the stems will begin to "bow"—the fibre contracts, and leaves the core, the two resembling a bow and string. When this occurs, and a slight rubbing suffices to make the woody core break and fly off from the fibre, the flax is ready for lifting.

Lifting.—Flax must never be taken off the spread on a wet day, nor while dew is on it. Great care must be taken to keep the butts or root-ends quite even. It is laid down in bundles of a size to make small beets; these are tied moderately firm, and stooked for a few days, if the weather is settled; but if the weather is doubtful, it is better to carry the flax to a loft, or stack it.

The above directions assume the existence of favourable weather. In the opposite case, some deviation will be necessary. Thus, should unsettled weather threaten towards the end of the retting, the flax had better be taken out before it is quite ready, as, in the "hard" state, it can better withstand unfavourable weather while on the grass. Or, supposing the retting to have been complete, and either wet weather, or scorching dry weather, should occur when the flax is quite dry on the grass, it is well to lift somewhat prematurely, and stack, as a few months' stacking will produce the same effect as a prolonged and more favourable grassing; indeed stacking always improves it. If rain continues during the grassing, mildew and other injury can only be avoided by lifting the flax in large handfuls, and setting it up in the form of a hollow cone, as seen in Fig. 667, taking care to lift by the boll ends, and to slightly twist the top of the cone, to give it strength against the wind.

667.



Drying.—If the grassing is properly performed, no other drying will be necessary. The application of fire-heat is always most pernicious. Drying in the field before retting is a Belgian practice, described further on. It has some advantages, and affords a convenient alternative when water is scarce at the retting season.

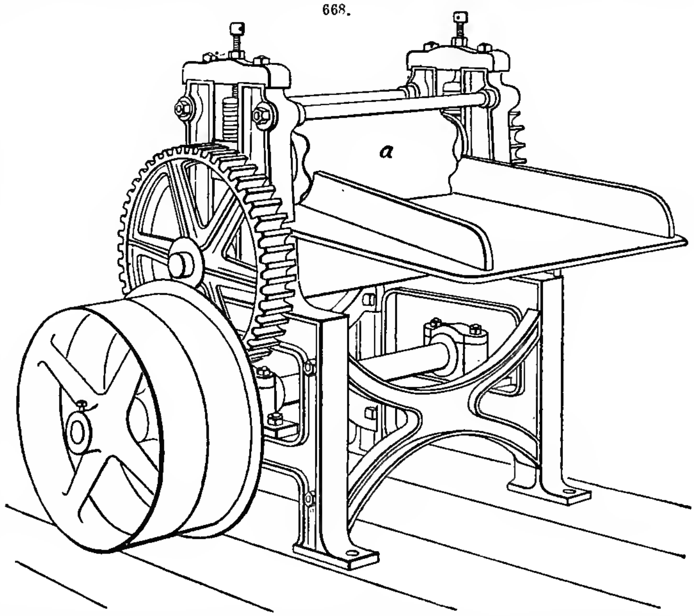
Breaking.—The efficiently retted and dried stems are next submitted to a process of breaking, to fit them for the final scutching. The Irish method of breaking was of the rudest kind, but very effective machines are now made to perform this operation of bruising the stems, and breaking up the boon or woody portion, so as to loosen it from the fibre. One of the most simple machines for this purpose is shown in Fig. 668. It consists of two pairs of fluted iron rollers, and a table to receive the stems. The "straw" is fed in by hand between the first pair of rollers, which crush it somewhat, and pass it on to the second pair, with finer flutings, where the breaking-up is completed. The top rollers are free to move up and down, the requisite pressure being obtained by means of indiarubber rings, placed in recesses on the tops of the sliding bearings, and kept down by cross bars.

Another simple machine, which, while having only a limited power of production, breaks a small quantity well, is shown in Fig. 669. In a frame A, it has two fluted rollers, which effect a reciprocating motion from the crank B upon the fluted cylinder C.

Figs. 670 and 671 represent two flax-breakers on the Hodgkin–Brazier principle. The reciprocating motion is given to the large cylinder, and is communicated by the flutes to the rollers. The cylinder oscillates under the rollers, and is provided with a forward movement in excess of the backward movement, so as to deliver the fibre at a certain rate upon the endless travelling lath. This system possesses the disadvantages that the great strain thrown upon the cylinder frequently causes it to break, and that the crushing between the flutes is practically repeated upon the same spot, and tends to cut the fibre.

The machines shown in Figs. 672 and 673 are a great improvement upon the preceding; they are the invention of Samuel Lawson and Sons, Hope Foundry, Leeds. Their essential difference consists in having pairs of rollers, instead of rollers working upon a cylinder. Each pair of rollers is driven by a pinion gearing into the large internal wheel A, the strain being thus equally divided. A second similar wheel on the other side drives half the number of pairs of rollers. By this system, 8, and even 12 (Fig. 673) pairs of rollers may be driven in one machine. The rollers may also be made to vary from coarse to fine fluting, so as to operate gradually upon the stems. An arrangement is provided for regulating the amount of forward motion in the reciprocating rollers, so as to deliver the stems more or less quickly, thus retaining them for a longer or shorter time, as required. Another advantage is the constantly changing action of the rollers upon both sides of the stems. The spaces also between the rollers allow the dirt and impurities to fall freely away. These powerful machines act with equal efficiency upon other fibrous stems which need "breaking," as hemp, jute, &c. The six-pair one can break daily 3–4 tons of jute, or 1–2 tons of hemp, and a proportionately larger quantity of flax.

668.



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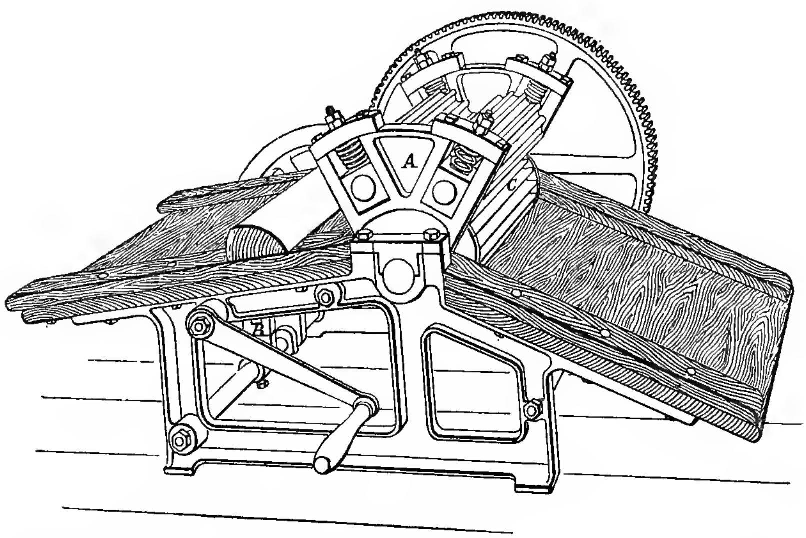
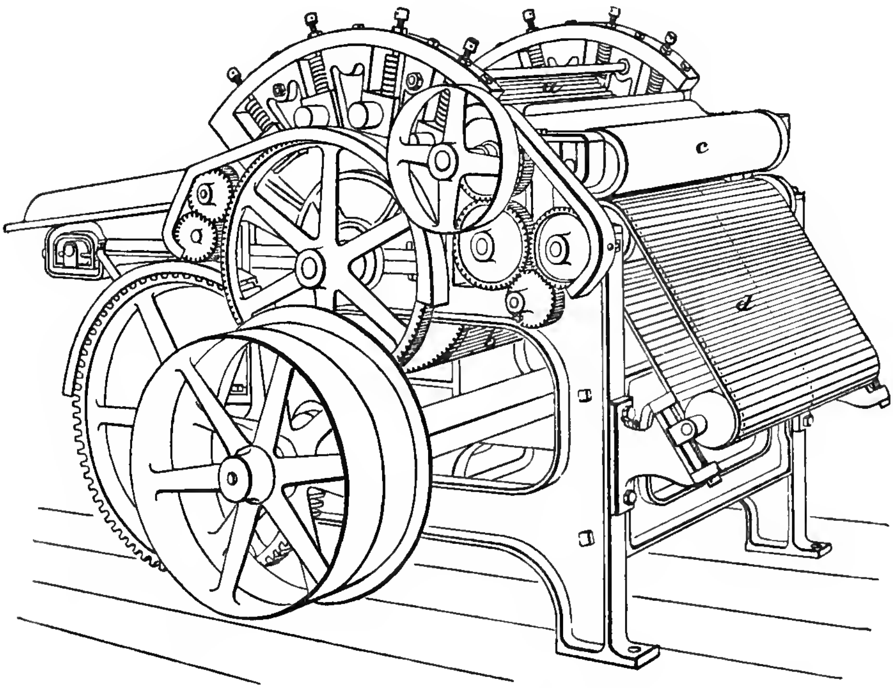


Narbuth's flax-breaker, requiring great power, and working at a high speed, is used in Hungary in preference to all others. An outline of it is shown in Fig. 674. The drum is replaced by a series of rollers *b*, 5 in. in diameter, moved by one large spur-wheel D, and gearing into the breakers *a*, carried by the frame A, and oscillating with the latter round the axis C. The oscillation, which is transferred from the main-shaft, through the rods F P, and eccentric G, is very rapid. Motion is given from shafting to the pulley O, and from H to M, whence a belt passes to the pulley I, on the same shaft as the pinions for driving the spur-wheel D. The stems are placed on the feeding-cloth *c*, and pass between the breakers, the upper rolls pressing them into the grooves

670.



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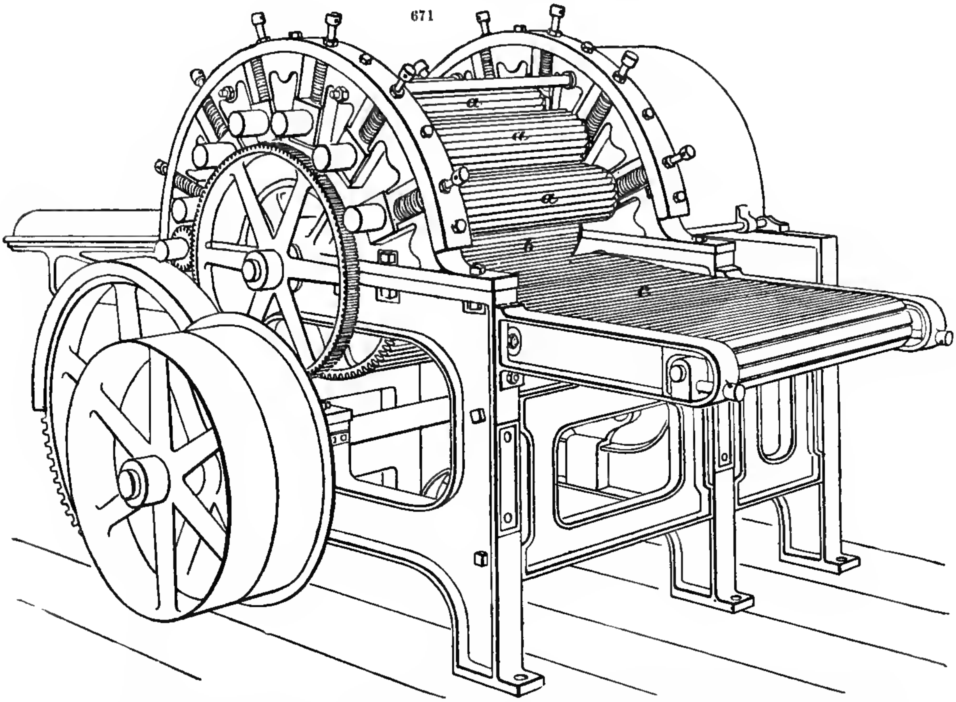

between the knives *b*, where they are broken, whilst the forward and backward motion of the rolls *a* removes the broken woody refuse from the fibre. This machine is equally applicable to hemp.

A flax and hemp breaking-machine, largely used in Portugal, is shown in Fig. 675. It consists of a large grooved drum A, rotated by the crank *k*; around it, are placed 14 workers or

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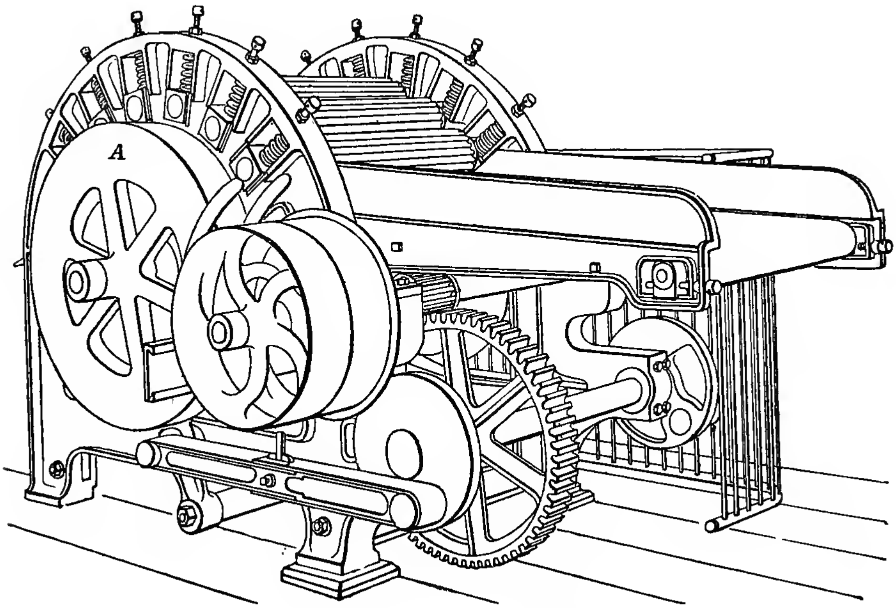

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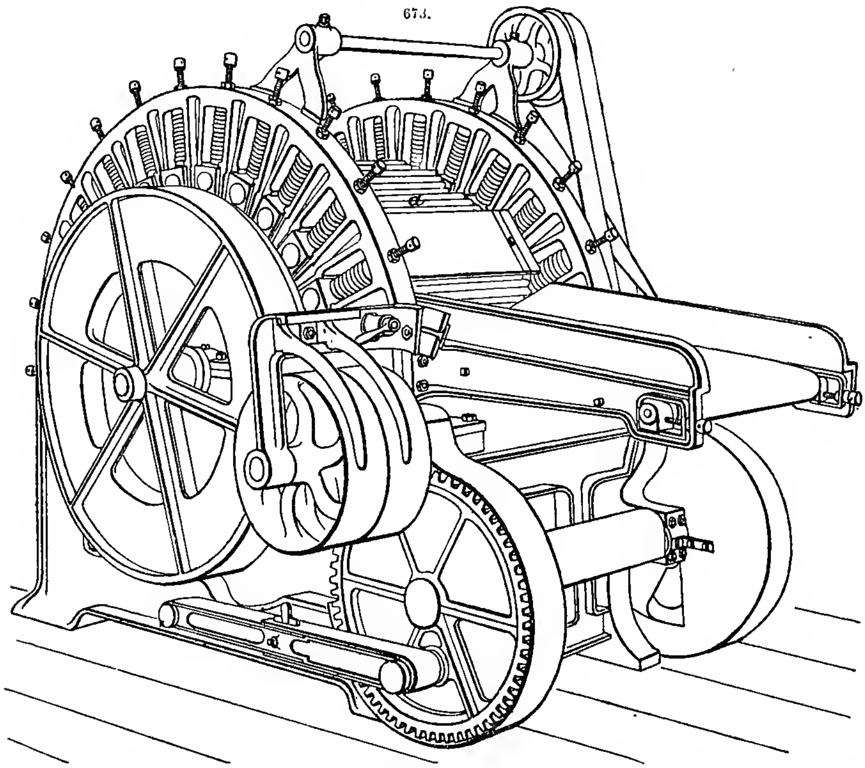
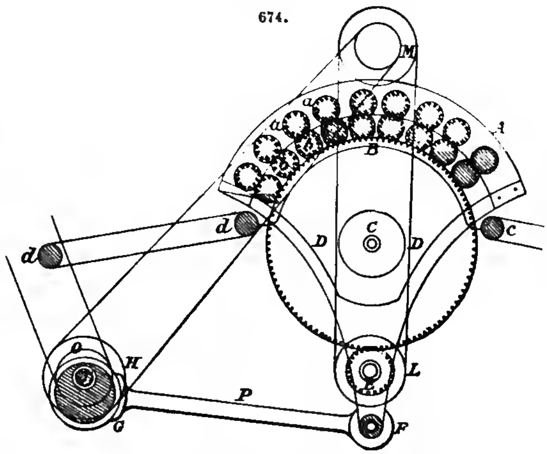


beaters *a*, supported by bearings fastened to the slides *b*, moving in the dovetail slots *d*. To regulate these slides, and to prevent damage to the rollers by excessive feeding, a strong rope *c* is passed over the slides of all the bearings; the rope runs beneath the machine, over the guide-pulleys *e*, and is fastened to the beam *f*, which is turned into position by levers, and secured by the pin *n*. The feed and delivery tables are *h* and *i*.

It is of the utmost importance that the breaking should be well performed, as this will reduce the amount of scutching required, and thus result in a lessened proportion of tow.

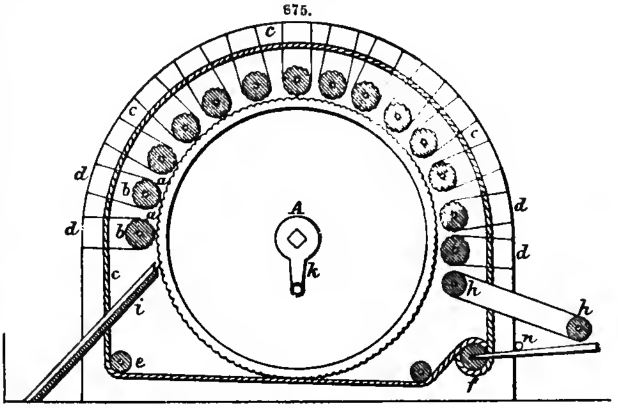
674.



Scutching.—Scutching is the last process with which the cultivator is concerned. By it, the fibre is freed from the broken particles of woody matter, and rendered fit for market. It is of great importance that the stems be fed in a uniform manner to the scutcher; the more regular the length of the stems, the more evenly their ends terminate, and the straighter the stems, the less will be the loss of fibre in scutching. The operation is performed in several ways. Both on the Continent and in Ireland, the primitive method of hand-scutching is only partially retained, aud it is doubtful whether any mechanical appliance could equal the quality of the work done by the skilled operatives of Belgium and Holland, chiefly by reason of the judgment required to be displayed in accommodating the scutching to the ever-varying condition of the straw. Nevertheless, mechanical scutching is coming into extensive use, on account of its greater rapidity, and will in time doubtless usurp entirely the position of the older system. It may be carried on in two ways:—(*a*) by scutching-mills; (*b*) by scutching-machines.

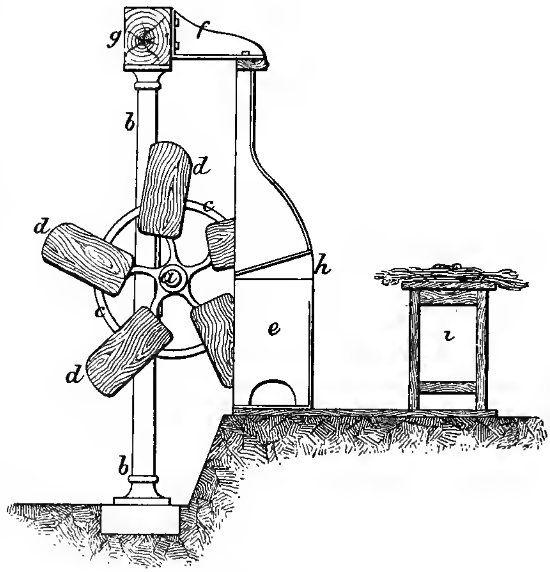
(*a*) Scutching-mills consist of long rooms divided into a number of "berths" or partitions, generally not exceeding 50; they are built of brick, and well lit by side windows. Throughout their length, runs a wrought-iron shaft *a*, fixed in bearings on a row of wooden or iron pillars *b*. At each berth, this shaft carries a wheel, termed a "wiper-ring" *c*, provided with a number (usually 5) of wooden blades *d*, as shown in Fig. 676. Parallel with the shaft, and at a little distance from it, is placed the partition *e*, made of iron as a protection against fire, firmly bolted at foot, and stayed at top by a bracket *f* from the beam *g*, which unites the row of pillars. The scutching-blades work against projected wedge-shaped openings *h* in the partition, the lower edge being horizontal, and a little above the centre of the wiper-shaft. The wiper-rings are fixed at distances of about 2 ft. 9 in., and as the projected openings are about 9 in. wide, each workman has a "berth" of 2 ft. to stand in. The floor on the pillar side of the partition is much lower than on the other, to afford space for the woody "boon," dust, tow, &c., without impeding the blades. Every care must be taken in the fitting to prevent the dust entering the workmen's berths, as it is highly pernicious. After leaving the breaker, the flax is well shaken by hand, to free it as much as possible from the boon, and is then taken into the scutching-room, and placed in suitable handfuls or "streaks" on the table *i*. The workmen stand in a row between this table and the partition, one in each berth, with the left hand against the partition, and the wedge-shaped slot in front. Each takes a handful or streak of the broken straw from the table, and inserts one end of it in the slot through the uncovered part of the projection, resting the middle of the streak on the bottom edge of the slot, and sliding it

675.



gradually forward, so as to bring it well under the action of the scutching-blades, which strike it in the direction of its length. When the shove or woody boon has been beaten out of one-half of the flax, he withdraws it, and inserts the other half, to be similarly treated. He then passes the handful, thus roughly scutched, to his neighbour, who treats it in exactly the same manner, and finishes the operation. The scutching-blades in the second operation are set closer to the slot than in the first, and consequently there is more thorough scutching. It is customary for the men to work in pairs: the one who performs the first operation is technically called a "buffer"; the other, a "finisher" or "cleaner." The finished flax is finally moved from the table and carried away to store.

676.



The operation of scutching necessarily causes a waste of fibre, because, however much care be used, some of the fibre is broken by the action of the scutching-blade, and also by adhesion to portions of the woody part of the straw. This waste is called "scutching-tow," or "codilla"; "tow" proper results from the subsequent operation of hackling. Although less valuable than the original fibre, it has considerable worth, being used according to its quality, for spinning yarns for twines, sackings, canvas, linen, and similar purposes. The codilla drops to the ground behind the partitions, and contains a large quantity of boon, which must be separated. This is done in the first instance by rough hand-shaking; as, however, it is impossible to get all the boon out in this manner, it is afterwards passed through a "shake-willow," very similar to the "rag-willow," described under the head of Rags, with certain modifications to adapt it to this special work. In this machine, almost all the boon is taken out of the codilla, which is then packed in bales ready for sale. The quality depends on the quality of the flax, and its treatment. The great improvement that has taken place of late years in the construction of machines for preparing and spinning tows has caused them to rise very much in value. The principal point in scutching is to make as little tow as possible; the next point is to send the latter into the market clean and free from boon, so as to ensure a high price for it.

As a rule, scutching-mills are worked by steam-power. It is a very important fact that, with properly constructed engine and boiler, the "boon" or woody matter separated from the flax-straw is quite sufficient fuel for generating the steam required.

(*b*) Machine-scutching, called also "barrel-scutching," in contradistinction to the scutching-mill, which is an "arm-scutch," is effected by a revolving drum or cylinder *a*, placed in a cast-iron frame, and covered with sheet iron *b*, as seen in Figs. 677, 678. Around the periphery of the drum, and parallel with its axis, are fixed tough, flexible wooden blades, the leading edges *c* of which are sharpened; at the back of each blade, is a row of semicircular metallic scrapers *d*, resembling finger-nails; and behind them, projecting metallic blades *e*. In front of the machine, are two iron stocks or face-boards *f*, pivoted at the base, and adjustable by means of screws and lock-nuts. On the inner surface of the stocks, are fixed sheet-iron curved spring-plates *g*, also adjustable; and, at each side of the machine, is an opening in the cast-iron frame, to allow the straw to enter. The operation is as follows:—The workman takes a streak of the straw, and inserts one end of it through the opening in the side of the stock, retaining the other end in his hands. The revolving blades strike the straw in the direction of its length. The metallic scrapers answer the purpose of human fingers, in separating the straw, and exposing new portions to the action of the blades. Meantime, the workman gradually slides the straw towards the centre of the machine, and withdraws it through the space between the two stocks. He then inserts the unscutched end to be similarly treated. Having thus rough-scutched the whole streak, he hands it to his neighbour, whose blades are set more closely, and by him the scutching is finished. Each machine thus requires two workmen—a "buffer," and a "finisher." The machines are placed in a row, side by side, but independently in a room, and are driven by a shaft and pulleys. The back of each machine is provided with a fan for drawing off the dust, boon, tow, &c., into a flue which delivers outside the building. This plan is gradually going out of use.

The following illustrations of scutching machinery are due to Thomas Barraclough, Engineer, Manchester. As to the relative merits of the two systems, it may generally be assumed that in large establishments, with skilled labour, scutching-mills are the better, because the cheaper in first cost; for small establishments, where the labour is not so efficient, scutching-machines are preferable.

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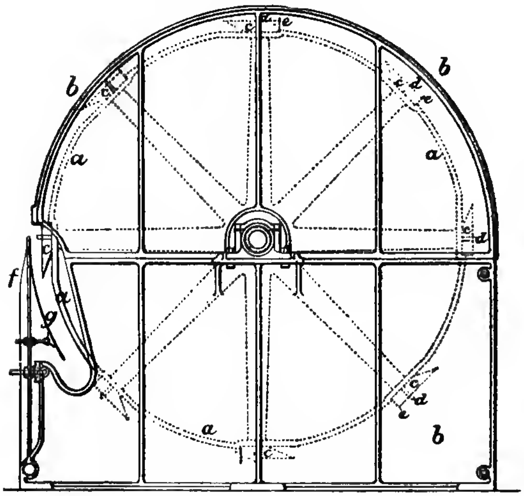

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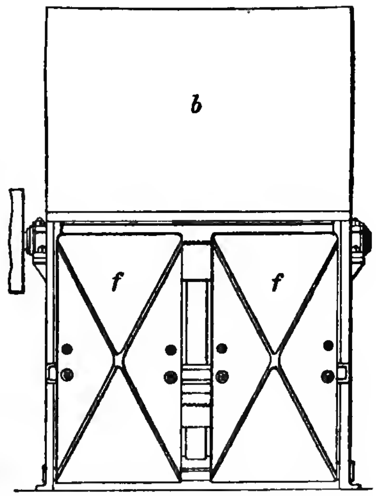

There are now many advocates for brushing the flax before baling it for market. For this purpose, the brushing-machine described under *Agave americana* (p. 912) is used. It is said that 5*s*.–10*s*. a ton expended on the brushing of the fibre will add 2*l*.–4*l*. a ton to its value.

Local Modifications.—The above-described methods of cultivating the flax-plant, and preparing its fibre, refer more particularly to the industry as conducted in Ireland, much of the information having been obtained through the kind services of Michael Andrews, the energetic Secretary of the Flax Supply Association, Belfast. For those who intend introducing the culture into new districts, interest will attach to the following brief description of the principal local deviations, as adopted by the chief flax-producing countries, taken in their alphabetical order.

Belgium.—Both white and blue blossom is grown; the former yields a coarse, but abundant and strong, fibre, chiefly used in admixture with hemp; the latter gives a finer, softer, and more valuable fibre. A north-east aspect is preferred; in sheltered spots, the fibre is weakened by the too vigorous growth of the stalk in warm damp weather. Sewage, and stimulating artificial manures are used, but are usually applied to the preceding crop. The finest and strongest flax is grown on loamy land; but selection of soil is deemed second to good tillage and manuring; sandy and cold clay soils, however, are objectionable. The land is ploughed in October–November, out of corn stubble, after potatoes, mangold, or beet. A month or two before sowing time, it is dressed with powdered colza cake, and watered with liquid manure. At sowing time (20th Feb. till end of March), it is harrowed and rolled, the seed is sown, and the land is rolled again; seed used, about 7 bush. to 2½ acres. In light land, the flax is hand-rolled when abraird. Pulling begins about 24th June; when the reed is fine, it is left longer to ripen than when coarse; when the best quality is required, it is pulled before the seed is ripe enough for sowing. The handfuls are stooked the same day, without being tied in beets, in the form shown in Fig. 679; the stooks are tied at each end. Here it remains till dry enough for tying into beets, which are built into "hedges." These are formed by laying two poles on the ground, and ranging the beets on them, about 8–10 beets high, the tops and butts reversed alternately, the length of the hedge depending upon the quantity; one row is then laid lengthwise along one edge, and on this are placed the butt-ends of another row, forming a slanting surface; the ends and top are carefully straw-thatched, to keep out sun and rain, and two poles are driven into the ground at each end as a

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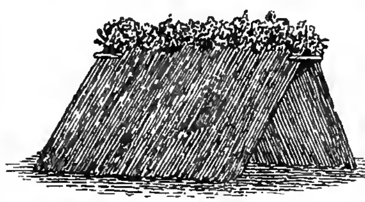

support. A hedge is seen in Fig. 680. The flax remains in hedge till dry enough for storing or stacking—about 1 month in favourable weather,—being occasionally examined. If heating occurs, the hedge is taken down and rebuilt. When dry, the flax is removed to store or stack, there to await the retting process in the following spring. Before retting, the beets are placed on a floor, and the seed is threshed out with the mallet shown in Fig. 681. Two beets, with butts and tops reversed, are then tied together with 3 straw bands, forming "bundles," as seen in Fig. 682.

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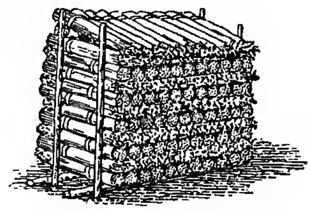
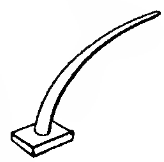


It is seldom that the farmer prepares his own flax; usually he sells it as a standing crop to a "flax-worker," and this fact, of the manipulation of the straw forming a distinct industry, ensures more skill being brought to bear, and accounts in a great measure for the superiority of the Belgian flax. The best descriptions are prepared in the Courtrai district, where the river Lys is available for retting purposes, and where generations of flax dressers have earned a livelihood. The Lys is practically a canal, and the slowness of its current, and (?) softness of its water, have much to do with the quality of the flax prepared in its neighbourhood. The bundles are packed in wooden crates, lined all around with straw, to prevent the flax coming into contact with the sides, and to impede the current flowing through the flax. The bundles are packed vertically, and covered with straw. The filled crates are then floated into the river and kept near the bank by tying to stakes; boards are laid on the top of the straw, and loaded with stones, so as to sink the crates and submerge the flax. The retting is not allowed to advance far, when the flax is taken out, and set up in hollow cones (as shown in Fig. 667), and dried; it is then retied, repacked, and put back into the river to complete the retting. The Belgians do not rely only upon the test mentioned above for ascertaining when the retting should be terminated, but employ an additional one: the fibre is carefully separated from a single straw, and held about 6 in. apart; it is then placed close to the ear, and gently jerked—it should not break, and if sufficiently retted, the sound should be soft, if not, the sound is sharp and ringing; only the most skilful can discriminate the condition by this delicate test. The lapse of a long period between the first and second retting is considered favourable for the production of superior fibre. When the retting is complete, the flax is again set up in cones, and left till the fibre separates from the woody core; it is then tied in single beets, and stored for scutching. Before scutching, each beet is opened, and sorted by experienced manipulators; that in perfect condition is put by for first-class fibre; that which is over-retted is scutched separately; and that which is "hard" is made up into bundles, and retted a third time. The best flax is scutched by hand, though machines are largely used. The latter are rude and simple, and generally home-made.

681.



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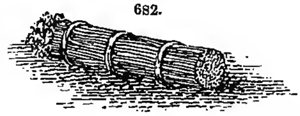

In the so-called "blue districts," the flax is retted in stagnant water, the same season as grown. In some instances, to improve the colour, branches of alder are tied into faggots, and put into the ditches some time before the retting season; these are removed before the flax is put in, the leaves being in a decomposed state. The water, of a black colour, is then stirred by long paddles, and the flax is packed in the ditches as in Ireland.

France.—Well-manured, light clay soils are preferred. Of manures, horse-dung and guano are considered detrimental, as drying the fibres. It is common to herd sheep on the ground, or to manure with cow-dung and sewage. The common rotation gives one crop of flax in 7 years, though rotations of 10, 11, and 14 years are sometimes adopted. The flax crop may follow pasture, clover, hemp, oats, carrots, beans, potatoes, beet, or colza. In N. France, the usual rotation in good soil is:—1st year, wheat; 2nd, rye and turnips; 3rd, oats; 4th, flax; 5th, clover; 6th, colza; 7th, potatoes. On good stiff soils:—1st, potatoes; 2nd, wheat; 3rd, flax; 4th, clover; 5th, rye; 6th, oats; 7th, buckwheat. On poorish sandy soils:—1st, flax; 2nd, rye; 3rd, clover; 4th, buckwheat; 5th, carrots; 6th, potatoes; 7th, barley. On a rich loam (10–12 years' rotation):—1st, beet; 2nd, oats; 3rd, clover; 4th, wheat; 5th, flax; 6th, wheat; 7th, beans; 8th, wheat; 9th, potatoes; 10th, wheat; 11th, oats. The treatment of the best French flax differs little from the Belgian method, in fact, quantities of it are taken to the Lys for retting.

Holland.—The land is considered best for flax after one crop of rye or oats, preceded by rape. On broken-up lea lands, it is a risky crop; but such lands after oats are favourable. The quantity of seed used is about $2\frac{1}{2}$ bush. an acre—$\frac{1}{8}$ less when it is home-saved seed. Weeding begins when the plants are $\frac{1}{2}$ in. high, and lasts 6 weeks. The saving of sowing-seed being an important point, the time of pulling is principally regulated by the condition of the seed, which is tested by cutting the capsule across, so as to sever the seed, the section of which should exhibit a compact defined form, and not appear displaced by the knife. As pulled, the flax is tied in beets, and stooked as shown in Fig. 683; it remains in the field till dry enough to be conveyed in barges to the retting pond. It is put into small stacks, or stored in a barn, and rippled. It is then retted in ditches of stagnant water; these have been previously cleared out, and the mud is used as a covering for the flax. The retting is conducted much the same as in Ireland. The grassing receives great care: in ordinary weather, the flax is spread in the usual manner; but if very wet and broken, it remains in the beets, three of which are placed upright, leaning against each other, to get partially air-dried, after which each beet is cut loose, and placed in a cone, as shown in Fig. 667, till dry enough for storing; it is always put into these cones for final drying.

683.

Russia.—Though Russia grows more flax than any other country, the modes of culture and preparation are unequalled for rudeness and carelessness. The coarseness of Russian flax is partly due to the thin sowing, which is done to lessen the liability of the crop being laid by the severe thunder-storms, of common occurrence at the time when it is in flower.

Characters and Uses of the Fibre.—Of all vegetable fibres, flax occurs in the greatest variety, as regards the length of the filaments, their colour, fineness, and strength; but the fibrous bundle always retains the character of being very readily divisible into its distinct filaments, by rubbing it between the fingers; it then becomes soft and extremely supple, while preserving a great tenacity.

A transverse section of a flax-stem is shown in Fig. 684: *a*, bark; *b*, weody fibre; *e*, epidermis; *f*, bast fibres, coloured distinctly blue by test H; mag., 100. The individual fibres are seen in Fig. 685: *a*, sections of the fibres, isolated and in groups; *b*, the fibres viewed longitudinally; one of them shows the creases produced by repeated bending; *c*, ends; *a'*, sections of fibres situated near the butt of the plant; mag., 300. Under test F, the fibres assume a transparent blue colour, the X-like creases taking a much deeper tint. The interior channel appears as a yellow line, which, in the centre of the transparent blue stem, is characteristic of flax. The dimensions of the fibres are as follow:—length, 0·157 in.–2·598 in.; mean, about 1 in.; diameter, 0·0006–0·00148 in.; mean, about 0·001 in. The chief characteristics of flax are its length, fineness, solidity, and suppleness. Its remarkable tenacity is due to the fibrous texture, and the thickness of the walls; its suppleness permits it to be bent sharply; its length is invaluable in spinning; and the nature of the surface prevents the fibres from slipping on each other, and contributes to the durability of fabrics made with them. Flax may be made lustrous, like silk, by washing in warm water, slightly acidulated with sulphuric acid, then passing through bichromate of potash vapour, and gently washing in cold water. Samples of flax exposed for 2 hours to steam at 2 atmos., boiled in water for 3 hours, and again steamed for 4 hours, lost only 3·5 per cent. of their weight, while Manilla hemp lost 6·07; hemp, 6·18–8·44; jute, 21·39. The conversion of flax into textile fabrics is a large and distinct industry (see Linen Manufactures).

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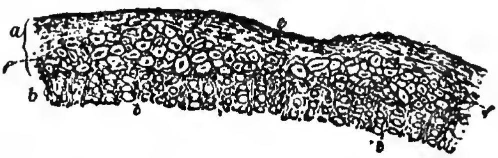

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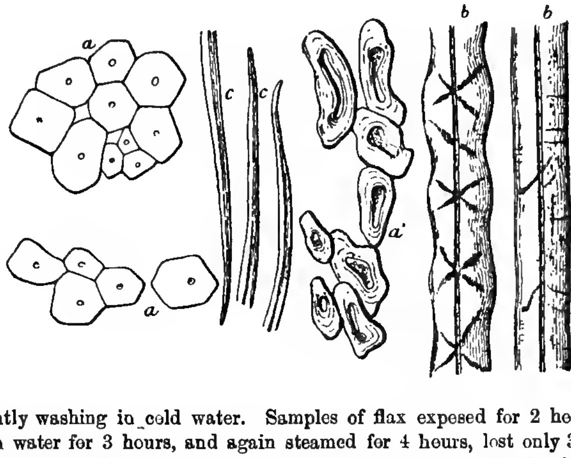


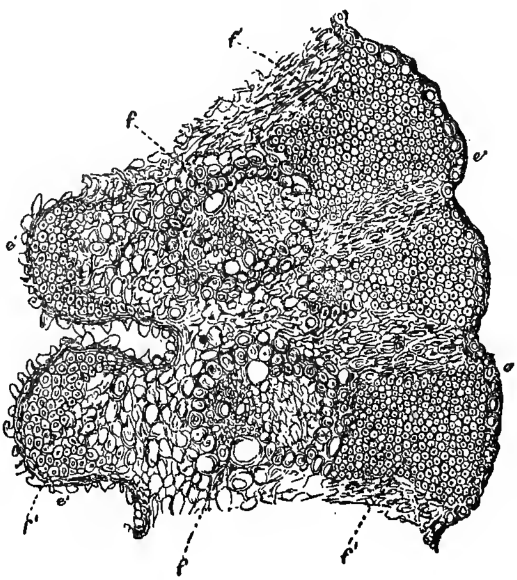
Brands, Prices, and Imports.—Flax is sorted and bracked differently at the various ports where it is chiefly shipped. Ordinary Riga brands are as follows:—K, crown; H K, light crown; P K, picked crown; H P K, light picked crown; S P K, superior picked crown; I S P K, light superior picked crown. Crown flaxes of "grey" or "white" colour are shipped from Riga, mostly to France and Belgium, as:—G K or W K, grey crown or white crown; G P K or W P K, grey or white picked crown; G S P K or W S P K, grey or white superior picked crown. The Livonian or Hoffs flaxes shipped from Riga are:—H D, hoffs dreiband; W H D, white hoffs dreiband; P H D, picked hoffs dreiband; W P H D, white picked hoffs dreiband; F P H D, fine picked hoffs dreiband; W F P H D, white fine picked hoffs dreiband; S F P H D, superior fine picked hoffs dreiband; W S F P H D, white superior fine picked hoffs dreiband. The lower Riga flaxes are:—W, wrack; W P W, white picked wrack; P W, picked wrack; G P W, grey picked wrack; D, dreiband; L D, Livonian dreiband; S D, Slanitz dreiband; P D, picked dreiband; P L D, picked Livonian dreiband; P S D, picked Slanitz dreiband. The S D and P S D qualities are distinguished as Lithuanian Slanitz, Wellish Slanitz, and Wiasma Slanitz, there being differences in the produce of the several districts. The Archangel flaxes are known as 1st, 2nd, 3rd, and 4th crown; and 1st and 2nd Zabrack. St. Petersburg ships:—Pscow 12 heads, Longa 12 heads, Staro Russ 12 heads, Saletsky 12 heads, 9 heads, and 6 heads, all of which are white, or water-retted; also Rjeff, 1st, 2nd, 3rd, and 4th crown, and Zabrack, all brown or dew-retted; many other minor dew-retted flaxes come from St. Petersburg, bearing the names of the locality of production, as Melinki, Bejetsky, Ouglitch, Kostroma, Jaróslav, Vologda, Wiasma. Flax shipped from Pernau is distinguished as Fellin and Livonian, the former being the better, under the following marks:—M, Marienburg; G, cut; R, risten; H D, light dreiband; D, dreiband; O D, ordinary dreiband; L O D, low ordinary dreiband. Inconsiderable shipments are made from the ports of Narva (as No. V. and No. VI.), Libau (as crown; and 4 brand), Memel (as 4 brand and N B), and Revel. Tow is classed as Archangel, No. 1 and No. 2; and Petersburg, No. 1 and No. 2. Codilla, as Archangel, No. 2 and No. 3; Petersburg; and Riga.

The approximate relative market values of the chief brands are:—*Archangel*, 3rd crown, 52*l.*–54*l.* a ton; Zabrack, 39*l.*–48*l.*; *Petersburg*, 12 head, 25*l.* 10*s.*–36*l.*; 9 head, 22*l.* 10*s.*–25*l.*; *Egypt*, government dressed, 45*l.*–50*l.*; common to good, 19*l.*–35*l.* French flaxes of exceptional quality bring as much as 180*l.*–200*l.* a ton.

The exports from Riga in 1877 were 33,292 tons of flax (excluding tow and codilla); and in 1878, 29,682 tons. Archangel, in 1877, shipped 10,361 tons; and in 1878, 8059 tons; about ½ to Great Britain, and ¼ to France. Königsberg, in 1878, exported 135,854 cwt.; and in 1879, 135,600 cwt. Dunkirk, in 1877, shipped 518,399 kilo.

The imports of flax into the United Kingdom in 1879 were as follows:—*Dressed:* from Holland, 13,924 cwt., 52,888*l.*; Russia, 6178 cwt., 15,047*l.*; Belgium, 994 cwt., 3730*l.*; other countries, 2179 cwt., 5695*l.*; *Rough or undressed:* Russia, 1,046,687 cwt., 1,857,324*l.*; Belgium, 185,112 cwt., 814,393*l.*; Holland, 107,944 cwt., 365,931*l.*; Germany, 52,221 cwt., 86,426*l.*; France, 12,453 cwt., 30,444*l.*; other countries, 5362 cwt., 10,577*l.*; *Tow or Codilla:* Russia, 141,885 cwt., 209,539*l.*; Belgium, 98,933 cwt., 110,094*l.*; Holland, 16,581 cwt., 16,858*l.*; other countries, 4641 cwt., 5715*l.*

686.



Lygeum Spartum — Esparto (Fr., *Sparte*). — Endogen; perennial grass, of creeping habit, and with the leaf-sheaths internally glabrous. A native of the Mediterranean regions, but chiefly abundant in N. Spain; selected for culture in Victoria. It grows in similar soils and situations to those frequented by *Macrochloa tenacissima*, and in many respects closely resembles that plant. A section of the leaf is shown in Fig. 686: *e e'*, the epidermis of each side of the leaf; *f*, fibro-vascular bundles, situated in circles, coloured yellow by test H; *f'*, fibres scattered throughout the parenchyma of the leaf, coloured blue by the same test; mag., 100. The dimensions of the filaments are:—length: max., 0·17 in.; min., 0·04 in.; mean, 0·1 in.; diameter: max., 0·0008 in.; min., 0·00048 in.; mean, 0·0006 in. The fibre is tough, and said to have been used for rope-making by the Romans. It is commonly supposed to contribute largely to the esparto grass of commerce, so largely employed by paper-makers; but W. H. Richardson asserts positively that the commercial article, from whatever locality, is the produce solely of *Macrochloa tenacissima* (q.v.).

Macrochloa [Stipa] tenacissima—Alfa, or Esparto.—Endogen. This grass is a native of Spain, Portugal, Greece, and N. Africa, ascending the Sierra Nevada to 4000 ft.; it is recommended for culture in Victoria. The habit of growth is tufted, and the leaf-sheaths are hairy internally, by which characteristics it is distinguished from *Lygeum spartum*, which is popularly, though erroneously, supposed to yield a portion of the alfa or esparto of commerce.

Cultivation of the Plant.—The plant grows in root-clusters, 2–10 ft. in circumference; between the clumps, little channels convey away excess of moisture. The leaves attain a length of 6 in.–3 ft., and are about 0·16 in. in diameter, becoming dry and closer when ripe. The flowers appear in April–May, and ripen in May–June; the seed falls in June–July, and germinates in the following autumn. Seed is generally produced annually, its quantity depending much upon the rainfall. The young seedlings are very delicate, and easily killed by late frosts. For the first 2 years, growth is scarcely perceptible; and not till 12–15 years have elapsed, will the plant begin to yield serviceable produce. It then continues to develop up to a great age. Cultivation, properly speaking, is almost unknown to it, and men have mostly been content to draw upon the very extensive wild growth of the plant. Nevertheless, if supplies are to be maintained, this subject must receive attention. The following remarks therefore are intended to indicate what might be, rather than what is done.

Situation and Climate.—The zone where the plant is indigenous may be included between 32° and 41° N. lat.; here it is found at altitudes varying from sea-level to 3000 ft. The most favourable localities are at moderate elevations on the sea-coast, none comparing with those where the plant is under the immediate influence of the sea-air. Here the fibre is fine, short, and even. At the same time, much finer esparto, with longer leaf, is found inland; but instead of being all of uniformly superior kind, the prime will form only ½ or ¼ even of the whole, the remainder being coarse and rank. Sunshine is eminently beneficial, if not essential. The coast grass is preferred by paper-makers; while the longer growth from the interior is sought after for making sieves, baskets, &c. A southern aspect produces the finest fibre.

Soil.—The plant prefers calcareous or chalky soils, sands, and stony land; on clay, it never thrives. Neither depth nor richness of soil is necessary: it flourishes on arid, sterile spots, even in the Sahara itself, where no other plant exists. It is never grown on land which is capable of producing other crops, and it is not certain that the fibre would be improved or increased by good soil.

Propagation.—This may be effected in either of three ways—(*a*) sowing, (*b*) transplanting, and (*c*) burning down the *atochas* or annual flower-stems.

(*a*) The seed-collecting time varies with the altitude and exposure: on coast-lands, the seed will be ready by June; further inland, in July; on the highest interior lands, August or later. If gathered prematurely, the seed is useless; if the right moment be missed, the seed will have fallen. The surest test of maturity is a roughness to the touch when the fingers are lightly passed over the ear. The ears are then cut and sun-dried, and the seed is extracted by hand, or by passing the ears between wooden seeding-rollers. If stored thoroughly dry, and kept so, vitality is retained for years. In September, the ground is prepared by light ploughing, or harrowing. Sowing is best performed in October–November, when rain may be reckoned upon. The seed is scattered broadcast. It needs but little covering of soil: generally it will suffice to turn cattle on the land immediately after sowing; but when cold is anticipated, bush-harrows and rollers may be used. In the 2nd year, the *atocha* will appear, and will develop till the 10–15th year, when it should be productive. The quality of the fibre then yielded does not repay cost of gathering; but leaving it causes the *atocha* to rot, while regular pulling from the first conduces to the health and strength of the plant. After 4–5 years, the clusters of *atochas* are thinned; and again in the 8th–9th year. This operation may be entrusted to women and children.

(*b*) To transplant an *atocha*, it is taken up entire, without separation of, or injury to, the roots. It is then divided into 4 or more portions, which are planted out in holes, measuring 8 in. each way, and 2 ft. apart. The holes are then filled in, and well trodden down, to exclude the air. The best time for transplanting is early autumn; after the frost has set in, it is very risky. It may be done in the spring, after sufficient rainfall. In the autumn planting, the beds are opened early in September, so as to be ready for the first showers.

(*c*) The old *atochas* are fired after the esparto has been gathered; they will then send out new shoots, which will have all the vitality and fruitfulness of the old ones. After the first 2–3 years, the leaves are collected annually, to prevent the decay of the calices; and, after the 5th–6th year, are economically valuable. By this method, the growth of the plant is stimulated, and the ground is cleaned and benefited. Such plants are quite equal to those raised from seed.

Each of these methods is advantageous under certain circumstances. Sowing is attended by the drawback that, on the average, 12 years are required before the plant affords any return, and there is great danger from frost during the early years of growth. Transplanted plants are productive in 6–8 years, and are more proof against cold; but the process is very costly, and often impossible from lack of labour. On the whole, sowing is preferable to transplanting, except in exposed situations. On new lands, choice lies between these two plans; but on old lands, burning is superior to either, affording a full crop of good quality in the 5th–6th year. All that is necessary is to confine the burning within the prescribed limits, which is easily effected, as it proceeds very slowly. The land should be divided into as many proportions as there are years in the life of an *atocha*, say 50–60. Commencing with the worst, one such portion should be burned each year, thus leaving always about $\frac{1}{10}$ of the land unproductive, and undergoing renewal. Quadrangular plots, 3 times as long as wide, and 10–100 acres in area, with lanes between, would be most convenient for arranging the rotation. The advantages of properly conducted burning are so great as to place that method unquestionably foremost in all cases where it is possible, at the same time, sowing and transplanting may be resorted to for the purpose of filling up the vacancies so common and numerous between the clumps.

Harvesting.—The gathering of the crop should never commence earlier than July; the general harvest is not organized till August, from which date it may proceed safely till the end of October, according to the amount of labour available. The harvest period is determined by the maturity of the leaves, which, in that state, are removed by a steady pull, from the *atocha*, which is left uninjured in the ground, ready to send up new shoots in the following November–December. The dislodgment of the leaves is performed in several ways. According to one plan, a short drum-stick called *arancadera*, or *cogedera*, is used. The tops of the leaves are taken in the right hand, and twisted round the pointed end of the drum-stick, when a sudden upward and sideward pull tears the leaves from the *atocha*, leaving them collected in the left hand. By another method, the drum-stick is replaced by a flat strip of leather; and in a third plan, use is made of the hand alone, protected by a leather covering. As soon as the left hand is full, the bundle is secured, by turning one or two of its own leaves round it, and is laid on the ground to dry. Two of these bundles make a *manada*, 10–12 *manadas* make a *hace*, and 3 of the latter make a *carga* or donkey-load, which, when dry, weighs about 8 *arrobas* (2¼ cwt.), and is the recognized standard of measure by which esparto is bought in the interior of Spain. Harvesting can proceed only in fine weather; wet not only softens the ground, and allows the root of the plant to be torn up, but also causes the leaves to adhere most tenaciously to the stem—the crop is thus greatly reduced in value, and the plants are destroyed. Where the plants have been ill-treated, and are consequently of very irregular growth, it will be beneficial to have two harvests annually, for a year or two, taking the mature leaves in August, then, in the following February–March, those which have matured in the meantime. Judicious pulling is above all things necessary, in order to maintain an esparto plantation.

Produce.—It is said that 10 tons of dry esparto may, under favourable conditions, be obtained from 1 acre of land.

Chief Localities of Production.—In Spain, the plant is found growing wild in the provinces of Guadalajara, Toledo, Ciudad Real, Albacete, Cordova, Jaen, Granada, Almeria, Murcia, Alicante, Valentia, Baleares; the largest quantities occur in Almeria and Murcia. It is remarkable that Italy is almost entirely destitute of it. Spain was, for a long time, alone in supplying our markets with this grass; but the increasing demand caused such recklessness in cultivating and harvesting, that the plant has been killed out in many places, and the supplies from Spain are now small as compared with those from N. Africa. Foremost among the African esparto-producing countries, is Algeria. It is divided into 3 provinces, Algiers, Oran, and Constantine. The N. limit of wild esparto in the first province is formed by a line passing through Ain Federel, Chatonmia, Ain Oussera, El Birin, and Toubia; the S. limit extends beyond Laghouat. The whole comprises an area of about 2,500,000 acres, of which at least half is north of Djelfa. Much of it cannot be profitably utilized without the construction of railways to transport it to the coast. In Oran, the circles of Sebdon and Daia are almost entirely covered with esparto, extending from St. Kelos, north of Sebdon, to beyond the Chotts, as far as the mountains of Ksour. The quantity obtainable is almost boundless. In the circle of Daia, it covers about 900,000 acres; in the subdivision of Mascara, there is an immense field; as also in the Bagh Aghalik of Foenda, in the circle of Saida, and through the whole country traversed by the strategic route from Daia to Tiaret. Most of this has been conceded to the Franco-Algerian Company, who are laying a railway from Saida to Arzew to convey the produce. In the subdivision of Setif (in Constantine), the circle of Bon Saada contains about 170,000 acres; the subdivision of Batua, about 250,000 acres; and in the neighbourhood of Tebessa and Ain Beida, there are about 150,000 acres. In all these places, transport is the one difficulty. Large quantities of esparto are produced in Tunis. It is brought in loose bundles from a number of places, as Shebbat, Agareb, the hills of Hamamah, Zluss, Shirah, Gabes, Green, Zarat, &c. Shipments take place chiefly at Susa, Sfax, and Gerba; also, in minor quantities, from Bugarah and Zerzis. Tripoli and Morocco also contribute considerable quantities.

Characters and Uses of the Fibre.—The leaf of esparto presents an appearance altogether different from those of the endogens generally, as will be seen by reference to Fig. 687. The fibro-vascular groups or bundles *f* are spread throughout the interior of the leaf, but the intervals, instead of being occupied by parenchyma, with large cells and thin walls, are filled with a compact mass of fine solid fibres *f'*. The fibres *f* are coloured yellow by test H, whilst *f'* are coloured blue by the same test; *e*, external epidermis; *e'*, internal epidermis; mag. 100. In Fig. 688, are sections of the fibres:—*a*, section of a group of fibres; *b*, fibres seen longitudinally; *c*, ends; mag. 300. The dimensions of the fibres are:—length: max., 0·137 in.; min., 0·019 in.; mean., 0·058 in.; diameter: max., 0·00072 in.; min., 0·00028 in.; mean., 0·00048 in. The extreme fineness of the fibres, their uniformity, their tendency to curl, and their transparency, resulting from the purity of the cellulose composing them, indicate their peculiar suitability for the manufacture of paper. For this purpose, esparto may now be said to rule the market, and any other paper material would have to bear comparison with it as a standard. Lesser quantities of the fibre are used in the manufacture of inferior cordage, sieves, basket-work, &c.

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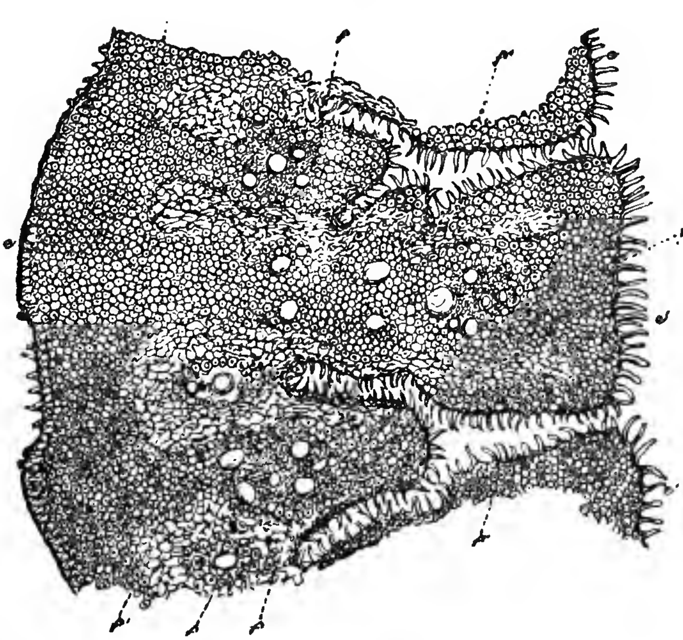

Exports, Imports, and Value.—The exports from Malaga to the United Kingdom were 16,012 tons in 1876; 12,305 tons in 1877; and only 3453 tons in 1878. Carthagena shipped 11,000 tons in 1876; and 10,000 tons in 1877. Mogador in 1878 exported 2417 bales (6050 cwt.), all to the United Kingdom. The exports from Tripoli in 1878 were valued at 139,998*l.*; and in 1879, at 174,997*l.* The shipments from Susa were 7683 tons in 1875; 8476 tons in 1876; 7183 tons in 1877; and 4674 tons in 1878.

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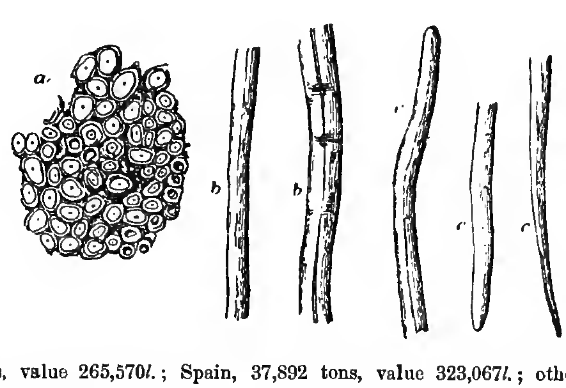


The imports into the United Kingdom, in 1878, were:—From Tripoli and Tunis, 60,478 tons, value 329,474*l.*; Algeria, 39,941 tons, value 265,570*l.*; Spain, 37,892 tons, value 323,067*l.*; other countries, 2194 tons, value 14,189*l.* These figures are somewhat exaggerative, as they include other vegetable fibres imported for paper-making. The approximate market values are as follows:—Spanish, fine to best, 10*l.* 5*s.* a ton; fair to good average, 10*l.*; Oran, hand-picked, 7*l.* 10*s.*; fair to good average, 7*l.*; Tripoli, hand-picked, 6*l.* 10*s.*; fair average, 6*l.*; Susa, 8*l.*; Gabes and Sfax, 7*l.* Ide and Christie, of 72, Mark Lane, are probably the foremost house in this trade.

Malachra capitata.—Exogen; annual or perennial shrub. Probably native of S. America, but now found everywhere within the tropics. It occurs throughout the hotter parts of India, from the N.-W. Provinces to the Carnatic, and thrives in Bombay and Bengal. It flourishes without any attention in marshy soil. It yields fibre 8-9 ft. long, which is extracted and prepared precisely like jute (*Corchorus*), but requires to be retted directly it is cut. When well cleaned, it has a silvery lustre, and is almost as soft as silk; with proper cultivation and preparation, it is anticipated that it will equal jute.

Malva sp. div.—Exogen. The fibres of *M. rotundifolia*, *M. crispa*, and *M. sylvestris* are widely utilized; also of *M. peruviana* in Peru, and *M. mauritiana* in Italy, Portugal, Spain, &c.

Manilla hemp.—*See* **Musa textilis.**

Maranta obliqua.—Iturite fibre.—Native of British Guiana. The fibre is used by the Indians for making their pegalls.

Marsdenia tenacissima—Jetee.—Exogen; small climber. Found wild in the sub-alpine regions of Bengal, in the Rajmahl Hills, and in Chittagong; grows in dry and barren places, and might easily be cultivated. The bark of the stems yields a valuable fibre, which is extracted by cutting the stems into sections, splitting them, drying them, steeping them in water for about an hour, and scraping them clean with the nails or with a stick. The hill-men simply dry the stems, and altogether dispense with retting. About 6 lb. of clean fibre is a good day's work. The fibres are fine and silky, and of great strength, a line made of them breaking at 248 lb. dry, and 343 lb. wet, as against hemp at 158 lb. and 190 lb. It is used locally for bow-strings, and for netting.

Mauritia flexuosa—Tibisiri.—Endogen; palm, 80–100 ft. A native of the Lower Amazon, where it completely covers large tracts of tide-flooded land. The epidermis of the leaves furnishes a material of which cordage for hammocks, and a variety of other purposes, is manufactured. The central bunch of unopened leaves is cut down, and on shaking, the tender leaflets fall apart. Each is then carefully stripped of its outer covering, a thin, ribbon-like, yellowish skin, which shrivels up like a thread. These strips are tied in bundles, and dried, and are afterwards rolled and twisted into cords. In fineness, strength, and durability, the fibre is surpassed by that obtained from *Astrocaryum vulgare*. The fibres are fine, solid, and of very irregular diameter. The dimensions of the filaments are:—length: max., 0·118 in.; min., 0·039 in.; mean, 0·058 in.; diameter: max., 0·00064 in.: min., 0·0004 in.; mean, 0·00048 in.

Melodinus monogynus [Echaltium piscidium].—Exogen. Indigenous to Silhet. The bark contains a quantity of fibrous matter, which the natives of Silhet use as a substitute for hemp.

Mexican fibre.—*See* **Nidularium karatas.**

Musa sapientum—Edible Banana.—Endogen. This well-known plant is common throughout the tropics of both hemispheres, and is very generally cultivated for the sake of its fruit. It thrives best on land containing much decayed vegetable matter, but flourishes also in the poorest soil, and even near brackish water, and its cultivation is capable of wide extension, with very little trouble and expense. It is propagated from suckers, which rapidly attain maturity; some varieties, within 8 months; others, within the year. Each throws out from its roots and around its stem some 6–10 new suckers, which are cut down annually to make room for fresh shoots, and may be set out to form new plantations. Ordinarily, this plant is grown exclusively for its fruit, and thousands of tons of the fibrous leaves are thrown away as useless, or allowed to manure the ground. Prof. Key, of Madras, suggests that by cutting away a portion of the suckers, and leaving a portion, supplies of fruit and fibre may be obtained simultaneously. It appears very doubtful whether the quality of either fruit or fibre can be maintained in this way. On the other hand, the fibre has never yet been produced of a quality equal to that of *M. textilis*, the so-called Manilla hemp, and no doubt a great point would be gained, if, while retaining the fruit crop as the chief consideration and remuneration, a large quantity of less valuable fibre, suitable for paper-making, could be produced at a very low price, say below 10*l.* a ton.

A 400-acre experimental farm in British Guiana, planted with suckers at distances of 12 ft. by 9 ft., produced an average of at least 700 stems an acre annually. For fruit-raising, this distance is found to be most suitable; but for fibre-producing only, the distance should not exceed 8 ft. each way, giving at least 1400 stems an acre. The average yield of each plant was 80 lb. of fruit, and 4 lb. of fibre, only 2½ lb. of the latter being clean and good, the remainder dirty, broken, and fit only for paper-making.

Dr. Hunter gives the following method of extracting the fibre:—Soon after the tree has been cut down, the upright stems, and central stalks of the leaves, are selected, avoiding any which are old, stained, or withered. The different layers are stripped off, and cleaned in the shade if possible. Each stalk is laid with its inner surface uppermost on a long flat board, and the pulp is scraped off by a blunt iron tool. When the inner side, having the thicker layer of pulp, is clean, the leaf is turned over, and the back is similarly scraped. When a quantity of this partially cleansed fibre has been collected, it is washed briskly in abundance of water, and thoroughly rubbed and shaken about, so as to remove the pulp and sap as quickly as possible. After thorough washing, the fibre is spread out in very thin layers, or hung up in the wind, to dry. Exposure to the sun, while damp, engenders a brownish-yellow tint, not easily removed by bleaching. In the W. Indies, recourse is sometimes had to retting; this stains the fibre, and reduces its strength; more often the leaves are put between a pair of crushing cylinders, and are then cleaned by boiling in a dilute solution of caustic soda, followed by washing and drying.

The fibre bears in every respect a close resemblance to that of *M. textilis* (see below). The mean dimensions of the filament are about 0·1968 in. in length, and 0·00112 in. in diameter. In Dr. Royle's experiments on the strength of the fibre, some prepared at Madras broke at 190 lb., other, from Singapore, at 390 lb., and a 12-thread rope at 864 lb. Samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 6·74 per cent. by weight, while Manilla hemp lost 6·07; phormium, 6·14; hemp, 6·18–8·44 per cent. Slips of sized paper weighing 39 gr., made from this fibre, bore on an average 78 lb., as against Bank of England note pulp, 47 lb.; it is said to make a good paper, and to bear ink without being sized. The fibre is fine, white, silky, long, light, and strong; but in most respects is inferior to Manilla hemp. As with other fibres, the quality depends in a very great degree upon the modes of cultivation and preparation. (See Fruit—Bananas.)

M. textilis—Manilla hemp, Abacá.—This is the wild plantain (or banana) whose fruit is bitter and non-edible. It is a native of the Philippine Islands, and has been named from the chief port of shipment. It is by no means generally distributed in the group. The provinces of Camarínes and Albáy, in the south of Luzon, produce the greatest quantity; the islands of Samár, Leyté, Cebú, and Mindanáo, afford smaller contributions, much of that from the last-named island being despatched from Cebú. Attempts to grow the plant in the northern and western districts of Luzon have always been unsuccessful, chiefly, it is thought, by reason of the extreme dryness prevailing there for a great part of the year. The plant is said to exist in Borneo and Java. Repeated efforts have been made to introduce the plant into other countries, especially the E. and W. Indies, but with very questionable success, and the Philippines still enjoy a monopoly of the trade in the fibre. Yet the edible banana grows luxuriously in all the tropics. This remarkable difference between the two species is intensified by the fact that *M. textilis* requires less rich land than its fruit-yielding relative. The question deserves scientific investigation.

Cultivation of the Plant.—The cultivation of the plant is simple. In Albáy and Camarínes, the finest growth is obtained on the slopes of the volcanic mountains, in open glades of the forest, where shade falls from the neighbouring trees. On exposed level land, the plants do not thrive so well; and in marshy ground, not at all. The necessary conditions seem to be shade and abundant moisture, with good drainage. Too rich a soil tends to produce luxuriant leaves with a diminution of fibre. In laying out a new plantation, use is generally made of the young shoots, which very quickly throw up suckers from the roots. In favourable situations, 10 ft. is the usual distance between the plants; in poor soil, 6 ft. During the first season, weeds and undergrowth must be kept down; afterwards, the vitality of the plants serves to exterminate other growths. The forest shade also is no longer necessary, the leaves protecting the buds from the sun. In exceptional instances, the plants are raised from seed. The ripe (but not over-ripe) fruit is cut off, and dried. Two days before sowing, the kernels are removed, and steeped in water over-night. Next day they are dried in a shady place; and, on the following day, are sown in holes 1 in. deep in fresh, unbroken, and well-shaded forest land, allowing 6 in. between the plants and between the rows. After a year, the seedlings, then about 2 ft. high, are planted out, and tended in the same way as suckers, care being taken to keep the soil heaped up around the stem. The plants raised from suckers require 4 years before producing fibre of any value; those raised from year-old seedlings need at least 2 years. At the first crop, only one leaf-stalk is cut from each plant; but subsequently, the growth is so rapid that the operation may be repeated every 2 months. A plantation of mature shrubs will yield about 30 cwt. of fibre an acre annually. The fibre is in best condition just before the flowering time, but this period is not always waited for in taking the crop, in which case, the fibres are shorter and finer. The plant is severed near its roots, and the leaves are cut off just below their expansion. The petioles of the leaves are the fibrous portions sought for, and exist in layers: the outer is harder and stronger, and furnishes the *bandála* fibre, fit for cordage; the inner is fine, and yields the *lupis* fibre, used for most delicate textiles; the intermediate layers afford fibres of varying degrees of fineness, used for coarser textiles. Immediately the plant is cut down, the fibre must be extracted, otherwise the latter assumes a reddish tint, and becomes of less commercial value.

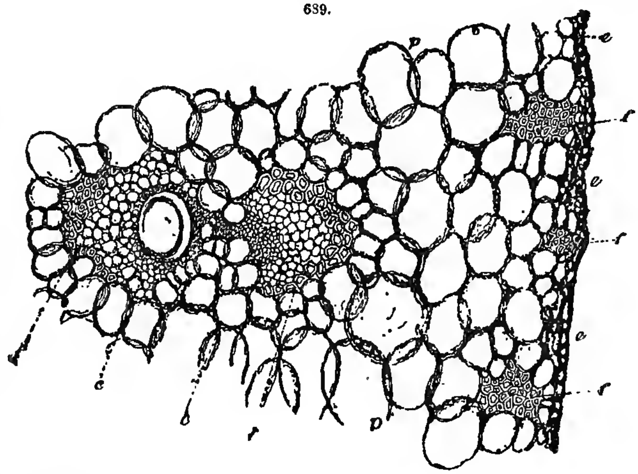
Extraction and Preparation of the Fibre.—The leaf-stalks of the cut plant are divided into strips, 3–4 in. wide, and 5–10 ft. long. These strips are subdivided, and are then subjected to a scraping process. The scraping is effected by drawing the strips by hand under a knife, 6 in. long by 3 in. broad, fastened to one end of a flexible stick, suspended perpendicularly over a smooth wooden block, and capable of having its pressure adjusted by means of a treadle. The strips are placed midway between the block and the knife, and are drawn each way. This operation is repeated 2–3 times, when the whole of the watery and pulpy portion of the plant is removed, leaving the clean fibres. One man at the knife, and one cutting down and transporting the plants, and cutting the strips, may together clean about 25 lb. of fibre in a day, though this is above the average. A full-sized tree may afford 1–1½ or even 2 lb. of fibre, but many yield only a few ounces; the average would not equal 1 lb. a tree; perhaps about 3200 trees may be reckoned to produce 1 ton.

Numerous attempts have been made to substitute machinery for the laborious and expensive manual operation above described; but as yet, no machine has been found efficient, at least none has been able to establish itself in the Philippines, though it seems strange that none of the stripping-machines used for dressing *Agave sp. div.*, and *Ananassa sativa*, can be adapted to this plant.

The cleaned fibre needs only to be hung up in the sun till dry.

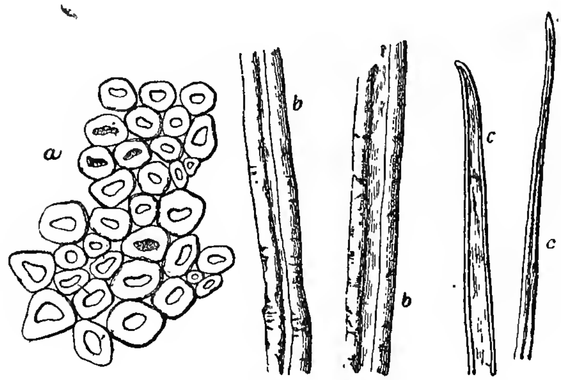
Characters and Uses of the Fibre.—Fig. 689 represents a section of the leaf-stalk of the plant; *e*, epidermis; *f*, fibro-vascular bundles, coloured yellow by test H; *c*, centre of the bundles, which assumes no colour under the test, and contains vessels and tissue in course of formation; mag. 100. The bundles are irregularly arranged, and the fibres composing them are closely packed. The fibres are shown in Fig. 690: *a*, section of a bundle of fibres; *b*, fibres seen longitudinally; *c*, ends; mag. 300. The fibres are always coloured distinctly yellow by test F. The filaments are white, lustrous, very light, and remarkably strong. After washing, the bundles are easily separated into flexible threads of even diameter. The central cavity is large and very apparent, the walls are of uniform thickness, and the ends taper gradually and regularly. The dimensions of the filaments are:—length: max., 0·472 in.; min., 0·118.; mean, 0·236 in.; diameter: max., 0·00128 in.; min., 0·00064 in.; mean, 0·00096 in.

689.



As before noted, the quality of the fibre varies much, according to its position in the stalk. The edges of the petioles contain the finest fibre, which is called *lúpis*, and is formed into the finest native textile fabrics. Above 5 tons per annum were once imported into France, at a cost of 100*l.* a ton, for making special under-clothing, but none is received now. The *lúpis* fibre is classified, according to its fineness, in the following descending scale: *binani*, *totogna*, *sogotan*, and *cadaclan*. The last is no longer used for weaving, and is sold with the *bandála*, which is the coarsest and strongest fibre, and is the only kind exported in an unmanufactured state. Only a small proportion of this sort is used up locally.

690.



Manilla hemp is imported into Europe, America, and other countries, almost exclusively for rope-making, for which purpose, its combined lightness and strength have procured for it a pre-eminent position, and enabled it to rule the market value of all fibres applicable to a similar end. Some samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 6·07 per cent. of their weight, while phormium lost 6·14; hemp, 6·18–8·44; and coir, 8·13 per cent. Worn-out rope affords excellent paper-stock. As minor applications of the substance, it may be mentioned that imitation horse-hair goods are produced from it, according to the process of H. R. Ungethum, of Lorintz, Schneeberg, Saxony, by dyeing with logwood and copperas, and imparting brilliancy by mechanical means. Rough and short fibre is used in brushes, as a substitute for bristles. The coarsest fibres, carbonized, are said to be used as carbon rods for electric lighting.

Exports and Value.—In 1873, the cultivation occupied 200,000–250,000 acres. It is nearly stationary, in spite of an increasing demand, the production being limited by the amount of labour available, and by the increasing attractions of sugar-growing. The exports from Manilla, in 1878, were 334,945 bales, value 703,385*l.* Of this quantity, 172,378 bales went to Great Britain, and 19,317 to British colonies, or altogether nearly ⅗ of the whole. In the same year, Cebú shipped 124,650 *piculs* (of 139½ lb.); in future, most of the Leyté hemp is likely to leave this port, instead of Manilla. Yloilo, in 1878, received 2400 *piculs* from other parts of the Archipelago, and shipped the whole to the United States. The distribution of the exports in 1871, was as follows:—N. America, Atlantic ports, 285,112 *piculs*; Great Britain, 143,498; California, 22,500; Australia, 6716; Singapore, 2992; China, 2294; Europe, 640. The local consumption cannot be ascertained; it must be very large, as this fibre principally composes the textile fabrics worn by the whole population of the Philippines. Our imports of it in 1878 were 425,866 cwt., value 553,577*l.*; in 1879, 340,765 cwt., value 439,108*l.* It arrives in bales, measuring 3 ft. 3 in., by 1 ft. 8 in., by 1 ft. 8 in., and weighing about 2¼ cwt. They are carefully covered with matting made from the leaves of the plant. The value of the fibre in the London market is approximately as follows:—ordinary, 20*l.* 10*s.*–39*l.* a ton; good and fine white, 30*l.*–66*l.* a ton.

There are many other varieties of banana or plantain which deserve examination as to their fibre-yielding properties. Among these may be mentioned *M. ensete*, *M. Banksii*, *M. Cavendishi*, *M. Basjoo* (in Japan) *M. violacea* (in Angola), *M. discolor*, *M. rosacea*, *M. ornata*, *M. troglodytarum*.

Nettles.—*See* **Bœhmeria sp. div., Laportea pustulata, Urtica sp. div.**

New Zealand Flax [Hemp].—*See* **Phormium tenax.**

Nidularium [Bromelia] karatas—Mexican fibre, Silk-grass (MEX., *Ixtle*; CEN. AMER., *Pita piñuella*).—Endogen. This plant grows wild abundantly in the W. Indies, British Guiana, Honduras, Central America, and Mexico; there are supposed to be several species or varieties, but much confusion surrounds the supposition. The plants are of a most prolific nature, growing spontaneously in almost all kinds of soil and climate. Cultivation in its native land is therefore extremely simple, and it is surprising that the plant has not received more attention from planters in America and our Colonies. The Indians cultivate the plant to some extent in Mexico, 1221 gardens being recorded in 1830. They generally select forest for this purpose, removing the undergrowth by cutting and burning. The roots of old plants are then set out at 5–6 ft. apart, and, at the end of a year, yield leaves fit for cutting. The leaves vary in size from 6 to 8 ft. long, and from 1½ to 4 in. wide, and are thin in proportion. In a wild state, the leaves are edged with thorns, but these are diminished in size and number by cultivation. The fibre contained in the leaves varies in quality, according to age; in young leaves, the fibre is fine and white; with increasing age, it becomes longer and coarser. The native implements for extracting the fibre are exceedingly rude—a flat board, and a heavy iron knife. No special machine seems to have been invented for the preparation of this fibre; but its close resemblance to the fibres of the agaves, and that of the edible pine-apple (see *Ananassa sativa*), would indicate the applicability of the same apparatus.

After the first crop, the leaves grow again; but the fibre subsequently produced is short, and of bad colour. Locally, the fibre is used for bow-strings, nets, fishing-lines, ropes, mats, sacking, and clothing. After being passed over the comb or hackles of a flax mill, it has been pronounced greatly superior to Russian flax, and equal to the best Belgian, for application to the finest textile fabrics. Fibre which was useless for spinning or rope-making would probably yield very superior paper-stock. It is very likely that this fibre contributes in no small degree to the large shipments of so-called "Mexican fibre," now extensively used in lieu of bristles for brush-making, and valued at 45*l.*–55*l.* (and even 160*l.*) a ton.

The above remarks are endorsed by the best botanical authorities; on the other hand, Arthur Robottom, of Mincing Lane, who, though not a botanist, has seen the plants growing, and whose knowledge of fibres is acknowledged, states that the leaves do not exceed 2 ft. in length, and that the plant is confined to Mexico, being gathered in quantity only in Zacatingas, Tula, and Plan de Amava. He adds that machinery has been introduced for separating the fibre from the leaves, but that it destroys that rigidity which gives the fibre its value for brush-making.

Nipa fruticans.—Endogen. A native of the Eastern Archipelago, extending northwards to the Mergui River, where it is found in perfection, but becoming very rare about Moulmain. It flourishes in brackish water, and where its lower part is inundated at high tide. In the Tenasserim Provinces, the leaves are extensively used for thatching houses, for cigarette-making, and for mat-making. The abundant fibre is not extracted for economic purposes. J. Fisher, of Singapore and 43, Mincing Lane, believes that the stems, weighing some 50 lb. each, would make excellent paper-stuff. The local profusion of the plant makes it worthy of attention.

Ochroma Lagopus—Corkwood Cotton.—Native of W. Indies. The down of its seed-capsules is fine, soft, and elastic; it is used for upholstery purposes, and has been employed in hat-making.

Ocymum pilosum [basilicum].—Exogen. Common all over N. India, and grown almost everywhere in Bengal, for its seeds. It is cultivated to a small extent in the western portion of the Hooghly district, on account of the strong fibre it yields for rope-making. The rope can be used only in the dry season, as it rots in the rains. The fibre might be available for paper-stock.

Œnocarpus Bacaba.—Endogen; palm. Native of the W. Indies. This tree yields a fibre from the base of the leaf-stalks, much resembling piassava.

Orthanthera viminea.—Exogen; 10 ft. This plant grows luxuriantly along the foot of the Himálayas. The fibres of the stem are very tenacious and long, and appear to be well adapted for rope-making.

Pachyrrhizus angulatus.—Exogen. A native of Central America; found everywhere within the tropics; proves hardy at Sydney. Requires a rich soil. Stems yield a tough fibre.

Pandanus odoratissimus.—Caldera bush, Screw-pine.—Endogen; bushy shrub, 10–30 ft. This plant is found abundantly in Bengal, Madras, Burma, the Straits Settlements, China, and the South Sea Islands. It grows wild in marshy places, and, in the Sunderbuns, is so abundant as to form impenetrable thickets on the sides of the creeks. It is somewhat slow of growth. The leaves, spathes, and aërial roots abound in good strong fibre.

P. utilis, the Vacoa, a Madagascar species, has leaves similar to the foregoing; in Mauritius, they are cut every year, after the plant is 3 years old, and are split into ribbons, measuring ¾–1 in. broad at the base, and tapering to a point. These strips are plaited, to form sacks, for the transport of sugar, each plant yielding about enough material for two sacks. In 1871, Mauritius exported 285,075 such bags, valued at 3394*l.*; in 1874, the figures were 154,578, 1878*l.*

The leaves are also made into matting, baskets, hats, and thatch, and are used for cordage and other purposes in the South Sea Islands. The root-fibres are much stronger than those from the leaves, and are occasionally used for making cordage, and for admixture with jute in gunny bags. Samples of the leaf-fibres, exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 12·21 per cent. by weight, while Manilla hemp lost only 6·07; phormium, 6·14; hemp, 6·18–8·44. This shows its inferiority to these fibres for rope-making. Both roots and leaves would probably afford excellent paper-stock.

Other species are *P. edulis*, *P. candelabrum*, *P. pedunculatus*, *P. spiralis*.

Pederia fœtida—Bedolee sutta.—Exogen; creeper. A native of Assam; it is abundant in the jungles, but the best fibre is obtained from plants growing on the alluvial deposits of rivers, as on the banks of the Brahmaputra. Another species or variety climbs trees; but its fibre is inferior. The plant could doubtless be cultivated; moreover, the supply of wild plants would not readily be exhausted, as on the plains, where they thrive best, the grass is burnt down annually, and, during the rains, the roots throw up fresh shoots. The proper time for collecting the plant is the cold or dry season; during the rains, the fibre comes off dirty and discoloured. The stem is divided into sections, a joint occurring at every 12–24 in. The cut stems, while still green, are divided at the joints, and the fibre is removed in the following way:—The operator takes each section in both hands, and twists it as much as possible, to disengage the fibres, having first carefully stripped off all the bark of the stem. He then disengages at one end enough of the fibre to take hold of, and gradually strips it entirely awsy. The process would be too slow, laborious, and costly for commercial purposes. Machinery has not yet been applied to it. Probably a pair of crushing rollers, and a simple scutching apparatus, would suffice. The fibre is possessed of great strength and flexibility, and has a silk-like appearance; it seems to be adapted to the finest textile purposes, in spite of its shortness, as governed by the length of the sections. Samples of the fibre, exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost only 4·26 per cent. by weight, thus showing its durability.

Phœnix dactylifera—Date palm.—Endogen. The leaves of this palm (See Fruit—Dates) are made into mats and baskets, and the fibre contained in the peduncle of the leaves is used for cordage. The filaments are of a clear-yellow colour, gross, irregular, stiff, and brittle. The fibre might probably be utilized for paper-making.

Phormium tenax—New Zealand flax.—Endogen; leaves 3–10 ft. This plant is a native of New Zealand, occurring as far south as lat. 46° 30′ S., also in Chatham's Islands and Norfolk Island, but not in Lord Howe's Island. It would probably thrive and become naturalized in the Auckland and Campbell's group, in Kerguelen's Land, and the Falklands. Large quantities of it are found in the mallee scrub of the Lachlan Plains in S. Australia, the leaves being 3–4 ft. long, and 1–2 in. broad; it doubtless occurs in many other parts of the Australian continent. In the Azores, St. Helena, Algiers, and S. France, it has been easily naturalized, and thrives well. In the Scilly Islands, it is largely planted to resist encroachments of the sea. Dr. W. Traill has most successfully cultivated the plant in North Ronaldshay, Orkney, and strongly recommends it to be grown on waste lands bordering the sea, raising the plants from seed in a hotbed, and transplanting when 6 in. high; about 8 years are required for the plants to attain maturity in such a position, but they render a double service. It has been proposed to introduce the plant in the Mississippi Valley, and other continental localities, but it prefers insular positions and coast lands. It might be brought under culture on inferior waste land, sea-beaches, and rocky declivities, not only in Australia, but in all climates where the winters are not too severe for it. In the south of New Zealand, it is never found far from the sea, nor at a great elevation; in the Northern Island, also, it is most abundant and best grown near the coast, but is also found abundantly in the interior up to 2000 ft.

It is essential to recognize the existence of several distinct kinds of the plant—whether species or mere varieties has not been decided,—as the fibre produced by them exhibits considerable differences. The chief sorts are:—(1) "Common Swamp" or *Harakeke*: grows almost everywhere, but attains its largest size (14–15 ft.) in rich alluvial soil, on river banks; its leaves are coarse, and afford a large yield of coarse fibre. (2) "Yellow Hill" or *Paretaniwha:* grows generally on clay hills, and is seldom more than 5–6 ft. high; its fibre is very good—soft and glossy, yet strong. (3) *Tihore:* grows in rich alluvial land which is dry, never in swampy places, and is rarely more than 6 ft. high; its fibre resembles No. 2, which is often mistaken for it; it seems to occur only where planted. The kinds growing on high and dry lands, though smaller, afford a much finer fibre, and are far more easily stripped, than the swamp-frequenting plants. The other species or varieties are so inferior in fibre-yielding qualities as not to be worth cultivation.

Cultivation of the Plant.—The chief climatic conditions having been referred to above, the cultivation may be discussed under the following heads:—

Soil.—The plant will grow in almost any soil, but the quality of the fibre depends almost entirely upon the degree in which the soil is favourable. The plant luxuriates in rich, moist, well-drained ground, and reaches its greatest size on the banks of running streams, where the roots are abundantly nourished by water that never stagnates around them. A rich, dry, but not deep, clay soil, with a yellow clay subsoil, favoured with plenty of light and air, but sheltered from the wind, is very suitable. Heavy crops also are raised on high-lying volcanic soil; and well-drained swamps give large returns. Stagnant marshes are prejudicial, but when drained and sweetened, without being made too dry, the plant assumes a vigorous growth. Most of the so-called "flax-swamps" have merely a margin of phormium plants around the edge.

Drainage and Tillage.—Where drainage is necessary, it should be effected by open trenches, dug sufficiently deep to keep the water about 12 in. below the surface. If the land becomes very dry in summer, the drains may be temporarily stopped, so as to irrigate the soil, for though the plant will not tolerate stagnant water, nothing conduces more to its rapid growth than occasional inundation. Reclaimed swamp should be ploughed as soon as it is dry enough, and be allowed to lie during the summer, or till March (in New Zealand), when it should be again ploughed, and immediately planted. Alluvial soil also should be ploughed in winter or spring, and left to dry till autumn, then be again ploughed, and planted, say in March–April, or when the autumn rains fall, the earlier the better, as the plants make root during the winter, and are ready for vigorous growth by the spring.

Planting.—Experiments in raising plants from seed prove that the rate of growth of the plant in its earlier stages is exceedingly slow, and that the seedlings do not inherit the characteristics of the plants whence the seed was derived. Consequently the only certain method of maintaining varieties, and the most rapid plan of commencing a plantation, is by subdivision of the root. Planting is done in rows. The distance generally recommended is 6 ft. between the rows and between the plants; but a more suitable space probably would be 4 ft. between the rows, and 3 ft. between the plants, as the plants would then afford each other shelter, and the drawing up of the leaves would produce finer fibre. Much economy of soil is thus effected, and the extra impoverishment of the land may be prevented by manuring. Another plan is to place 10–12 rows in close proximity, and then to have a road space of 10–12 ft., to facilitate gathering the leaves. An acre set out at 6 ft. each way will contain about 1000 plants; at 4 ft. by 3 ft., about $\frac{1}{3}$ more plants will be needed.

One phormium bush will afford 20–50 roots suitable for transplanting. The number of roots planted together varies from 1 to 8. When planting wide, 2–3 roots may be placed in a spot; but if close planting be adopted, one root alone will suffice. Care must be taken to avoid planting roots which have thrown up a seed-stem, or those from the centre of an old plant; the latter are not so productive as young roots, and will manifest a tendency to flower, thereby absorbing more nourishment than all the leaves. For this reason, the flower-stalks of the plants should be removed as early as possible, either by twisting off, or by cutting, and rubbing the wound with a little dry earth, to prevent "bleeding."

Diseases and Enemies.—Care must be taken to keep cattle from the plantation, or they will chew the leaves till only the fibre remains, and, where the leaves have been cropped, will draw out the young leaves to obtain the butts. Fires must also be guarded against. Attention is specially directed to a small "looper" caterpillar, about 1 in. long, which in some districts of New Zealand has been found to attack the nether side of the leaves in early summer, and eat away the fibre in patches ½–2 in. long and ¼ in. broad, causing an extra proportion of tow to be scutched out during the preparation of the fibre. Plants growing in sheltered places are most attacked, as the insect cannot so readily attach itself where the leaves are kept in motion by the wind.

Cropping.—Phormium grows in bunches or groups of plants or shoots, each shoot having 5 leaves; as 10 shoots on the average are contained in a bunch, each group will have about 50 leaves. These last vary in length from 3 to 10 ft., and each consists of a double-bladed leaf, which, when closed, is 2–4 in. wide. The plants are not ready for the first cutting till the 5th–8th year, according to the favourable character of the conditions under which they are grown. When every leaf is quite cut down, the plant will send up 4–6 full-sized leaves within the first year. If 2–3 of the centre leaves of each fan are left untouched, the cropping may be repeated annually, yielding each time 4–5 leaves. How long this treatment may be continued is not ascertained: it is probable that the plants will be gradually weakened, and will finally die out. It is also likely that plants which are cut annually will not send out as many new fans as those left entire. It would appear that after 13–14 months, the leaves commence to decay, and are then no longer of economic value. The usual period for removing the leaves (in New Zealand) is December–January. No appreciable difference can be discovered in the quantity or quality of the fibre yielded by leaves of various ages (within the two years' limit). The maturity of the leaf is ascertained by its texture and firmness, or by its being split at the point, or by the recurving of the blades from the central midribs. The top of the leaf should feel soft to the touch, and droop a little. It is generally conceded that only the outer leaves should be cut, and that, in doing so, great care should be taken not to injure the leaves which enclose the central shoot. With this view, the knife should be inserted at the leaf enclosing the central shoot, and the outside leaves, 2–3 on each side, be cut downwards and slanting outwards. No leaf should be cut before arriving at maturity, which it does in 6 months from its first appearance, as this weakens the plant, and makes it liable to go to flower.

Production.—On the best land, an acre may contain 2000 bunches of the plant, or 100,000 leaves. These leaves, after cutting off the gummy and useless butts, and drying in the sun, weigh about 5 to the lb., so that an acre may give nearly 10 tons of sun-dried leaves. When the outer leaves only are taken, the quantity will be reduced to 4 tons. Assuming a yield of 15 per cent. of clean fibre upon these 4 tons, the return should be 12 cwt. an acre, to which may be added about 8 cwt. of tow. The weight of green leaf required to produce 1 ton of fibre is stated by different authorities as follows:—5½ tons, 5½ tons, 6 tons, 6½ tons, 6¾ tons, 7 tons, 7–8 tons. To obtain 2000 bunches to the acre, however, the planting must be very close.

Extraction and Preparation of the Fibre.—Before describing the modern machinery invented for the extraction and preparation of this fibre, a few lines may be devoted to a consideration of the native methods, since all our mechanical skill has not been able to obtain a product approaching in quality that of the Maories.

Native methods.—(*a*) In preparing the Swamp variety for fine purposes, the natives select clean unspotted leaves of 12–18 months' growth, and, cutting off the upper leaf at about 6 in. below the point where the two blades adhere, reject the lower leaf, and the coloured edges and keel. The fibre is stripped only from that side of the leaf which was innermost when the blades were joined, the under side is cut across, and then with the smooth rounded edge of a mussel-shell, the whole row of upper fibres is torn away, with the cuticle adhering. The fibre is next scraped with the same shell, to remove as much as possible of the cuticle; when 12–20 leaves have been thus treated, they are thrown into a tub of water, to be kept moist till sufficient is ready to be taken down to a stream, where it is washed and scraped repeatedly till quite clean, then hung up to dry, and afterwards worked in the hand. Thus at most only ¼ the fibre contained in a leaf is utilized: ½ the leaf is discarded, and ½ the fibre of the other is rejected.

(*b*) When dressing fibre for their mats, the natives take more time and trouble: the fibre is soaked in water for 4 days, and then beaten with a stone or mallet; this is frequently repeated for 4–5 weeks or longer, weakening the fibre, but making it very soft and durable.

(*c*) The fibre is stripped from the leaves, and then allowed to dry, before the "scull," or adhering matter, is scraped off; it is not touched with water. The result of this is that the fibre is harsher, and not so silky, but sufficiently white. This plan is adopted only when water is not at hand.

(*d*) The *tihore* fibre is simply torn out from the leaf, rubbed between the hands to open the bundles, and scraped with the nails to remove the tissue.

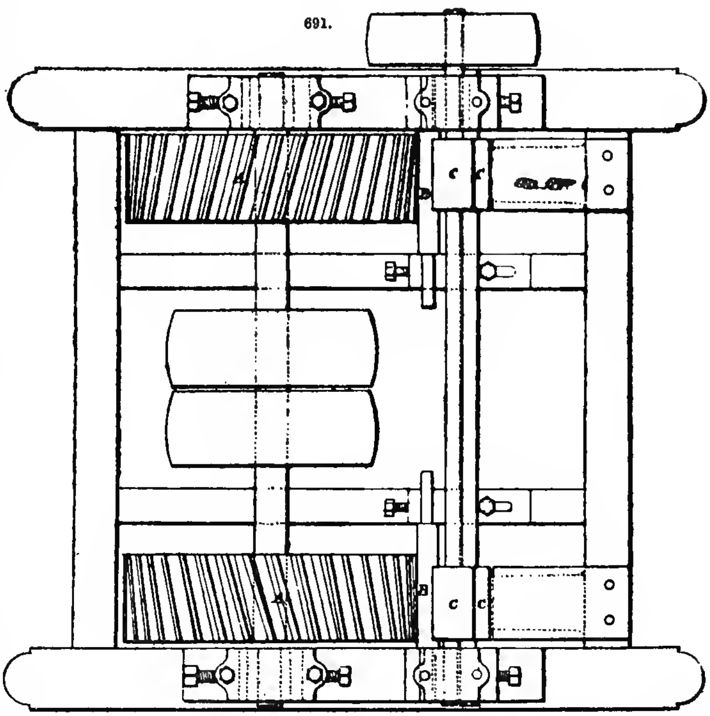
Only those mussel-shells with a straight edge can be used for stripping. After 2–3 days, the shell becomes too smooth for stripping, and is then used only for scraping off the scull. The fibre is stripped out much easier when the stalks are dry. The natives select only fully matured leaves, which are quite perfect, and show no signs of decay. It is probable that an average day's work of the native women does not exceed 2 lb. of clean fibre. It is evident, therefore, that native hand-dressing is out of the question for preparing the fibre on a commercial scale, hence a number of machines have been invented for the purpose.

Improved Methods.—The methods devised by Colonial and European machinists can be considered as improvements solely on the score of increased rapidity of production, the object being to turn out a large quantity of fibre fit for rope-making, whereas the native-dressed fibre is applicable to fine textiles.

The machines chiefly used are of three kinds, known respectively as Fraser's, Price's, and Gibbons'. They are identical in principle, and vary only in the matter of detail. The leaf is held between horizontal feed-rollers, revolving at a certain speed; as it passes out in a crushed state from them, a drum, armed with beaters on its circumference, and revolving more rapidly than the feed-rollers, strips the epidermis and vegetable tissue away from the fibre, means being provided for adjusting the drum to a proper distance from a roller, bar, or other contrivance, against which the leaf is stripped, so that neither may the leaf pass through uncrushed, nor the fibres be cut. Vulcanized indiarubber cushions, or steel springs, are placed over the journals of the upper feed-roller, so as to accommodate the varying thickness of the leaves. The quality of fibre produced much depends upon the shape and speed of the beaters, but more upon the ease and accuracy with which the machine can be kept adjusted. The proportion of leaf left undressed is governed by the firmness with which the feed-rollers grip the thin end of the leaf, and the distance between the point where crushing takes place and that where the leaf is held.

Gibbons' machine is illustrated in plan in Fig. 691; sections of the working parts are shown in Figs. 692 and 693. The beating-drum A is provided with angular beaters a, so arranged as to allow one edge of the leaf (by preference, the thin one) to be constantly acted upon, before the thick edge comes into contact with the beaters: this is accomplished by inclining the beaters in one direction to the axis of the drum, but all running parallel, which allows them to be placed nearer together. The beating-block or anvil B, by which the stripping is effected, consists of a round iron bar, with four-sided ends, which can be shifted so as to expose four different surfaces to the beaters as each is worn out; it is then rejected, and a new one is put in. The bar may be turned round while the machine is in motion, and is adjusted by pinching-screws. The feed-rollers C are deeply and sharply fluted, and hold the leaf firmly to the tip.

691.



Fraser's machine presents the following differences in points of detail:—(1) The beating-block is replaced by a thick plate, rounded at the end, which is slipped under the feed-rollers; the back of the plate has a flange, which is pressed forward by two screws against indiarubber, which pushes the plate back when the screws are loosened. The adjustment is easily made by the feeder. (2) The worn-out plate can be withdrawn, and another substituted, in a few seconds, without stopping the machine; and the old plate can be re-ground.

Price's machine differs in the following respects:—(1) The stripping is done between the beaters and the lower feed-roller, which is a cast-iron, smooth, hollow cylinder; being 3 in. in diameter, and constantly revolving, it presents a greater change of surface to the beaters, and thus lasts much longer, but when worn down, the machine has to be stopped, and taken to pieces, while the old cylinder is withdrawn, and a new one substituted. The old one can be re-ground. (2) The proportion of undressed leaf is reduced to a minimum, by the beating on the lower roller; but the smoothness of the latter sometimes permits the thin end of the leaf to be pulled through by the beaters.

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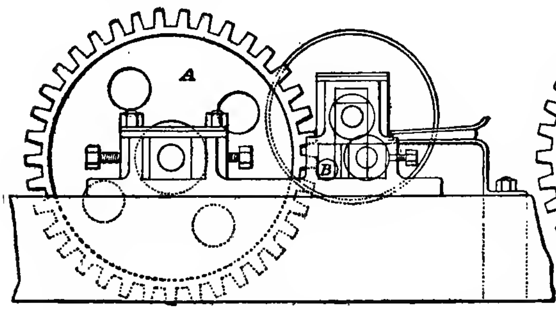

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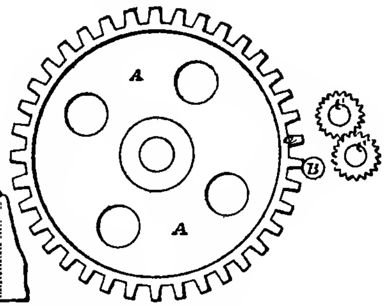

There is no appreciable difference in the practical value of the three machines as far as the quality of the fibre produced is concerned. The number of green leaves passed through in a given time depends on the diameter and velocity of the feed-rollers, on the size and shape of the leaves taken in, on the liability to stoppage by fibre getting round the shafts, and on the ease with which the machine may be cleaned when choked. The first condition is about the same in all: 30–35 leaves a minute is quite as much as the out-taker can manage, without entangling or losing a large part of them, and it is in this direction that improvement may be directed. Feeding at the rate of 2¾ ft. a second, will pass through 33 average sized leaves a minute, or 5 cwt. an hour. Gibbons' and Fraser's machines have an advantage over Price's, in admitting leaves with large butts, cut square at the end.

An improved arrangement is that known as White's, which consists of several different machines. The first machine is for breaking and stripping the leaves: a general view of it is given in Fig. 694; plan, in Fig. 695; and longitudinal section, in Fig. 696. The leaves are

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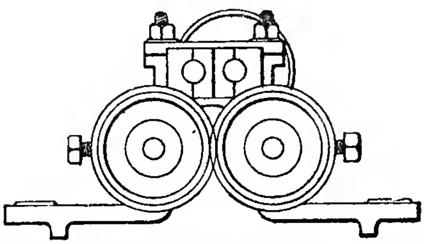

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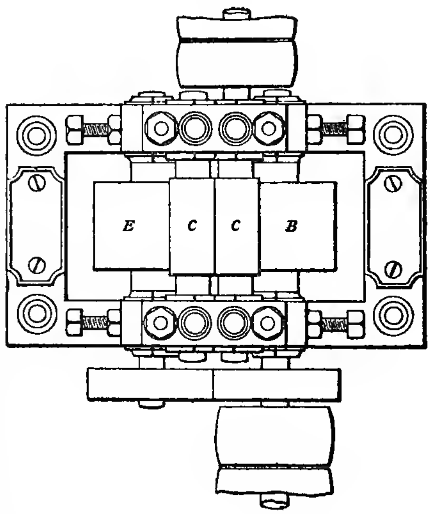

introduced through an iron feeding-mouth, 3 in. broad, and ½ in. deep, which leads close to a pair of horizontal fluted feed-rollers C, about 6 in. long. These work into each other, so that the leaf is thoroughly crushed before it reaches the horizontal stripping-drums E, about 6 in. long, and placed immediately behind the feed-rollers. After being turned, these drums are provided with grooves on the surface, about ¼ in. deep, aud at an angle of 35° to the length of the drums. These revolve outwards from the feed-rollers, at the rate of about 2200 a minute, or about 8 times the speed of the feed-rollers; they have a slow reciprocating action, and strip both sides of the leaf at once. The necessary gearing is fixed on the shafts of the drums, and springs are provided, so as to accommodate thick and thin leaves. When the ribs are worn down, the grooves may be re-cut.

After leaving this machine, the leaves are passed through one consisting of a pair of plain feed-rollers, and a pair of circular revolving brushes, the latter being arranged as shown in Fig. 697. These brush off all the fleshy matter which the stripping-drums have brought to the surface, and pass out the fibre in a clean state.

The fibre is then passed into the "finishing"-machine, entering first between a pair of plain feed-rollers, and then between a pair of smooth rollers having a rapid reciprocating action, which divides the fibre into very fine filaments, and makes it particularly soft. The two latter machines can keep four of the first in constant work. The fibre is then soaked in water for some time, and finally dried and baled. The rate of feed is 200 ft. of green leaf a minute, and the fibre produced is much superior

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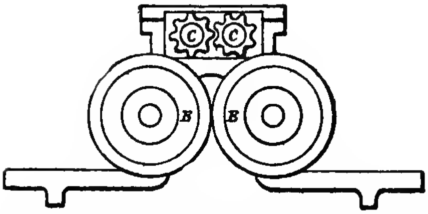

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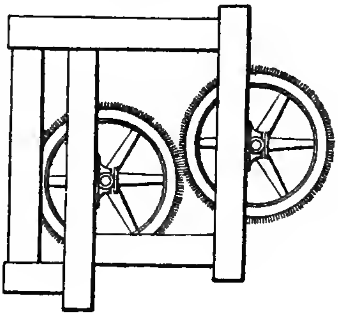

to that from the other machines. The different machines may be combined in one, as shown in Fig. 698: *a*, feed-rollers; *b*, strippers; *c*, revolving brushes; *d*, delivery-rollers; *e*, finishing- and drying-rollers; *f*, wringing-rollers; *g*, friction-rollers, for the travelling delivery-band *h*.

The many other machines for operating upon the leaf in its natural state may be classified as follows:—(*a*) By percussion on elastic surface: Booth's (New Zealand patents, No. 67), Nodding's (N. Z. pat., No. 71), Pownall's (N. Z. pat., No. 62). (*b*) By percussion on non-elastic surface: Purchas and Ninnis' (N. Z. pat., No. 1), Scherff's (N. Z. pat., No. 43), Howland's. (*c*) By combing on elastic metallic surface: Trent's (N. Z. pat. No. 60), Cox's (N. Z. pat., No. 38). (*d*) By scraping on elastic metallic surface: Pownall's (N. Z. pat., Sep. 1870).

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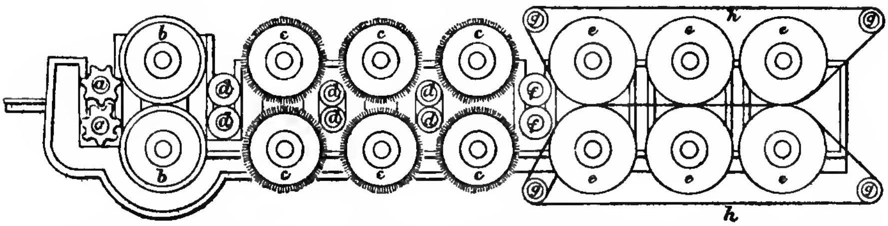

Thorough washing of the fibre immediately after leaving the stripper much improves the quality. Long soaking is not suitable; therefore, in order effectually to remove the adherent matter, mechanical force must be added, to shorten the duration of the washing. When water can be applied abundantly and with some force, the fibre is best washed in a strong jet with slight percussion, and in no case may the percussion be carried to such a point as to break up the fibre. Handling and bruising the liberated fibre except under water, should be avoided till all vegetable tissue has been removed. When the washing is complete, rolling may be used, to save time in drying, and to consolidate and define the fibrous bundles. Ordinarily the stripping-machine leaves much adherent tissue, which can only be removed by washing, a process that tends to entangle the bundles, and deprive them of the clean defined form so essential for rope-making. Washing is performed in two ways, known respectively as "cold-water" dressing, and "warm-water" dressing. In the former, bundles of about 20 leaves are suspended in cold water, and allowed to soak for 2 hours; in the latter, the fibre is washed, and then left to steep for 6–24 hours in tanks of warm water, kept at an even temperature of, say 32° (90° F.) by means of steam or fire-heat.

The greater part of the tissue, and the whole of the gum, mucilage, and bitter principle, having been removed by the stripping and washing processes, the next step is to destroy the green colour in those parts of the tissue still adhering to the fibre. This is effected by the operation of bleaching. If the fibre, on leaving the water, be dried at once, without exposure to the sun, it will dry green; this colour will survive for a long while, but can be removed at any time, by simple wetting and exposure to the sun. Usually, the operation is performed at once. In summer, the fibre is spread thinly on clean grass for 4–5 days, then turned over, and left for 2–3 days longer; when dry, it is taken into store. In winter, it is left on the grass for 2–3 weeks, and is then finished by hanging on wires or poles, exposed to sun, wind, and rain. After about 5 weeks' exposure, it begins to lose strength, and, if badly dressed, will commence to deteriorate much earlier. Each row of wires should consist of 3, arranged in a triangle, so as to keep the fibre open, and admit the air. The rows should be 10–12 ft. apart, so as to admit carts. About 1 ton of fibre will occupy 1 mile of wires, so that in winter a mill would require 1½–2 miles of them, covering 2–2½ acres of ground. About 15 acres of bleaching ground would also be necessary for a mill running 3–4 machines; and storage room for 15–20 tons, or about 12,000 cub. ft.

The next operation is scutching, which is intended to straighten out and clean the fibre thoroughly from the pieces of dry tissue still remaining on it, and from the dust and dirt picked up during the drying and bleaching. Scutching has been described at length when speaking of flax (*Linum usitatissimum*)—see p. 973; but the great length of the phormium fibre makes it much more difficult to scutch than flax. The process would be facilitated by cutting the hanks in two, so as to have lengths of 4–5 ft. A perfect scutching-machine has yet to be invented. The loss of fibre in scutching commonly amounts to 3–5 cwt. a ton.

The difficulty of effectually cleansing the fibre by purely mechanical means—beating and washing in water—has led to experiments in other directions. The principal methods which have assumed a practical form are the following:—

McMillan's: three distinct ways are adopted for removing the extractive matters—(1) Boiling with cow-dung for 2–3 hours, and then washing in cold water; (2) boiling with small proportion of common salt for 1 hour, and washing; (3) boiling in sea-water for 1 hour, and washing. The fibre is of equal quality from each process, but is of better colour in (2) and (3) than in (1).

Journeaux's: the crushed leaves are softened by a water-bath at 88° (190° F); then passed between pressure-rollers to remove refuse matter; then subjected to vinous fermentation in a water-bath at 32° (90° F.): finally squeezed, washed, and dried.

Thorne's: the leaves are crushed, and washed in cold water; then subjected to a bath of boiling water, in which animal matter has been digested.

Nattrass's: the leaves are boiled in a solution of prussiate of potash, before the fibre is extracted.

A more generally useful improvement is the application of a small quantity of oil to the fibre, adding to its appearance, and reducing its liability to undergo further maceration in water. The best time to apply the oil is at the end of the scutching; the fibres might be lightly coated with oil while passing through a second scutcher for the purpose. Animal oils may be used, but a proportion of mineral oil would perhaps be better. Fibre intended for export should not be oiled. Tarring is not advisable.

Baling.—A uniform size of bale similar to that of Manilla (*Musa textilis*)—3 ft. 3 in., by 1 ft. 8 in., by 1 ft. 8 in., is most suitable. The bales should be well covered, and not bound with iron lashings.

Characters and Uses of the Fibre.—A section of the leaf of the phormium plant, taken in the thin part, is shown in Fig. 699: *e*, epidermis; *p*, coarse parenchyma; *p′*, parenchyma filled with grains of chlorophyl; *f*, fibro-vascular bundles, coloured very slightly yellow by test H; mag. 100.

The fibres are nearly white, soft, supple, and of silky lustre; the bundles are of irregular size, separate with difficulty, and are very elastic and light. Their breaking strain, when the force is gradually applied, is high, viz. 23·7, as compared with flax 11¾, and hemp 16¾; but they break readily when bent or knotted. The isolated fibres are of regular diameter, their walls have a uniform thickness, and the surface is smooth. They are stiff, straight, and very fine; the central channel is very evident. The ends taper regularly and gradually, like those of flax. The fibres are represented in Fig. 700: *a*, sections of groups of fibres; *b*, fibres seen longitudinally; *c*, ends; mag. 300. The fibres are coloured distinctly yellow by test F. Their dimensions are:—length: max. 0·59 in.; min., 0·196 in.; mean, 0·354 in.; diameter: max., 0·0008 in.; min., 0·0004 in.; mean, 0·00064 in. A comparison of the fibres of *Phormium tenax*, *Musa textilis* (Manilla hemp), and *Agave sisalana* (Sisal hemp), shows the mean length of their ultimate fibres to be respectively 0·39 in., 0·21 in., and 0·21 in.; the mean diameter of the ultimate fibres to be 0·00045 in., 0·00083 in., and 0·00112 in.,

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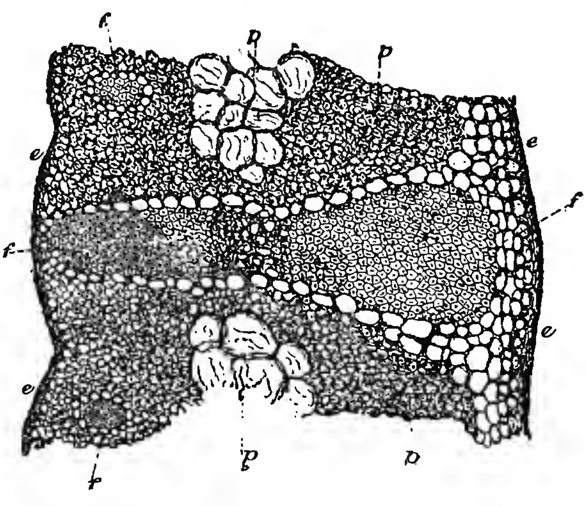

and the thickness of the cell-wall, 0·00015 in., 0·00024 in., and 0·00028 in. Samples of phormium fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 6·14 per cent. by weight, against Manilla hemp, 6·07 per cent., and hemp, 6·18–8·44 per cent.

It seems pretty certain that the principal uses of this fibre will be for rope-making, for the manufacture of very coarse textiles, and for paper-making, but especially the first. The tips and butt-ends of the leaves should be removed before the stripping takes place, and these rejected portions would be locally available for paper-making. As compared with Manilla hemp for rope-making, phormium white rope, kept dry, lasts longer and wears 34 per cent. better than Manilla rope; but when wetted with salt water, the durability of the phormium rope is reduced 34 per cent., while that of Manilla rope is much increased. When phormium rope is well oiled in the laying, however, it does not seem to be at all inferior to Manilla, even when exposed to sea-water. The former, when wet, is much harder and stiffer than the latter; when dry, looser in texture. It shows greater difference of length when wet and dry, especially after being in sea-water. The fibre is rendered harsh, and otherwise injured, by treatment with alkaline solutions, chiefly owing to the destruction of its natural oil. Contrary to the opinions of many, the fibre has proved to be well suited to the manufacture of coarse textiles. The "long tow," or "toppets," obtained in preparing fibre for cordage purposes, is easy to spin, and is useful for making wool-packs, corn-sacks, &c., requiring no alteration in existing jute machinery (see Jute Manufactures); it claims the attention of the colonists, who could ship the long fibre to this country for rope-making. Fibre prepared by Thorne's process, mentioned above, has been successfully converted into coarse sheeting, towelling, and canvas, by A. K. Forbes, of Hatton Mill, Arbroath, who deserves credit for his efforts to utilize the fibre. Native-dressed fibre has been manufactured into fine damask towelling, fairly good linen, and strong Scotch sheeting. It is evident, however, that the fibre cannot compete with flax alone for fine textiles, and that its only use in this direction in this country will be for mixing with flax, to impart additional strength (see Linen Manufactures). The refuse fibre is eminently fitted for paper-making, its tenacity making it suitable for bank-note paper. It might be exported to England in the form of half-stuff (see Paper).

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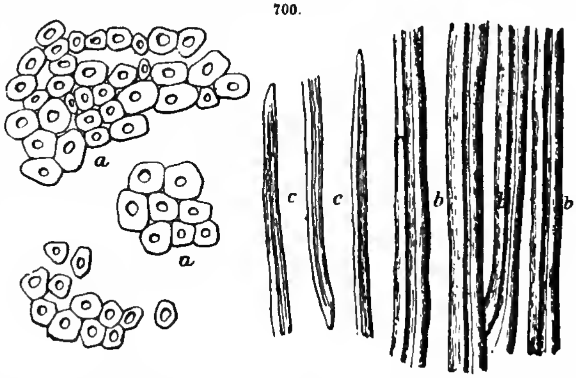


Exports and Value.—The exports of the fibre, in 1873, amounted to 6454 tons, value 143,799*l.*; 1874, 2039 tons, 37,690*l.*; 1875, 639 tons, 11,742*l.*; 1876, 906 tons, 18,405*l.*; 1877, 1138 tons, 19,457*l.* The value of the article in the London market, where it is known as "New Zealand hemp," is approximately as follows:—dressed, 20*l.*–22*l.* 10*s.*; half-dressed, 17*l.*–19*l.* a ton.

Piassava.—*See* **Attalea funifera, Leopoldinia Piassaba.**

Pimelea sp. div.—Exogen. *P. clavata* is not unfrequent in W. Australia. Its bark is pervaded by an extremely tenacious fibre, largely employed by the natives for their nets, fishing-lines, and kindred purposes. Some are of opinion that the bark could be profitably collected for textile manufactures, if so, it is the only species of sufficiently large and gregarious growth to render the fibre commercially available from the wild plants. A beautiful fibre, of similar utility, is yielded by *P. axiflora*, *P. hypericina*, and *P. pauciflora*, all found in the forest gullies of Victoria and Queensland, and the two latter also in Tasmania. On the Murray River, the natives use the bark of *P. microcephala*, a shrub of the desert.

Pinus sylvestris.—Pine-wool (Ger., *Waldwolle*).—Exogen. For several years in Silesia, and latterly also in Thüringer Wald, Jönköping in Sweden, Wageningen in Holland, and other places, the needles of the pine-tree have been utilized for the production of a textile material used in underclothing as a substitute for flannel, and accredited with valuable medicinal properties. The leaf needles are first distilled with water, for the extraction of the oil contained in them. The waters are used in medicinal baths. The remaining material is treated with boiling soda solution, for the removal of the vegetable matters. The resulting fibre, equal to about 13½ per cent. of the fresh needles, is spun into yarn, and then woven. The thread resembles that of hemp. The material is largely used in Vienna and Breslau for hospital and military blankets. The fibre is also employed as a substitute for horse-hair in stuffing.

Pipturus sp. div.—Exogen. *P. propinquus* occurs as a bush in Insular India, the South Sea Islands, and in Australia, from the north of New South Wales, through the littoral mountains of Queensland. It yields a fibre similar to that of *Bœhmeria nivea*. *P. velutinus*, in New Caledonia, affords a very beautiful fibre for fancy textiles ; *P. argentea*, the *Konganga*, or "Queensland grass-cloth plant," occurs in N. America, the E. Indies, Sunda Islands, N. Australia, and Queensland.

Plagianthus sidoides.—Currajong, or Corragine.—Exogen ; shrub, 20–25 ft. This plant is a native of Australia, and is found growing plentifully on the top and upper sides of the Strzelecki Range, on the Gippsland gold-fields, and on the Dandenong Range ; it is also indigenous to Tasmania, chiefly on the southern side of the island, in ravines and shady places. It grows rapidly. The bark may be stripped off very readily, even to the points of the smallest twigs, by cutting round the stem. It is doubtful whether the fibre could be got in sufficient abundance for general rope-making, though by miners it is much prized for cordage purposes. It might be applied to the manufacture of hats, paper, and even textiles. *P. pulchellus* and *P. betulinus* also are much esteemed in New Zealand, Tasmania, Victoria, and New South Wales.

Poa sp. div.—Endogen. *P. cæspitosa* is common on the river-banks of Victoria, and from its leaves, the natives make excellent mats.

P. cynosuroides is a native of N.-E. Africa, and S. Asia, and has been selected as eligible for culture in Victoria. It is a harsh perennial grass, 5–6 ft. high, not serviceable for fodder, but affording useful fibre, which, in N.-W. India is used for rope-making, and in India generally, for the manufacture of coarse mats. Both species deserve attention from paper-makers.

Prionium Palmita—Palmet.—Endogen. This plant is found in great abundance over the whole or nearly the whole of the S. African peninsula. Its fibrous leaves are used for making hats, baskets, &c., and are adapted for textile manufactures, paper, cordage, stuffing, brushes, &c.

Psamma arenaria.—Bent-grass, Marrem, or Moram.—Endogen. A native of the sandy coasts of Europe, N. Africa, and middle N. America. It is very valuable for binding sandy soils. Its fibre is used for paper-making, matting, and agricultural tie-bands.

Ramie.—*See* **Bœhmeria nivea.**

Raphia [Sagus] Ruffia.—Endogen. This palm is a native of Madagascar, and is believed to be peculiar to that island. It grows very abundantly on the coast, and more or less all over the island, reaching, in sheltered situations, to an altitude of 4000 ft. The leaves are 20–30 ft. in length, and consist of a great number of long grass-like pinnate fronds, set at right angles to the main rib. The fibre is extracted by peeling off the cuticle on each side of the leaf, leaving a thin, white fibrous substance, which is divided into different widths, by means of a kind of comb, according to the intended use. This is chiefly for matting, largely employed in covering floors, and wrapping up goods. The fibre is also employed by the natives for fine textile purposes. It is exported chiefly to the Mauritius, whence considerable quantities are imported into this country, under the name of "Raffia," to be used as agricultural tie-bands, &c. The value of the article in the London market is approximately 40–50*l.* a ton, though it fluctuates from 25*l.* to 240*l.* It is imported in strips, $\frac{1}{4}$–$\frac{3}{8}$ in. wide, but capable of subdivision into exceedingly fine threads. It is usually plaited in hanks of 1–2 lb. weight, made up into bales of $1\frac{1}{2}$–$5\frac{1}{2}$ cwt.

R. [S.] tædigera.—About 60 ft. This species is a native of Brazil, and inhabits exclusively the tide-flooded lands of the Lower Amazon and Pará rivers, being quite unknown in the interior. The leaves are often 50 ft. long and upwards. The leaf-stalk is 10–12 ft. long below the first leaflets, and yields a smooth, glossy rind, which the Indians tear off in strips, and apply to numerous purposes. The ribbons may be subdivided into very fine strips. The filaments are fine, regular, smooth, and supple. Their dimensions are:—length: max., 0·118 in.; min., 0·058 in., mean, 0·098 in.; diameter: max., 0·0008 in.; min., 0·00048 in.; mean, 0·00064 in. The fibres are coloured deep-yellow by test H. The fibre is imported into England and some parts of the Continent, in strips about 7 ft. long and 1 in. wide, for the preparation of agricultural tie-bands, especially for hops. Its suppleness and strength are increased by wetting. The London market value is approximately the same as that of the preceding species.

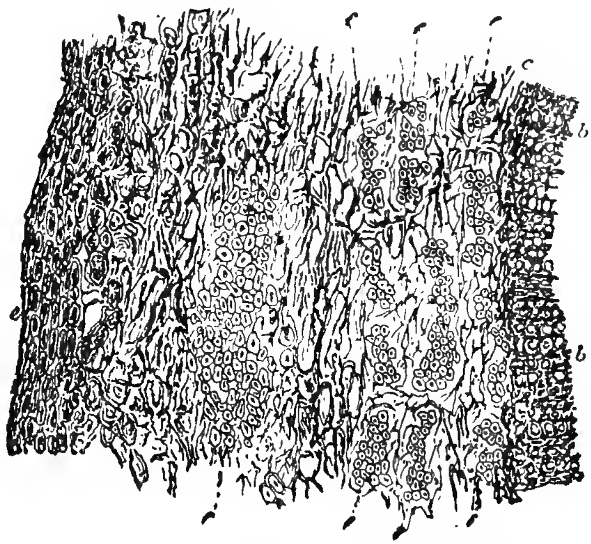
Rheea.—*See* **Bœhmeria nivea.**

Sabal Palmetto.—Endogen. This palm is a native of Carolina and Florida. The leaves are full of tough fibre, and are manufactured into hats. Machinery has been introduced into Fernandina, Florida, for preparing the fibre for cordage and paper manufacture.

Saccharum sp. div.—Endogen. Several species of this reed are found in India, and utilized on account of their fibre. *S. munja* grows abundantly in almost every part of Upper India, and is a common weed nearly throughout Bengal also. The leaves have been used since time immemorial for making cordage. They are gathered after the rainy season, dried, and twisted into ropes of great strength. The fibre is occasionally exported from Kurrachi, in Scinde. It can be procured in unlimited quantity and at small cost, and deserves attention from paper-makers in this country. *S. sara* is a rank weed like the last, and is plentiful in Bengal. Its leaves are rudely beaten, and then twisted into rope, which is very strong and durable, even when exposed to the action of water. It would appear to be as suitable as the preceding species for paper-making. *S. spontaneum* is wild and common in marshy places all over Bengal. It is perennial, and can be procured in any quantity. It is used for making mats, thatching houses, &c.

Salix sp. div.—Osiers.—Exogen. The many varieties of osier are very widely distributed in temperate regions. They are cultivated in beds chiefly for the manufacture of baskets. Their utilization for this purpose usually necessitates the removal of the bark from the woody stem. This is performed in France in the following way. The stems are cut when the sap has risen, and are soaked in water for some time. Each stem is then placed between two sharp teeth of hard wood; on drawing the stem through, the bark is peeled off in ribbons or strips. These strips are used by gardeners, as tie-bands, but they are admirably adapted for paper-making, if procurable in sufficient quantity. A section of the stem of *S. alba* is shown in Fig. 701: *b*, lignose; *c*, cambium; *e*, epidermis; *f*, bast fibres, coloured yellow by test H; mag. 100. The dimensions of the fibres are:—length: max., 0·118 in.; mean, 0·078 in.; diameter: max., 0·0012 in.; min., 0·00068 in.; mean, 0·00088 in. *S. cordata* on the Peel's River (N. America), and *S. arctica* on the Mackenzie, afford the native tribes fibre for their nets. *S. japonica* occurs in Japan.

701.



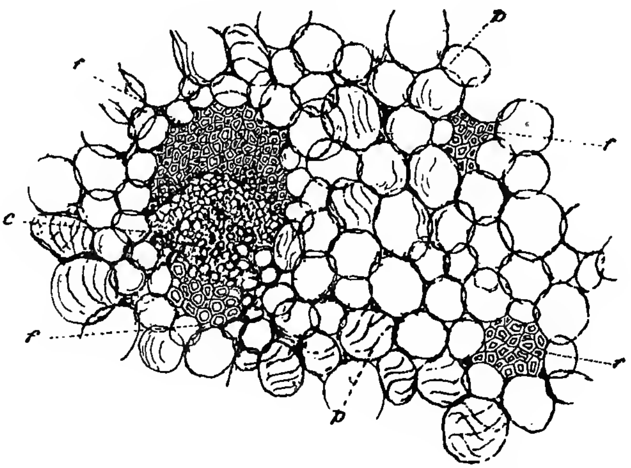
Sanseviera zeylanica — Bowstring - hemp. — Endogen. This plant is found in abundance all round the coast of Ceylon; it also occurs in the Bay of Bengal, and extends thence to the Japanese and Chinese coasts. It frequents the jungly salt soils of the sea-shore, growing under bushes; it is easily propagated, on almost any soil, from the slips which issue in great abundance from the roots; it requires little or no care, and, being perennial, seldom needs renewing. The wild leaves are about 12–16 in. long; but under cultivation, they attain a length of 3–4 ft. They contain an abundance of fibre extending throughout their whole length. The natives practise several methods of extracting this fibre. In some cases, the leaves are retted for 5–15 days, which process is effectual in separating the fibre from the pulpy matter, but causes a deterioration in the strength and colour of the fibre. A preferable plan is that of beating the leaves, and then placing them on a smooth board, and scraping them carefully, in order to remove the pulp from the fibre. For commercial purposes, neither system would be remunerative: probably a slightly modified form of the machinery used for preparing the fibre of *Agave*, *Ananassa*, or *Phormium*, described above, would be found efficient. Full-grown leaves 3–3½ ft. long yield at the rate of about 1 lb. of clean fibre for every 40 lb. of the green leaves. Dr. Roxburgh estimated that an acre of land would afford 1613 lb. of clean fibre at a gathering, and reckoned that in good soil and with suitable weather, two crops might be taken annually, after the plants are advanced enough.

The fibre is as soft and fine as human hair, yet possesses extraordinary strength and tenacity. When made up in hanks, it has a close resemblance to silk. It is, in most respects, more like pine-apple fibre than any other. A section of the leaf is shown in Fig. 702: *f*, fibro-vascular bundles, coloured yellow by test H; *p*, parenchyma; mag. 100. The dimensions of the filaments are:—length: max., 0·236 in.; min., 0·058 in.; mean, 0·118 in.; diameter; max., 0·001 in., min., 0·0006 in.; mean, 0·0008 in. In point of strength, the fibre seems capable of competing successfully with Manilla hemp. The coast natives employ it largely for making bow-strings, and it is generally in use for cordage purposes. Samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost only 5·55 per cent. by weight, as against Manilla hemp, 6·07; phormium, 6·14; hemp, 6·18–8·44. Properly prepared, much of it might be employed with advantage for fine textiles; and the tow has long been known as producing an excellent paper. The wide diffusion and easy cultivation of the plant, and the proved valuable qualities of its fibre, especially recommend it to the attention of agriculturists in India and in those colonies where the climate is suitable; and regular shipments of the fibre, uniform in quality, would soon procure it a place in our markets.

Other species are *S. lanuginosa* and *S. cylindrica*, indigenous to the E. Indies; and in addition, *S. guineensis*, *S. angolensis* and *S. longifolia*, in Africa.

Scirpus lacustris—Marsh Gladden.—Endogen. This rush is common in Britain, and generally in the north temperate zone, in boggy places. In America, it is known as the "Californian tule." It is used for making baskets, hassocks, bottle-covers, bee-hives, &c. It has recently been proposed as a paper material, being said to yield at least 50-60 per cent. of pulp, suitable for the best writing and printing papers.

702.



Sesbania aculeata—Dhunchee. — Exogen; annual, 6–10 ft. This plant is found in tropical and sub-tropical Asia, Africa, and Australia. It is very common in all parts of India, springing up in rice-fields, and other wet cultivated land, during the rainy season. It is also cultivated by the natives in low, wet soils; it requires little attention, is rapid in growth, and is considered advantageous to the soil as a rotation crop. Sowing takes place when the soil has been moistened by the first showers of April–May; about 30 lb. of seed is allowed to an acre; and less weeding is necessary than for jute. The crop is ready for cutting in September–October, though the fibre does not suffer if the plants are left standing till the seed is ripe, in November. The produce varies from 100 lb. to 1000 lb. of partially cleaned fibre from an acre. Europeans have obtained an average of 500 lb. clean fibre, and 275 lb. seed from an acre.

The fibre is 6–7 ft. long. It is coarser and harsher than hemp, unless cut very early. This may in part be caused by the native method of preparation, which resembles that in vogue for *Crotalaria juncea*. At the same time, the fibre is considered superior to jute (*Corchorus*) in strength and durability. It is best suited to the manufacture of cordage, for which purpose it is locally preferred to both *Crotalaria* and *Corchorus*. A 3½ in. rope broke at 75 cwt., the Government proof requiring only 49 cwt. Samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 6·07 per cent. by weight, or exactly the same as Manilla hemp in a similar trial. If properly prepared and scutched, it would doubtless command a sale in this market for rope-making.

Several congeneric plants might afford equally useful fibre; as *S. grandiflora* and *S. ægyptiaca*, in the E. Indies, Java, and Australia.

Sida rhombifolia [retusa]—Queensland hemp.—Exogen. This plant is found growing as a weed in wild luxuriance in many parts of Queensland, and gives much trouble to cultivators. It affords much fibre, having great strength, and average length and fineness. The attention of English paper-makers has been called to it, and it is recommended to be steeped and broken, to remove the bulk of the woody matter, and then to ship it in that state. Its value in that condition is placed at 11*l.*–12*l.* a ton; when thoroughly cleaned, it is worth upwards of 30*l.* a ton, and is fit for textile purposes.

S. rhomboidea—Sufet Bariala.—This is merely a variety of the above species; it is common in Bengal and Assam, where it springs up in the rainy season. Sown thickly on good soil, it shoots up rapidly, without branching. It yields an abundance of delicate flax-like fibres, exhibiting great strength, and 4–5 ft. long. A line ½ in. in circumference, after exposure to wet and sun for 10 days, bore 400 lb. Samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost 6 per cent. by weight as against Manilla hemp, 6·07; and hemp, 6·18–8·44 per cent. The fibre seems to be in every way superior to jute.

Many other species and varieties of *Sida* abound in Asia and Australia, and are deserving of investigation, e. g. *S. tiliæfolia* is cultivated in China, and its fibre is esteemed superior to hemp, while N. Australia produces *S. corrugata*, *S. intricata*, *S. virgata*, *S. petrophila*, and S. Australia furnishes *S. cordifolia*, *S. spinosa*, and *S. macropoda*, in addition to the first species indicated above.

Sisal Hemp. *See* **Agave sisalana.**

Spartina cynosuroides—Prairie Grass.—Endogen. This perennial grass inhabits fresh-water swamps in the eastern parts of N. America, and has been recommended for culture in Victoria. Its value as a paper fibre is said to equal that of esparto grass (*Macrochloa tenacissima*).

S. juncea.—This species is found in salt-marshes in N. America. A tough fibre can be readily obtained from its leaves.

Spartium junceum—Spanish Broom.—Exogen. This plant is a native of the Mediterranean region, and is found widely cultivated as an ornamental garden plant, and as a forage plant. It was anciently grown in S. France, on arid coast-lands and similar spots, for the sake of its fibre, which was employed in textile fabrics. It may now be recognized as affording a useful paper fibre. The plant is hardy, and flourishes in the poorest soil. The seed is sown in winter, with some other crop. For three years, the plant receives only an occasional thinning out. The young spring shoots are cut in February–March, or sometimes not till after harvest, the former being preferable. Towards the end of August, they are collected in small handfuls, and laid on the ground to dry, after which, they are made up into larger bundles of 25–30 handfuls each, and stored. On a damp day, they are beaten with a mallet, so as to flatten them without breaking them, and towards the end of September, they are put under stones in a river for half a day. In the evening, they are taken out and arranged in rows on a specially prepared plot of ground, near the stream, ready for watering. For this purpose, a bed of fern, straw, or chopped box is prepared, and on this the bundles of broom are placed one over another, the whole heap being finally covered with another layer of straw or box, on the top of which stones are placed, so as to keep the whole secure, and exclude sun and air. Thus placed, it is watered every night for eight days, allowing about 1 hecto. water for each bundle of fifty handfuls. On the 9th day, the retting is complete. The bundles are then alternately washed in running water, and beaten on a flat stone, till the fibre is separated from the woody portion. The bundles are next spread fan-wise on the ground to dry and bleach, when they are again collected and put away till winter. The fibre is then combed clean, and spun and woven into various textiles. At Casciana, on the Leghorn and Florence railway, hot-spring water is used for the retting; and a company was some years since started for growing the plant and manufacturing the fibre on a large scale.

Spathodea Rheedii.—Exogen; small tree. Found in Bombay, in gardens; also in the Khandalla Ghâts, and in Malabar. The fibre extracted from the branches and roots is used for making nets.

Sponia orientalis.—Exogen; small tree. A native of Ceylon, the Coromandel Coast, common along the foot of the Ghâts, and occurring in the Kennary forests, Salsette, in Nepal, Bengal, Sylhet, and Assam. The under-bark consists of numerous reticulated fibres, used for clothing by some native races.

S. Wightii—Chitrang.—This plant is a native of India, being especially abundant in the Concans. The fibrous bark or bast occurs in strips 12–30 in. long, 3–15 ft. wide, and 0·0039–0·03 in. thick. It is used not only as bast, but also in the manufacture of cordage. This fibre, and that of *S. orientalis*, are also said to be utilized in Mauritius and Venezuela.

Sterculia sp. div.—Exogen. *S. rupestris* is the true "bottle-tree" of the Brigalow scrubs of New South Wales and Queensland. *S. diversifolia* occurs from the eastern parts of Victoria to the south-western parts of Queensland. Both afford a fibrous bark, which may be useful for paper-making, and other purposes.

S. guttata is a tree, growing to a height of 70 ft. It is a native of Malabar. The bark of trees of the 10th year is employed by the natives on the western coast of India for making coarse clothing, and cordage. The tree is felled, its branches are lopped, the trunk is cut into pieces 6 ft. long, a longitudinal incision is made in each piece, and the bark is opened, taken off entire, chopped, washed, and sun-dried. In this state, it is very pliable and tough, and is used for clothing without further preparation.

S. villosa is a large tree of the Deccan, and the mountainous districts eastward of Bengal; common in many places on the outer hills of the N.-W. Himálaya up to 3600 ft.; also in Assam, Cuttack, and S. India generally. The bark is easily stripped off the whole length of the trunk, the inner layers containing fine fibre, while the outer are composed of coarser and stronger qualities. The fibre is manufactured into ropes for elephant-catching, and other purposes, which are very strong and lasting, and but little affected by wet. It is also used for making bagging and paper.

S. fœtida, *S. rupestris*, *S. Dombeya*, *S. acerifolia*, *S. ramiflora*, indigenous to Australia, the E. Indies, America, and Natal, as well as *S. tomentosa* in Angola, afford excellent fibres; so also *S. caribæa*, of Trinidad and New Caledonia.

Stipa semibarbata.—Endogen. Native of Tasmania; common in some localities. After the seed has ripened, the upper part of the stem breaks up into fibre, which curls loosely and hangs down. The quality of the fibre in this state must be inferior to what it would become under proper treatment.

S. arenaria is a closely allied and taller species, confined to Spain and Portugal. In Australia, occur *S. setacea*, *S. pubescens*, and *S. micrantha;* in the Argentine Republic, *S. Ichon* and *Chusquea Loretziana.*

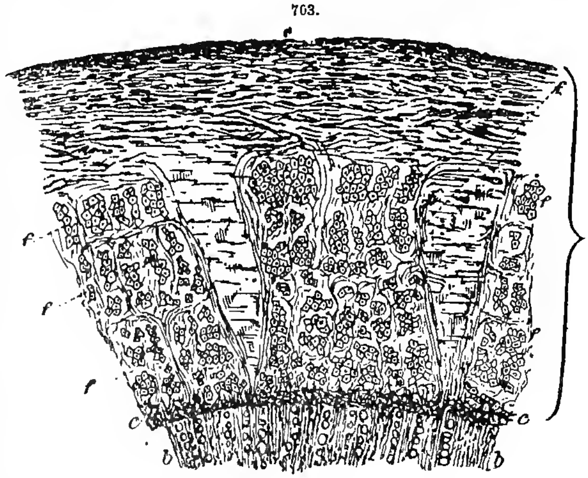
Strophanthus—Vegetable Silk.—A native of Senegal. Its seed hairs are used for stuffing purposes.

Thespesia sp. div.—Exogen. *T. Lampas* is a native of India, and is found especially in the Concans, where it is used like *Crotalaria.* *T. populnea* occurs in S. America, and in the Society and South Sea Islands; in British Guiana, it is used for making coffee-bags.

Tilia europæa—Lime-tree bast.—Exogen. This tree abounds in certain forests in Russia, where the collection of its bark forms an important industry. The trees are cut down at the age of 8–16 years, when the sap is rising, in May–June, the bark being then most easily removed. The bark is divided into longitudinal strips, 4–6 ft. long, which are loosened by the aid of a knife, and then torn off by hand, and spread out to dry. When soaked in water, the cortical layers separate; the fibres from the interior are most esteemed, the outer ones being coarser. The wood is converted into charcoal, and the sap is occasionally evaporated to yield sugar.

A section of the young bark of *T. argentea* is seen in Fig. 703: *a*, bark; *b*, lignose; *c*, cambium; *e*, epidermis; *f*, bast fibres, coloured deep yellow by test H; mag. 100. The fibres are abundant, tenacious, supple, short, and fine. Their dimensions are:—length: max., 0·196 in.; min., 0·05 in.; mean, 0·078 in.; diameter: mean, 0·00064 in.

703.



The bast for foreign consumption is made into mats, which generally measure about 6 ft. by 3 ft. 6 in. These are used especially for packing large objects, as machinery and furniture; and immense quantities are consumed by gardeners. The annual production of these mats in Russia is estimated at about 14 millions, ¼ of which is exported. The fibre is also converted into pit-ropes and clothes-lines in France, and fishing-nets in Sweden, for which purposes its durability eminently fits it. It would doubtless yield excellent paper. Revel, in 1879, exported 15,200 pieces of mat-bags to England. The great local consumption of the bast is for shoemaking; in the governments of Nijni Novgorod, Wiatka, Kostroma, and Minsk, the manufacture amounts to about 7 million pair annually. The useful bast of *T. pauciflora*, *T. parviflora*, *T. vulgare*, *T. platyfolia*, and *T. angustifolia* are employed in Europe, the Caucasus, and Central Asia, more particularly in S. Russia, and *T. cordata* in Japan.

Tillandsia usneoides—Spanish Moss or Vegetable Hair.—An epiphyte, found attached to several kinds of trees in the United States, S. America, and W. Indies. The largest and most tenacious is gathered from the cypress. The stripping is done by negroes, at intervals of 7 years on the same tree. When gathered, the "moss" is placed in a sunny spot, and left exposed to wind and weather for a month. The greyish bark then peels off, leaving the fibre almost clean. It is baled, and taken to factories, to be cleaned. It is first washed in boiling water with soap; then hung out on racks to dry; and finally dusted in a fan-mill. The best qualities can hardly be distinguished from horse-hair. All are used for stuffing purposes. New Orleans is the centre of the industry.

Touchardia latifolia.—Exogen. A shrub, allied to *Bœhmeria nivea*, found in the Hawaian Islands, and yielding a tough and easily separable fibre.

Triodia [Festuca] irritans—Porcupine grass.—Endogen. A brittle grass, abundant in waste tracts in Australia, and might be used for paper-making.

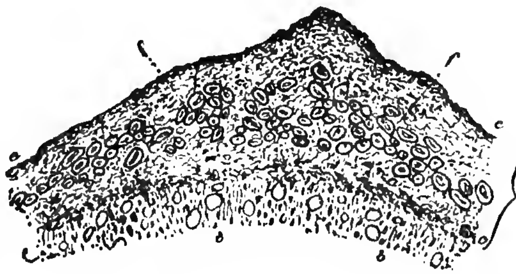
Tritoma sp. div.—Endogen. *T. uvaria* and *T. recurvata* are utilized as fibre-plants at the Cape of Good Hope. The leaves are crushed, and digested in hot water; the fibres separate in about 12 hours. The plants were introduced into Victoria in 1876.

Typha elephantina—Elephant-grass.—Endogen; grass, 6–10 ft. This species and *T. angustifolia*, both natives of India, are used for making mats.

Urena sp. div.—Exogen. Species of this genus are found in the intratropical girdle around the globe. *U. lobata* is a common shrub in India, and is generally found in waste places during the rains. It abounds in strong fibre, which is considered suitable for the manufacture of sacking and twine. Slips of sized paper, weighing 39 gr., made from this fibre sustained 75 lb., as against Bank of England note pulp, 47 lb.; it was said to bear ink well, but to work "woody" and "hairy." *U. sinuata* occurs in Bengal, and probably differs but little from the preceding.

Urtica sp. div.—Nettle (FR., *Ortie*; GER., *Nessel*).—Exogen. Of the European members of this genus, *U. dioica*, *U. pilulifera*, and *U. urens*, the first only seems to deserve any attention. The wide distribution and hardy nature of the common nettle (*U. dioica*) are well known. Its cultivation as a fibrous plant has been experimentally conducted at Stralau, near Berlin, with the result of obtaining stems 3–5 ft. high, without manuring or weeding. Hopes are entertained of a double crop annually. The plants are liable to the attacks of a caterpillar. A section of the stem of the plant is shown in Fig. 704: *a*, bark; *b*, lignose; *e*, epidermis; *f*, bast fibres, coloured deep blue by test H; mag. 100. The fibres, when extracted from the plant by retting, are soft, very supple, long, of considerable strength, lustrous, and white. Treated like hemp, they have recently been converted into textile fabrics, which were declared equal to linen. Paper made from them has attracted much attention.

704.



U. (Girardinia) heterophylla, the Neilgherry nettle, or "vegetable wool," is a native of Concan, Coromandel, Prome, Zeongdung, Nepal, Assam, and Burma. It succeeds well by cultivation. The bark abounds in fine, white, glossy, strong fibres, which have a rougher surface than those of *Bœhmeria nivea*, and are therefore more easily combined with wool in mixed fabrics. The natives subject the stems to a retting process for 10–12 days, by which they are so softened that the outer fibrous portion is easily peeled off. The tow of this fibre is especially valuable. Samples of the fibre exposed for 2 hours to steam at 2 atmos., then boiled for 3 hours, and again steamed for 4 hours, lost only 2·85 per cent. by weight, as compared with Manilla hemp, 6·07 per cent.

U. argentea in the South Sea Islands, *U. cannabina* in Siberia, and *U. japonica* in Japan, are utilized locally. Other nettles will be found under *Bœhmeria* and *Laportea*.

Xerotes longifolia—Tussock-grass, or Mat-rush.—Endogen. Found over almost the whole colony of Victoria, especially on dry, open, sandy country, such as that between Melbourne and Frankston, where, with *Lepidosperma gladiata*, it covers miles, to the exclusion of almost every other plant. It grows 18–24 in. high, attaining 6 ft. and more when near water, but the fibre is then much weaker. It is reckoned the best indigenous substitute for esparto for paper-making. The best samples come from the driest localities.

Other species, indigenous to Australia, are *X. filiformis*, *X. tenuifolia*, *X. glauca*, *X. rigida*.

Xylopia sp. div.—Exogen. The fibres of *X. frutescens* and *X. sericea*, in Brazil, are locally employed for cordage.

Yucca sp. div.—Endogen. These plants are indigenous to the southern portions of the United States, and some of them have been widely distributed. *Y. brevifolia*, the mis-called "Californian cactus," grows abundantly in the Mojave desert, between the 34th° and 35th° N. lat., and between the stations of Mojave and Ravena, in California. There are many square miles of ground occupied by this plant. The height attained is 10–20 ft., and the diameter of the trunk, 18–30 in. The habit of growth varies much. The soil is a fine, warm sand, very dry for a depth of 2 ft., but moister below. Existing supplies of the plant are being rapidly consumed for paper-making.

Y. gloriosa, or Adam's needle, is found in America, from Carolina and Florida, to Texas and Mexico. In India also, it is met with growing wild in Bengal, and other places. These are, perhaps, the best-known species. The whole genus has been utterly neglected from an industrial point of view, no real attempt having ever been made to grow the plants on a commercial scale, though their hardiness, their preference for arid barren sands, and the quality of their fibre, would seem to be special recommendations. The fibre resembles in many respects that of the agaves, and is applicable to similar purposes.

Zizania aquatica.—Endogen; grass, 7–14 ft. A native of N. America; found especially in Canada, on the shores of Lakes Erie, St. Clair, Ontario, &c. It is an annual, frequenting only swampy ground. It seems to be available in immense quantity. It makes admirable paper, possessing the advantage of being almost free from silica.

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(*See* Brushes; Cotton Manufactures; Hosiery; Jute Manufactures; Lace; Linen Manufactures; Paper; Rope; Small Goods.)

FLOORCLOTH (Fr. *Toile cirée;* Ger. *Wachstuch, Wachsleinwand*).

The term "floorcloth" was formerly applied to canvas covered with several layers of paint; but this kind of floor covering is now specially called "oilcloth," the original word having acquired a much wider signification. Oilcloth, although a great improvement upon its predecessors in point of cleanliness and durability, has nevertheless some defects, and it is chiefly owing to these that it is now being rapidly superseded, as far as price will permit, by other fabrics. Even the best qualities of oilcloth are cold, hard, and slippery to the feet, especially when wet. Linoleum, kamptulicon, and other substitutes for oilcloth, do not possess these defects, and are yet much more durable, and quite as cleanly. The whole of the thickness of oilcloth is built up, as it were, of a number of films of paint, each of which requires a long time to harden. The time necessary to produce an oilcloth of good quality must therefore be very great. The whole thickness of the more modern substitutes for oilcloth is, in most cases, obtained by one or two operations, the great saving effected in time being more than sufficient to compensate for the extra expenditure on machinery.

Oilcloth.—The basis of oilcloth is a coarse canvas, generally made of jute. The breadth of each web varies from 6–8 yds., while the length sometimes attains 150 yds. On its arrival at the works, the canvas is cut into convenient lengths, which are then nailed to upright frames. These frames are provided with screws, by means of which the fabric can be uniformly stretched. Too much strain must not be put upon it, or the shrinkage, which takes place when it becomes wet, will cause it to give way. At convenient intervals of height, opposite each frame, are stages or platforms, on which the workmen stand while preparing the surface. The first operation to which the framed canvas is subjected is "size priming," which consists in brushing its surface with a weak solution of size. The object of this is not only to give a body to the cloth, but also to protect the fibre from the injurious action of the acid products generated during the oxidation of the linseed oil which is subsequently applied. Cloth which is covered with paint without a protective coating of size soon becomes rotten and brittle. Although the surface of the canvas is much smoother after this priming, yet a number of loose fibres still project, and, to remove these, the cloth is either rubbed while still damp with flat pieces of pumice, or it is allowed to dry, and is then sheared with large knives. Sometimes the drying of the size is accelerated by admitting hot air into the building in which the frame is situated. When the priming is thoroughly dry, and the face of the canvas is freed from loose fibres, the first coat of paint is applied, commencing, as in sizing, at the top of the web. The consistence of this paint is much thicker than for ordinary painting purposes; the pigment in general use is yellow ochre. Sometimes red oxide of iron is substituted; but paint mixed with this substance does not dry so well. The first layer of paint is not applied by means of paint-brushes, but with the help of long steel trowels, similar in shape to those used by plasterers. The paint is well worked into the interstices of the canvas, and the excess is scraped off by the edge of the trowel. Both sides of the canvas are treated in this way, and are then allowed to dry, either with or without the aid of artificial heat. Some manufacturers still appear to think that oilcloth seasoned at ordinary temperatures is superior to that which has been dried at an elevated temperature in stoves. There does not, however, appear to be any perceptible difference between the finished goods turned out by the two methods. When the first layers of paint are sufficiently hard, another coat is laid upon the side which is intended for the back of the cloth. As soon as this dries, the back is finished, with the exception of any trade mark which may be necessary, and which should be applied at this stage. The first layer of paint on the face side of the cloth is rubbed with lump pumice, before the next coating is applied. This is again done with a trowel, and the operations of trowelling, drying, and pumice-scouring are repeated three or more times, according to the quality of the oilcloth to be produced. When sufficient thickness has been obtained, the face coating is applied. As this forms the groundwork of the pattern which is subsequently printed upon the oilcloth, it requires more care, both in mixing and laying on. A brush is used in the latter operation, instead of a trowel. When this last coat is sufficiently dry, the whole piece of oilcloth is cut down from the frame, and removed to the printing-room. The method of doing this, and the nature of the blocks used, are the same as for linoleum, and are described below. After printing, the oilcloth is seasoned, usually by hanging it in a room heated to at least 24° (75° F.). It is then taken down, and, when the edges have been trimmed, is ready for use. Oilcloth, when not sufficiently seasoned, is so soft that the pattern soon wears off; it also has the disadvantage of shrinking considerably after it has been laid down.

Linoleum.—The larger proportion of the bulk of linoleum is pulverized cork (see Cork). By far the greater part of the cork used in this industry consists of the refuse cuttings from the manufacture of corks for bottles. In making these, there is a large amount of waste, amounting to about 40 per cent., for which there is hardly any other application. Thin sheets of cork, called "virgin cork," can also be procured at a low price; but they are more difficult to break up, and are not so elastic as the older bark. The cuttings are emptied out of the sacks, in which they arrive, into a deep sieve, the quick lateral motion of which causes all pieces of stone, iron, &c., to fall to the bottom, the lighter cork passing on into the breaker. A considerable quantity of dust and dirt falls through this sieve, amounting to about 5 per cent. of the whole weight of the cork.

The working parts of the cork-breaker are shown in transverse section in Fig. 705, while Fig. 706 is a view from above: *a* is a steel shaft, with a rectangular projection *b*, upon which are fitted the cast-steel discs *c* and *d*. These discs, which are toothed like saws on their peripheries, are ½ in. thick, and 7 and 9 in. respectively in diameter. Closely adjoining, and partly fitting in between them, are steel plates *e f*, firmly bolted together, and fixed to the framework of the machine by the bolts *g h*. Both discs and plates are kept in their places by nuts, which screw on to the shaft and bolts.

The shaft should work at a rate of not less than 180 rev. a minute. As the hardest steel soon loses its edge when used for cutting cork, the teeth will require sharpening about once a week. There should, therefore, be duplicates of both discs and plates, and the framework of the machine must be so arranged that all parts may be easily accessible. The quickest and indeed the only practicable method of sharpening the teeth is by means of a thin emery wheel, similar to those used for sharpening saws. The bearings of the shaft *a* must, of course, be so constructed as to admit of its being adjusted, as the discs and plates wear away. The cork passes into this machine through a hopper, fixed to the upper part of the sheet-iron casing, with which the whole machine is surrounded.

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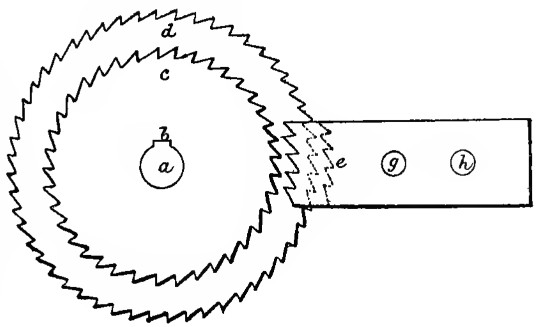

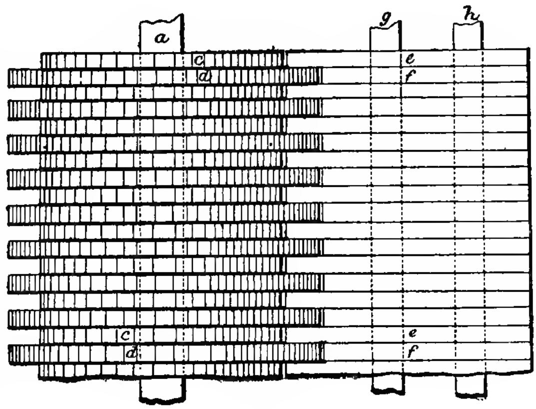

706.

On leaving the breaker, the cork appears in pieces about the size of peas, which are then reduced to powder by means of ordinary horizontal mills, resembling those used for grinding corn. The best stones for the purpose are lava stones; French burrs, although more durable, do less work, owing to their smoother faces. The ground cork, on leaving the millstones, passes into a screw elevator, by which it is raised into a sieve. Great care must be taken to prevent an escape of the powdered cork into the atmosphere of the mill, as a mixture of cork-dust and air in certain proportions is highly explosive. This has been the cause of frequent accidents; in one instance, the roof of a cork-mill was blown off, and the building was set on fire. To diminish the risk from this source, it is advisable to construct the roof of iron, leaving several of the sheets loosely fastened at the lower end, so that any sudden pressure from within may find an outlet, without destroying the whole of the roof. The degree of fineness of the sieve depends upon the quality of the linoleum to be produced. Coarse cork renders the fabric more elastic; but the surface is not susceptible of a high finish, and the printing is necessarily imperfect. On leaving the sieve, the finer particles fall into sacks, while the coarser residue returns to the mill. The sacks of powdered cork, having been brought to a uniform weight of 56 lb., are placed in a drying-stove, heated day and night to not less than 38° (100° F.). Here they must remain for at least 24 hours; in damp weather, even longer. From the drying-stove, they are brought to the first mixing-machine, where they are roughly mixed with the cement which unites the particles of cork, forming crude linoleum.

It may here be remarked that some kinds of cork are much darker in colour than others; on leaving the sieve, the light-coloured dust should be reserved for making brown linoleum, while the darker shades should be used for red. In buying the cuttings, it must be remembered that wet cork is dear at any price, as it takes a very long time to dry, and involves a considerable consumption of fuel.

Next in bulk to the cork, as a component part of linoleum, comes oxidized linseed oil (see Oils—Linseed), which is produced by exposing boiled linseed oil in a thin film to the action of the air, at a temperature of not less than 21° (70° F.). The most suitable quality of linseed oil for the manufacture of both floorcloth and linoleum is that known as "Baltic." The best way to test it is by boiling about 2 gal. in an iron pot, with the addition of ½ per cent. of ground litharge and ½ per cent. of red-lead. The temperature, controlled by a thermometer immersed in the oil, should not be allowed to rise above 260° (500° F.). In order to accelerate the process of oxidation, air is blown into the hot oil, by means of a pair of ordinary bellows. Small samples are taken from time to time, and cooled upon an iron plate. As soon as they appear "stringy" when cool, the pot is removed from the fire, and its contents are stirred till cold. If the sample in the pot become solid, the oil is suitable for oxidation; bad oil remains sticky and semi-liquid. The time occupied in testing a sample of oil in the above manner is 2–4 hours, according to quality. Where gas is accessible, it is to be preferred for heating the sample, on account of the greater facility it affords for regulating the temperature. Some oils are liable to froth over the edge of the pot; this may be prevented by continually raising the contents in a ladle, and letting them fall back into the pot. No reliable chemical test has yet been found to determine the quality of linseed oil, the sulphuric acid test being the only one which gives even approximate results. If the oil be at all fresh on arrival at the works, it should be stored in tanks for at least a month, to allow the mucilage and water contained in it to settle down. It is then run as required into the boiling pans, which are usually made to contain 10–15 cwt. In order to avoid accidents, these pans should be constructed of wrought iron, and be provided with a hood to carry off the gases evolved. As these gases are extremely offensive, they should be destroyed by passing them through a coke fire. It is not advisable to lead them into a boiler flue, as they contain acrylic and other acids, which speedily corrode the boiler plates. It should also be borne in mind that a mixture of these vapours with air in certain proportions is explosive; the fire into which they are conducted must not, therefore, be too near, nor the pipe leading into it of too great a diameter. The pans are heated by a fire underneath, and are built in such a way that the oil cannot reach the fire, even should it boil over. Each pan is provided with a stirrer, which should be kept in motion during the whole time of boiling, in order to prevent the driers from caking on the bottom of the pan. From the lower arms of the stirrer, hang pieces of heavy chain, which, by sweeping the bottom of the pan, keep it free from impurities. The temperature of the oil having been raised to about 177° (350° F.), the driers are stirred in. This should be done gradually, as the moisture contained in them causes the oil to froth. The driers used are the same as for testing the oil; it is not, however, necessary that the litharge should be ground. The temperature is kept at 149°–177° (300°–350° F.) for about 5 hours; the fires are then drawn, and the oil is allowed to cool. A higher temperature than 350° F. during boiling does not improve the drying properties of the oil, and careful experiments have shown that it is actually injurious. The colour of the oil is darkened, it acquires a strong smell, and the loss of weight by volatilization is considerable. The temperature of the boiling oil should therefore be carefully checked by means of a thermometer inserted through a hole in the hood covering the pans. When the oil is sufficiently cool, which will be the case in about 12 hours, it is pumped or run into the tanks of the oxidizing-sheds. The arrangement of these is given in Figs. 707, 708, and 709: *a* are pieces of thin cotton fabric, technically known as "scrim." Their width is either 6 ft., in which case, one piece only is required, or 3 ft, when two pieces are fixed side by side. The length of each piece should not exceed 25 ft., or the fabric will be unable to carry the weight of the oil accumulating upon it. The ends of these pieces of scrim are pasted or glued over bars of iron *b c*, and allowed to dry upon them before hanging up. The top bars *b* are fixed into notches in iron

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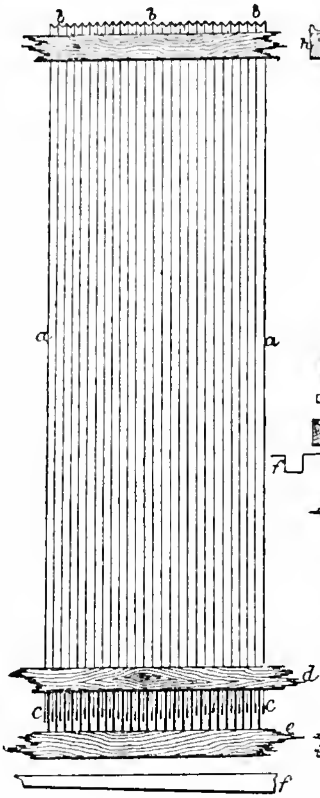

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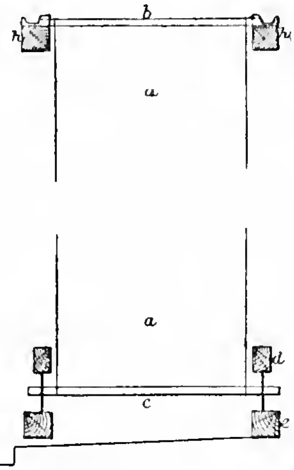

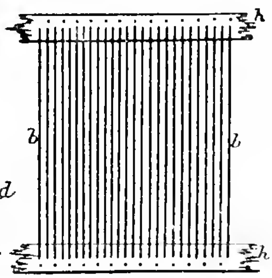

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castings, which, in their turn, are screwed to the upper beam *h*. The lower bars *c*, are kept in their place by inserting them between iron rods, fixed perpendicularly between the beams *d e*. Space must be left between *d e*, to allow for the stretching of the fabric, which sometimes takes place very unevenly. A few inches below *e*, is a smooth concrete floor, off which the oil runs into a gutter *f*, leading to the oil-reservoir. Fig. 707 gives a side view; Fig. 708, a section, and Fig. 709, a view from above of a bay in an oxidizing shed. Each building usually contains two of these bays; it is not advantageous to make the buildings of a larger capacity, on account of the difficulty of heating them uniformly. The interior of the building should be maintained at 21°–38° (70°–100° F.), except when the workmen are obliged to enter. Very efficient means of ventilation must be provided, in order to purify the atmosphere of the building before the entrance of the workmen, as the fumes of acroleïn, generated during the oxidation of the oil, are so irritating as to render access difficult until they have been removed. It is chiefly these vapours from the oxidizing buildings that give rise to the nuisance complained of in the neighbourhood of linoleum works. Attempts have been made to destroy them by passing them through a fire; but the great bulk of air which has to be treated with them, and in a short space of time, has rendered these endeavours fruitless.

The only method which has met with even partial success is that adopted in so many other industries, namely, passing them up a high shaft into the atmosphere. By this means, the inhabitants of the immediate neighbourhood are certainly relieved, but at the expense of those living at a greater distance. The boiled oil is pumped to the top of the building from a tank sunk into the ground at the lowest point of the drain *f*. Here it is conducted into movable troughs, supported on wheels, which fit into, and run along, the outer part of the iron castings bearing the bars *b*. The lowest part of the trough is situated immediately above the pieces of scrim, consequently, as soon as the trough is pumped full, the oil begins to overflow at this point. By running the trough backwards and forwards along the length of the shed, the whole of the scrim is uniformly flooded. Although the flooding is sometimes done by hand, yet it is preferable to move the troughs backwards and forwards, by means of chains passing through the end walls of the building, and worked outside by suitable gearing. To prevent the oil from escaping at the side, curtains of canvas, about 6 ft. deep, are hung from the beam *h*. The sheds are flooded once in 24 hours; in summer, or when the temperature is high, this operation may be performed twice in the same period. The pumps should be located outside the buildiog, so as to be easily accessible. As the oil soon becomes thick, and full of lumps, ordinary valve-pumps are of little use; chain-pumps and rotary-pumps have given the best results in practice. To diminish the risk from fire, it is well to isolate each oxidizing shed, and to surround it with a low bank, to prevent the burning oil from spreading, in case of accident. The roof should be covered with iron, although lined with wood, to prevent loss of heat. In calculating the dimensions of the heating apparatus, ample allowance must be made for the diminution of temperature during winter, as any stoppage in the oxidizing department would seriously interfere with the production of the whole manufactory. Each time the scrim is flooded, its surface becomes covered with a thin film of oil, which oxidizes or solidifies, and slightly increases the thickness. In 6–8 weeks, according to the temperature, the total thickness of the cotton fabric and the oxidized oil upon it will amount to about ½ in.; the whole piece is then known as a "skin." These skins should not be allowed to grow to a greater thickness than ⅝ in. before removal, as they then become so heavy that they are liable to give way, causing an interruption in the process. Part of the oil solidifies on the floor of the shed, forming a soft, pasty mass, called "scum." When thick enough, the skins are removed by cutting them immediately below the upper bars, allowing them to fall to the ground, and there cutting them into smaller pieces. The oxidized oil obtained in the above manner, is a yellow, translucent substance, of great elasticity, and possessing a smell somewhat resembling that of fresh paint. It is heavier than water, while the oil from which it was derived is lighter. It is insoluble in alcohol, ether, chloroform, and carbon bisulphide; even boiling naphtha will only dissolve traces of it. Treated with naphtha, under pressure in a steam-heated pan, it softens without dissolving, and can be worked into a paste in this condition. The only action which dilute acids have upon it is to extract the small quantity of oxide of lead due to the driers. Concentrated sulphuric and nitric acids decompose it rapidly; hydrochloric acid, slowly. Heated gradually by itself, oxidized oil chars without melting; it is only when the heat is applied rapidly that the mass becomes partially fused.

The cotton tissue enclosed between the two layers of oxidized oil is found to be completely rotten, the vapours given off by the oil during oxidation having an extremely injurious action, not only upon textile fabrics, but also upon wood, iron, and mortar. Although the quantity of vapour evolved is very considerable, yet the boiled oil gains 11 per cent. in weight when oxidized in the manner described. The bulk of oxygen absorbed must therefore be very large, and indicates the necessity of a plentiful supply of air in the oxidizing buildings. The skins, on coming from the sheds in which they were produced, are ground between ordinary grinding or mixing rollers, the resulting product being then spread out to cool upon a stone or concrete floor, in a layer of 3–4 in. If heaped up in bulk immediately after grinding, the oxidized oil will almost infallibly char, or ignite spontaneously, when the temperature of the surrounding atmosphere exceeds 21° (70° F.). This dangerous property is probably due to the rapid oxidation of particles of oil which had been enclosed in the skins and are liberated by the process of grinding. The solid oil is, however, capable of still further oxidation; even long after the linoleum floorcloth has been made and in use, the oil contained in it continues to harden. It may here be remarked that an asphalte floor soon becomes soft, when exposed to the action of oil.

When freshly ground, the oil feels damp, but it dries in 2–3 hours, and is then ready for the following process. This consists in mixing it with a certain proportion of rosin and kauri gum (see Resinous Substances—Kauri, Rosin). The gum, which need not be of the best quality, is first ground under "edge-runners," and sifted; the rosin is added in lumps. The proportions for ordinary linoleum are:—Oxidized oil, 8½ cwt., rosin, 1 cwt., kauri gum, 1 cwt. When linoleum of greater elasticity is required, the following mixture may be used, though it is rather more difficult to work:—Oxidized oil, 8½ cwt., rosin, 1 cwt., kauri gum, ½ cwt. The mixing operation is conducted in a steam-jacketed pan, fitted with an airtight lid or man-hole at the top, and a sliding valve at the bottom, capable of being opened gradually by a screw. Inside the pan, is a shaft carrying stirrers, the whole much resembling a vertical pug-mill, except that the gearing which moves the stirrers must be very massive, on account of the great resistance offered by the oxidized oil, especially at the commencement of each operation. The stirrers having been set in motion, the rosin is first put into the pan, and, as soon as it is melted, the ground oil and kauri are added alternately, in small quantities. When the whole charge is in the pan, the lid is screwed down, and the stirrers are allowed to revolve for a period of 2–4 hours. The steam may be turned off from the steam-jacket as soon as the mass has become warm throughout, as the oxidation of the materials suffices to maintain the temperature. A pipe leads the vapours into a furnace, where they are destroyed. Samples are taken from time to time through the lower valve, and, as soon as they appear homogeneous, the valve is opened, and the hot mixture, now termed "cement," is propelled by the action of the stirrers into a pair of cold grinding-rollers immediately beneath. These rollers are hollow, and, in summer, are kept cool by a current of cold water circulating through them. There should be good ventilation in the neighbourhood of the mixing-pan, as the hot cement gives off abundant fumes, which, though not disagreeable when diluted, are extremely pungent in their concentrated state, and have a powerful irritating action on the mucous membranes. After passing through the rollers, the cement is weighed into pans containing 46 lb. each, this being about the quantity required to mix with one sack (56 lb.) of ground cork. The pans are previously whitewashed, to prevent the cement sticking to them. As soon as it has solidified sufficiently, the cement is placed on a stone floor to cool, and is then ready for use. Before mixing with the ground cork, the cement is warmed in a room heated to 43°–49° (110°–120° F.). The colour of the cement is much darker than that of the oxidized oil, the amber-yellow of the latter having changed into a mahogany-brown in the mixing pan. The cement is not quite so elastic as the oxidized oil; but is much tougher, and can be worked into any shape when heated, which is not the case with the oil alone. By varying the proportions of gum and rosin, the degree of hardness and plasticity when heated can be regulated at will. When more generally known, this substance will undoubtedly find many applications in the arts. For instance, its solution makes an excellent marine glue, which has the advantage of being slightly elastic, and which is, of course, much cheaper than that made with shellac and indiarubber. At present, however, beyond its use for linoleum, it is only applied to making emery wheels. As it can be vulcanized, like indiarubber, it is eminently suited for this purpose, especially as it does not give off such a disagreeable smell when heated as the latter substance does.

Having been sufficiently softened by re-heating, each cake of cement is cut by a strong lever knife into four or six pieces, which are then ready for the first mixing-machine. This consists of three steam-heated rollers, about 9 in. in diameter, of which the two upper ones are placed level with each other, while the third occupies a central position beneath them. The bearings of each roller can be adjusted by screws, so as to regulate the feed of cork and cement. Above the upper two rollers, is fixed a hopper, large enough to contain a sack of cork. For this quantity of cork, one cake of cement is fed in at one side between the lower and the two upper rollers. It passes out on the other side, in the shape of thin shreds mixed with the cork. No unprotected lights should be allowed in this department, on account of the danger of explosion from the large proportion of cork-dust floating in the air. When lights are required, they should be placed in lanterns, communicating directly with the external atmosphere, and having no connection with the room in which this mixing-machine is located. The mixture of cement and cork-dust has also the dangerous property of igniting spontaneously if left in a heap in a warm place. As the vicinity of the steam-heated rollers generally elevates the temperature considerably, it is well not to mix at once more than one sackful of cork with a corresponding quantity of cement. When this batch has been removed, another is commenced, and so on. On leaving the first machine, the mixed cork and cement are either raised by an elevator, or carried in sacks, to the second machine, in which they are more thoroughly mixed, and incorporated with the colouring matter. This machine consists of a horizontal drum, in which a spindle, furnished with beaters, works at a speed of about 200 rev. a minute. On the upper side of the drum, a hopper is fixed, in such a way that it can be closed by an iron slide, fitted into a short shoot connecting it with the drum. The capacity of the interior is such that it will contain at least one sack of cork with the necessary cement and colouring matter. It is fixed immediately above the next machine, the communication being regulated by means of a slide. The colouring matter is put into the hopper together with the mixed cork and cement, as they leave the preceding machine. The quantity of colouring matter to be added must depend, not only upon the tint which is to be given to the finished linoleum, but also upon the quality of the pigment itself. It is customary at present to make the body of linoleum of two colours—brown and red. For the brown, yellow ochre and barytes are used; for the red, oxide of iron, and vegetable black. Many other colours may be produced by altering the colour of the pigments; but the brown hue of the cement and cork precludes white or any delicate tint. As a guide, the following mixture for red linoleum may be cited:—Pulverized cork, 56 lb.; linoleum cement, 46 lb.; red oxide of iron, 17 lb.; vegetable black, 13 oz.; litharge, 8 oz.

The small addition of ground litharge, ½–1 per cent., although general, appears to be merely a matter of routine, as excellent linoleum can be made without it. It hastens the drying of the linoleum, but renders it more brittle, and, for sanitary reasons, the less lead put into an article intended for use in dwellings, the better.

The various materials, having been beaten about in the drum for 2–3 minutes, are transferred to the next machine, by simply opening the slide which had hitherto supported them. The arrangement of this, the most important of the mixing-machines, is shown in Figs. 710 and 711. With the exception that the lower part is steam-jacketed, it resembles a sausage-machine of great strength. In Fig. 711, *a* indicates the hopper, through which the material falls from the preceding machine. On entering, the material is seized by revolving knives or cutters *b*, which carry it between the fixed knives *c*. The edges of the knives *b* are shaped like chisels, the bevelled edge being

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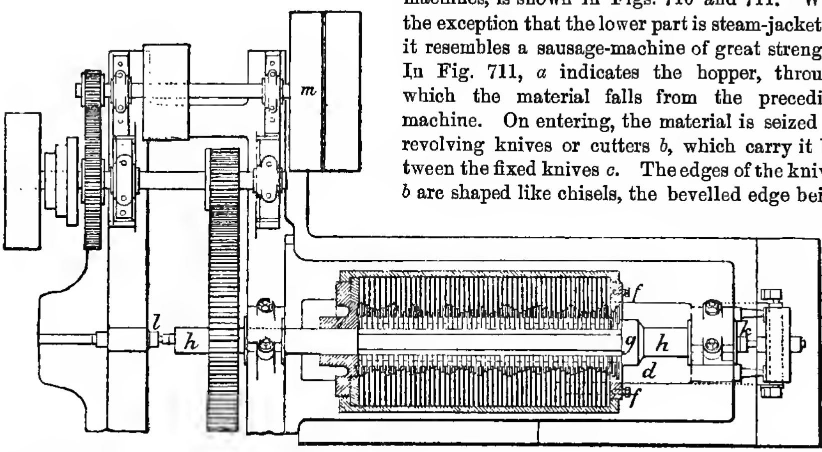

turned towards the outlet of the machine *d* (Fig. 710), in which direction, therefore, the material is gradually propelled. The fixed knives *c* (Fig. 711) are inserted before bolting on the back-plates *e*. Between each couple of fixed knives, iron distance-pieces are inserted, the thickness of which is the same as that of the revolving cutters—⅜ in. All the cutters are made of wrought, or malleable cast iron. The knives *b* are also separated by washers, equal in thickness to the fixed cutters. The screws *f* (Fig. 710) prevent the fixed knives from changing their position. The revolving cutters are kept in their places by a large nut *g*, screwed upon the steel shaft *h*. This shaft, as will be seen from the section (Fig. 711), is octagonal, the openings in both washers and revolving cutters being of a corresponding shape. The cutters and distance-pieces must be carefully planed and adjusted, to prevent them from catching each other, which would cause serious damage to the machine. In order to prevent the shaft *h* from shifting, it is fixed between steel pins *k l*, the chief thrust being upon *l*. Both these pins are adjustable by screws. The motive power is derived from the pulley *m*. A movable pulley is necessary here, so that the machine may be stopped at once, in case a bolt or other hard substance enters it. As shown in Fig. 710, the case, which is of cast iron, is constructed in two halves, united by bolts. The lower half, which is steam-jacketed, is fixed, while the upper half can be lifted off after the removal of the bolts. Steam is only admitted for a short time at the commencement of work; it is then turned off, as the heat produced by the friction in the machine, and by the rapid oxidation of the material, is quite sufficient to soften the latter.

It may even happen in summer that the heat from these sources will char and destroy the linoleum, in which case, cold water should be run through the hollow bottom of the machine, the steam pipes being supplied with a branch leading from a cistern. In passing through this machine, the linoleum mixture becomes very compact, and is so thoroughly mixed that the particles of cork and cement can hardly be distinguished by the naked eye. It issues from the machine below and around the nut *g* (Fig. 710), and falls into baskets, in which it is removed to the next machine.

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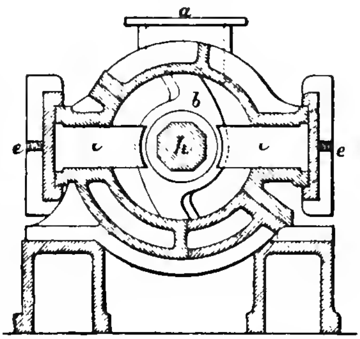


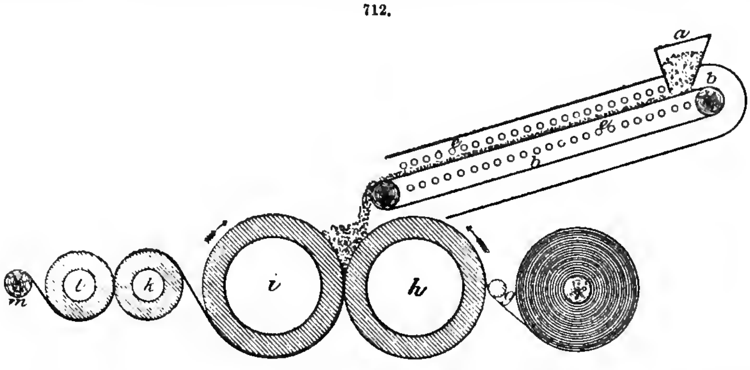
This consists of a pair of ordinary mixing-rollers, as used in the manufacture of indiarubber. One of the rollers is steam-heated, while the other is kept cool by a current of cold water running through it. The linoleum adheres to the face of the cold roller, and is removed from it by a steel scraper or "doctor," which is pressed against the face of the roller by a weighted lever. The material leaves this machine in the form of thin sheets, in which any particles of wood or other impurities can be easily detected. The sheeted linoleum is then placed in the hopper of the next machine, which is termed a "scratcher." This resembles the preceding one, with the exception of the "doctor," which is replaced by a rapidly revolving cylinder, studded with numerous points, which work upon the surface of the linoleum adhering to the cold roller, and remove it in the shape of small pellets. The method of covering the scratching-cylinder is to insert wire nails into thick strips of indiarubber, these strips being then wound around the wooden cylinder, and secured by screws. The elasticity secured in this way prevents injury to the "scratcher," in case any hard substance should be introduced.

The linoleum, as it leaves the scratcher, is in a condition somewhat resembling damp earth. While warm it is soft and plastic, and, if pressed into a mould while in this condition, it retains the shape of the mould on cooling. When cold, however, it cannot be moulded, and, if subjected to pressure, regains its original shape as soon as the pressure is removed. Care must be taken not to allow the warm material to accumulate after it has left the scratcher, as it is very liable to heat spontaneously, and either char in the centre of the heap or even burst into flame.

The next operation is to apply the prepared linoleum to the canvas, which is similar in texture to that used for oilcloth, and is made of jute. The width should be about 78 in., for although the finished linoleum is only 6 ft. wide, yet a margin must be allowed, so that the edges of the fabric may be cut accurately when finished. To prevent stoppage of the rolling-machine, a sufficient number of lengths of canvas for one day's work are sewn together by means of a sewing-machine.

The working parts of the machine used for rolling the linoleum on to the canvas are shown in section in Fig. 712. The granulated linoleum, as it leaves the scratcher, is placed in the hopper *a*. The bottom of the hopper is formed by an endless web of fine wire gauze *b*, similar to that used in

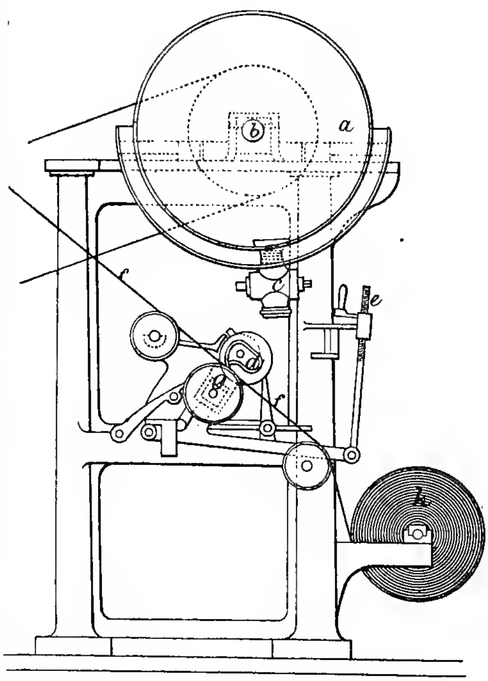
712.



paper-making. A rotary motion, communicated to the web by the roller *c*, carries it slowly forward through the steam-chest *e*. In the pipes of the steam-chest circulates steam at a pressure of about 30 lb. a sq. in. The quantity of linoleum carried forward by the wire gauze can be regulated by a slide on the lower side of the hopper *a*. The rollers *c d* must be kept perfectly parallel, or the wire gauze would gradually work towards one side of the machine, and become damaged. From the carrying-wire, the linoleum falls between the rollers *h i*. These are steam-heated to a temperature of at least 121° (250° F.), and their bearings are so mounted that the distance between the face of the rollers can be accurately adjusted. The best material for these rollers is chilled cast iron; if their faces were too soft, any nails which might enter the machine among the granulated linoleum would cause an indentation in them, and a corresponding projection on the face of the finished fabric. Such indentations cannot altogether be avoided; they are removed by drilling a hole of the requisite diameter in the face of the roller. Into this an accurately fitting plug of cast iron is hammered, the top of which is then filed off level with the roller. Another disadvantage of ordinary cast iron is that its surface soon becomes corroded by the acrylic acid of the oxidized oil, and, owing to its coarsely crystalline structure, it becomes so deeply pitted as to necessitate re-polishing. Chilled cast iron, on the other hand, offers more resistance to corrosion, and its texture being finely granular, the face of the linoleum pressed against it does not become rough.

The canvas passes from *f*, upon which it has been wound after sewing, over the top of the roller *h*. The object of the small guide-roller *g* is to bring the canvas, as soon as possible, into contact with the heated roller, in order to drive off any moisture which it might contain, and which would prevent the adhesion of the linoleum. The necessary tension is given to the canvas by a brake fixed upon *f*, and regulated by a weight or spring. When the canvas arrives between *h* and *i*, it meets the heated linoleum, which is pressed into it with great force. The thickness of the linoleum film is regulated by the space between the rollers. Passing round the heated roller *i*, the face of the fabric acquires an additional smoothness, and is then cooled as quickly as possible by passing between the polished rollers *k l*. These should be well supplied with cold water, especially in summer, as the face of the cloth becomes spongy if not cooled quickly. A slight pressure is applied between *l* and *k*, but not sufficient to retard the passage of the cloth, or it would buckle up between *k* and *i*. Steel wires are suspended at each side between *h* and *i*, to cut off any portion of the linoleum which may project beyond the canvas. The revolving wooden roller *m* takes up the linoleum after it has passed through the cold rollers, another being substituted for it as soon as it is full. As the canvas is generally made in pieces of about 100 yds., this is a convenient length for each roll of linoleum as removed from the machine, especially as it permits the canvas to be separated at the joint made by the sewing-machine. At this stage the face of the linoleum may be regarded as finished, with the exception of seasoning and, if required, printing. The back of the fabric, however, is plain canvas, which is exceedingly liable to absorb moisture, and to shrink in consequence. This must be prevented by filling its pores with a protective solution technically known as "backing." The usual backing, and that which gives the best results in practice, is a mixture of size and pigment, which is laid on warm. The following compound has a glazed surface when dry, which is sometimes preferred:—Oxidized linseed oil, 2½ cwt.; rosin, 2 cwt. 21 lb.; Kauri gum, 105 lb.; red-lead, 1¼ cwt.; Venetian red, 2 cwt. 21 lb.; shellac, 58 lb.; litharge, 18 lb.; naphtha, 20 gal.; methylated spirit, 5 gal. The materials are mixed for about 6 hours in a steam-heated pan, furnished with a steam-tight lid above and a tap below, and should be continually stirred. It has been claimed for this mixture that it is waterproof, but, as a matter of fact, it does not resist moisture so well as the size backing, and has the disadvantage of sticking to the face of the cloth in hot weather. The backing was formerly applied by hand as in the manufacture of oilcloth, but the operation can be much more rapidly and completely performed by a machine, a side view of which is given in Fig. 713. The backing is placed in the pan *a*, the lid of which is movable, and the bottom steam-jacketed. The pan should never be more than half-full. The shaft *b* is furnished with stirrers, which revolve in the backing, and prevent the pigment from settling. Through the tap *c*, the backing falls upon the back of the linoleum *f*, and is distributed roughly upon it with the help of a trowel. The cloth is carried upwards by means of a roller, covered with carding wire, which works against its face. The spreader *d* is steam-

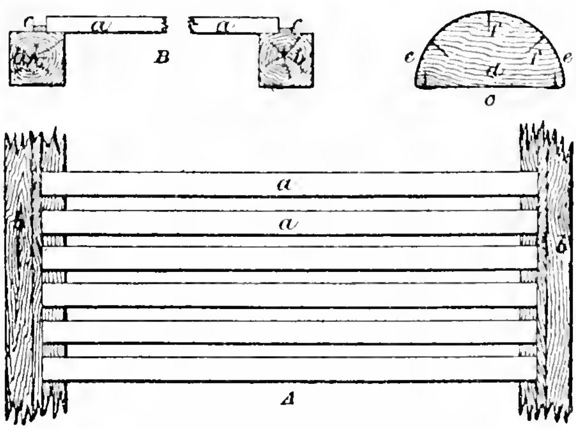
713.



heated, in order to keep the backing liquid, and is fitted with a steel scraper, which presses the liquid into the canvas, and removes all excess. The quantity of backing spread upon the cloth is regulated by the screw *c* raising or lowering the roller *g*, upon which the face of the linoleum runs. The roll of linoleum *h* is inserted as it arrives from the rolling-machine. The linoleum is allowed to hang for about 12 hours, or till the backing is dry, and is then ready for printing, or for seasoning if it is to be used plain.

The seasoning buildings or stoves are about 30 ft. in height, and are furnished with heating apparatus, so that the temperature may be kept at about 24° (75° F.). The cloth is hung in loops or bights upon racks, each bight being supported on battens. Fig. 714 shows the arrangement of these battens, A being a top view and B a section of part of a "bay" or division in a seasoning stove; *a* is the batten, the construction of which is shown in C. The material is thin sheet iron *e*, each end being filled up and strengthened by a piece of wood, fastened by the nails or screws *f*. These battens are not made perfectly straight, but have a slight curve or camber upwards when in place. The amount of camber is so calculated that as soon as the linoleum is hung upon the battens its weight straightens them. If the battens were made quite straight in the first instance the weight of the fabric would depress them in the centre, producing a convexity of surface in the linoleum, which would prevent its lying flat. The camber of the battens must be tested periodically with a templet, as the iron is liable to become bent. All lateral movement of the battens is prevented by the laths *c*. Wooden battens have been used, but they frequently crack and warp, owing to the high temperature in the buildings.

714.



The method of hanging from battens, although most prevalent, has several disadvantages. The linoleum, especially when fresh from the rolling-machine, softens, on account of the high temperature to which it is exposed, and its weight stretches the top part of each bight. For this reason the height of a "bay" should not exceed 25 ft. It is very difficult to maintain a uniform temperature at both top and bottom of so high a building as a seasoning stove, the consequence being that the upper part of a bight will be the more thoroughly seasoned, unless the position of the cloth be reversed during the process. Flat, horizontal racks have been adopted to avoid these defects. They are constructed of hoop-iron, the racks or trays for the reception of the cloth being about 3 in. apart. The pieces of linoleum are drawn into them by a rope, which may be driven by a small winding-engine. For plain linoleum these flat racks have proved successful, but with printed goods they are very liable to smear the wet paint during the drawing in.

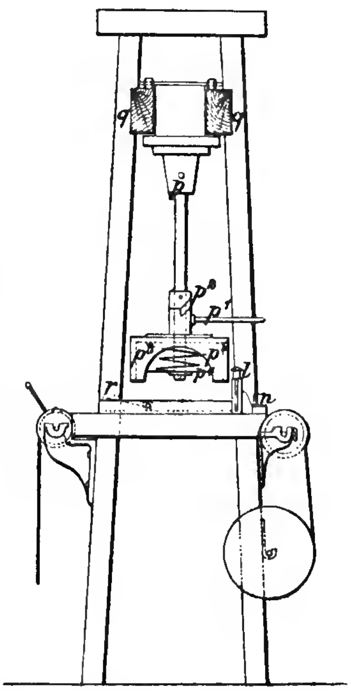
The linoleum which is intended for printing must first have its edges trimmed. This is done upon long tables, the sides of which must be perfectly true. A straight-edge runs along the side of the table, and carries a knife-blade, which cuts off the irregular margin of the cloth. The cuttings produced in this way, as well as all other scraps of linoleum, are separated from the canvas by hand, and are used, with an additional quantity of cement, for making stair-cloth. For printing by machine, several lengths of linoleum are joined by narrow strips of calico, covered with glue, and applied with the aid of a hot iron.

Hand Printing.—The blocks for printing floorcloth are made of at least three layers of well-seasoned pine, glued together so that the grain of the wood in one layer runs at right angles to that in the adjoining one. The total thickness of each block is 2–2½ in. according to width, it being essential that the block should be perfectly rigid, while it must not be too heavy for the printer to lift with one hand. The face is made of sycamore or pear-wood, preferably the latter. For each colour in the pattern, a separate block is required, and, in addition, there is usually an outline-block and a "smash"-block. The latter covers every colour except the outline, its object being to distribute the paint uniformly. When any pattern contains a large surface of colour, the smash-block is indispensable, as without it the paint will remain raised in the centre of each field, owing to the suction produced by raising the block. The smash-block is prevented from clogging, by beating it upon a clean pad, so soon as the paint begins to choke up the open spaces. The outline-block is applied immediately after the smash-block; it gives a finish to each field of paint, the edges of which would otherwise present a ragged appearance. For ordinary goods, the printing surface of the block is still made of wood; for finer work, metal is indispensable. The "dot" patterns for oilcloth are produced in a very simple manner. The pear-wood or boxwood face of the block is divided into small squares, by means of parallel saw-cuts, crossing each other at right angles, and penetrating to a depth of about ¼ in. The pattern is transferred to the surface of the block thus prepared, and those squares not included in it are cut away. It need hardly be remarked that patterns printed with such blocks present a dotted appearance, and, for this reason, they are only suited for oilcloth where the whole of the surface is covered with paint, and are not adapted for linoleum, where part of the surface remains plain.

For the commoner kinds of linoleum, and similar fabrics, the blocks used are made as follows:—The outline of the pattern is transferred to the pear-wood face of the blocks, and those parts of the wood which are not required for taking up the paint are removed by means of cutting instruments of various shapes. If the raised portions remaining be of considerable area, they are grooved, in order to distribute the paint more evenly. Such grooved wooden blocks possess, however, but little durability, and are in such constant need of repair that, where a large quantity of goods of one pattern have to be printed, it is more advantageous to construct the face of metal. The metal used is brass, about ½ in. wide, of a wedge-shaped section, and of different thicknesses according to the work for which it is intended. The pattern having been drawn upon the pear-wood face of the blocks, those parts which are to receive the paint are furnished with parallel lines, similar to the shading in a wood-cut, but on a much larger scale. Incisions are made along these lines with the help of small, thin, chisels, and the metal, having been cut into pieces of a suitable length, is driven in. The pieces are first perforated at short intervals with ¼-in. holes, to afford a passage for the air in raising the blocks, and thus prevent inequalities in the paint due to suction. In hammering in the metal, a small block of steel, whose thickness equals the height of metal required, is placed upon the wood. The hammer is stopped by the steel as soon as the brass is driven in far enough, and uniformity in height is secured. The distance apart of the parallel lines is regulated by the thickness of the metal to be used, and this again by the area of the printing surface on the block. For curved lines, the metal is bent by hammering it with steel punches of various curves upon a block of lead. When the whole block has been metalled, the face is ground down upon a flat sandstone and smoothed with lump pumice. When a block is heavily metalled, it is sometimes necessary to drive small nails into the pear-wood face, to prevent it from yielding under the lateral pressure caused by the insertion of so many metal wedges.

To secure an accurate fit, or "register," as it is termed, the outline-block is usually finished first, and the pattern is printed from it in lithographer's ink upon a smooth surface of floorcloth. While this ink is still wet, a fresh block is laid upon it, pressure is applied by means of an ordinary screw-press, and the pattern will be found transferred to the surface of the pear-wood. This process is repeated with other blocks, as many times as there are colours in the pattern. To keep the blocks in good condition, it is essential that they should be cleaned before the paint has time to harden upon them. This cleaning is best effected by washing them in coal-tar naphtha, with the aid of stiff scrubbing-brushes. Naphtha containing petroleum-spirit should be avoided for this purpose, as its solvent power is much less. Spirit of turpentine is sometimes used; this is both more expensive, and more injurious to the workmen, who are constantly exposed to its vapour. Once the paint has been allowed to dry upon the blocks, they can only be cleaned by the slow process of scraping each separate little piece of wood or metal. They should be kept in a dry room, protected from sudden changes of temperature. If exposed to damp, they are liable to warp, and become useless for printing on flat surfaces. In hand printing the printer stands between two tables, one covered with as many pads as there are colours in the pattern to be printed, and another supporting the floorcloth during the operation. The pad-table is generally furnished with a shelf for the paint-pots. The width of the printing-table slightly exceeds that of the blocks; its length depends upon the width of the fabric to be printed upon it. Figs. 715 and 716 give a section, and front view of part of a table for hand printing. The surface is padded with several thicknesses of flannel, or one of felt, and is then covered with a piece of oilcloth or thin floorcloth. At the sides, are hand-punches and pins *l*, by which is regulated the length of fabric pushed forward each time. There are two methods of ensuring accuracy in the "register" of the impressions. One is by driving pins into the corner of the face of each block; these, being in a prominent position, can be seen by the printer as he lowers the block, and as the pins of the first block leave small dots of paint upon the printed surface, it is easy to adjust the following ones. Should the small dots not be covered by the outline-block, they are removed by a palette knife while still wet. Another and preferable method is to fix, across that side of the table next to the printer, a ⌋-shaped bar of steel or iron *n*. Upon the upright edge of this bar, ∩-shaped stops are adjusted by screws, at intervals corresponding with the width of the blocks. One side of each block is furnished with two projecting metallic pegs, and if the printer brings these pegs into contact with the fixed stops before lowering the block, an accurate register is ensured. Along the whole length of the table, and higher than the head of the printer, run two strong beams q, between which hangs the press. This is suspended so that it rests upon small rollers, which run on iron rails screwed to the upper surface of the beams. The frame of the press is furnished with cross-pieces, which catch the beams as soon as pressure is applied, and prevent the press from rising. The press itself is a simple screw press, with a single short lever p^1. The pitch of the screw p^2 is so adjusted that about ¼ turn of the handle suffices to exert the whole pressure. A spring p^4 is inserted to cause the bottom of the press p^3 to rise instantly when the handle is released. That part of the press which touches the blocks turns on a swivel, and has two projections on its lower side, each of which falls on one side of the block; the pressure is thus equalized. A short leather strap is nailed to the back of each block, forming a loop, under which the printer passes his hand, for the purpose of lifting the block.

715.



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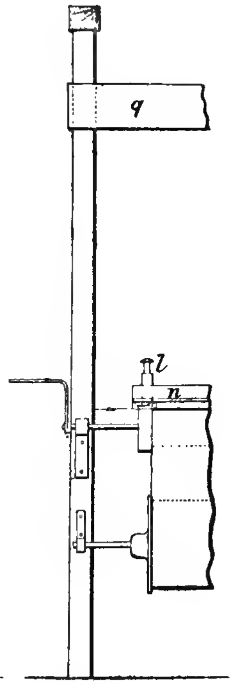
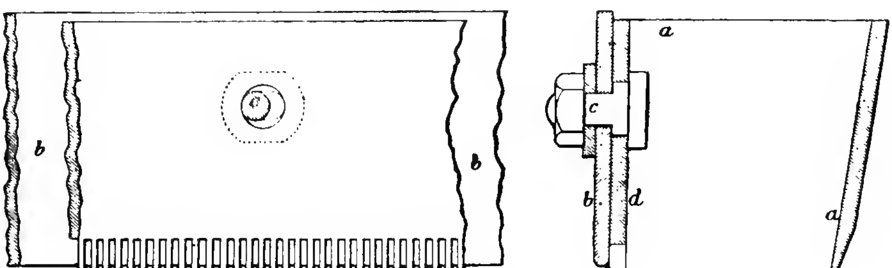
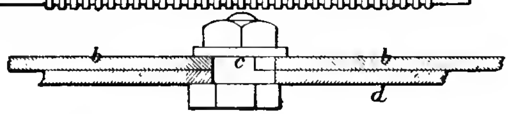


The pads are covered in the same way as the printing table. The colour is spread over them by means of paint brushes, and, in order to save the printer's time, this part of the work is generally performed by boys. It may here be remarked that, on account of the large proportion of lead contained in most of the paints, the greatest cleanliness is necessary in this department; the hands and face especially should not be brought into contact with the pigments, and beginners should be warned as to the possible results of carelessness. In distributing the colour over the face of the pad, care must be taken to ensure uniformity, as the slightest inequality would show on the printed surface. The block must be laid perpendicularly

717.

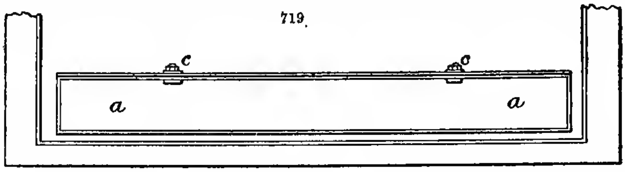




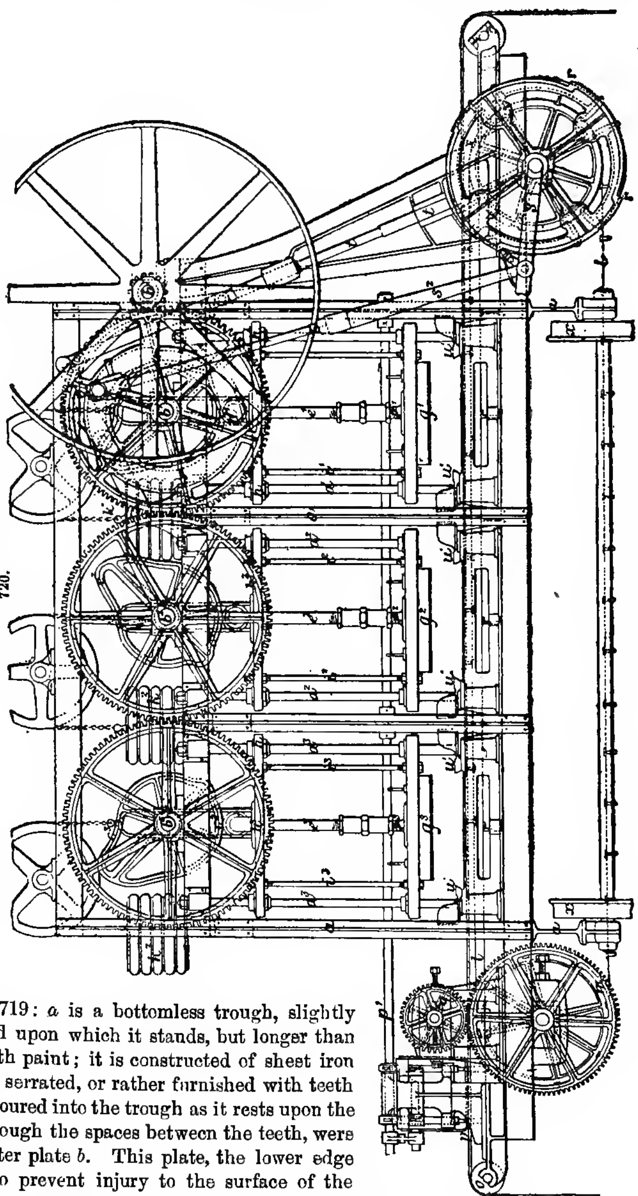
718.

upon both the colour-pad and the fabric to be printed, as the least lateral movement would suffice to destroy the accuracy of the impression. Where any error in the printing has occurred, the paint is removed by a palette knife while still wet, the surface of the floorcloth is cleaned with naphtha or spirit of turpentine, and a piece of tow, and a fresh impression is made. The paint as used has about the consistence of treacle, and, if kept for any length of time, it should be covered with water, which prevents the formation of a skin over the surface. The oil used for mixing the paint is composed of equal parts of boiled and raw linseed oil. Both these should be allowed to settle in tanks for at least a month before use. The proportion of driers to be added to the paint depends to a great extent upon the nature of the pigment. For ordinary dark paints, ground litharge is used; for white and the more delicate tints, acetate of lead (sugar of lead) is necessary. Although a large proportion of driers hastens the solidification of the oil which forms the medium of the paint, yet the film produced is not so elastic or so durable as when a smaller quantity is used. Raw oil alone gives a much better film than boiled oil; but an addition of the latter is necessary to meet the practical requirements of the case, raw oil drying too slowly.

719.



720.

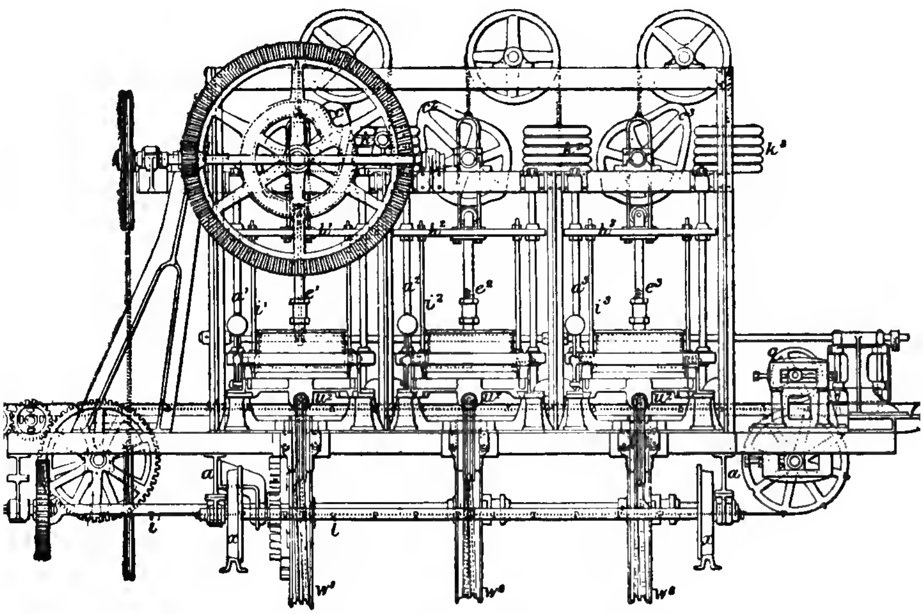


Before pouring water on the surface of the mixed paint, the brushes should be removed, and immersed in oil, to keep them from drying, as water softens the glue with which the bristles are fastened, and loose hairs may then be transferred to the blocks.

Although paint-brushes are still usually employed for distributing the colour on the pads, yet a species of "doctor" or scraper has recently been introduced, which threatens to supplant them entirely for this purpose. Its construction is shown in Figs. 717 to 719: *a* is a bottomless trough, slightly shorter than the colour-pad upon which it stands, but longer than the block to be supplied with paint; it is constructed of sheet iron or steel, and one edge *d* is serrated, or rather furnished with teeth like a comb. The paint is poured into the trough as it rests upon the pad, and would run out through the spaces between the teeth, were it not prevented by the outer plate *b*. This plate, the lower edge of which is rounded off to prevent injury to the surface of the pad, can be so adjusted as to regulate the quantity of paint passing beneath it. The bolts *c* are furnished with eccentrics, which act upon one of the plates only, so that by turning them, the outer plate or "doctor" is raised or lowered at pleasure. In using this trough, no paint-brush of any kind is needed. The paint can be kept in a can, and poured out as required, and the pads are cleaned with a palette knife after use. The only alteration required in the pads is a narrow ledge about ½ in. high on the upper side, to prevent the paint running off.

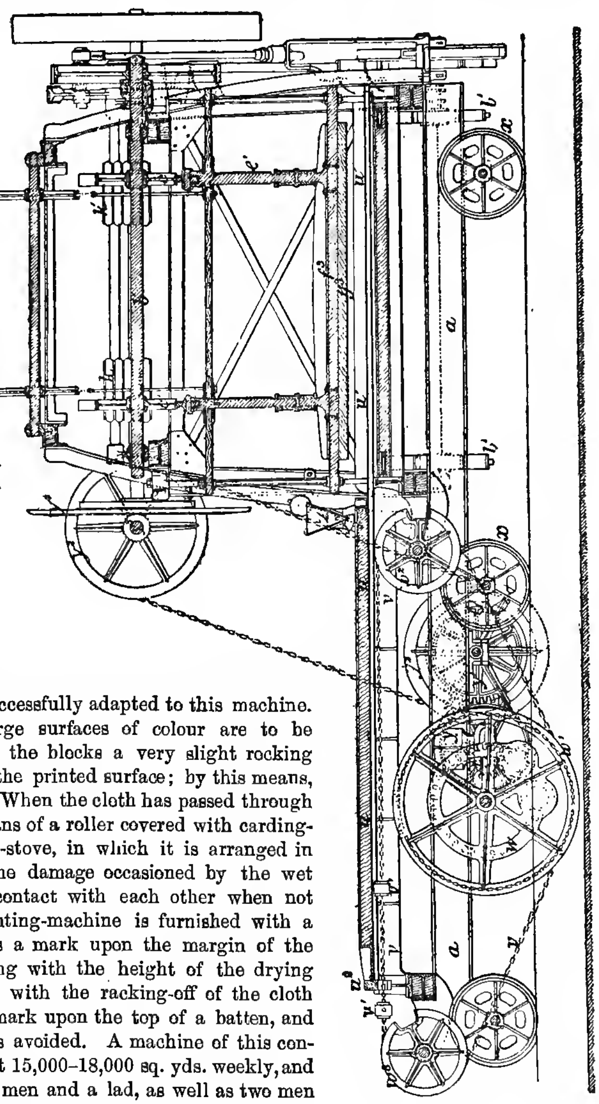
Machine Printing.—Many attempts have been made to print floorcloth by machinery; but their success has, with one exception, been only partial. All cylinder-machines are precluded, because, in order to ensure durability, the paint must be laid on thickly, and while the cylinder is revolving part of the paint runs downwards on its face, rendering one part of the impression thicker than another. Even machines which closely imitate the movements of hand printing have defects: e.g. they cannot be worked at a high speed, the paint being liable to splash when the blocks are raised too quickly. For simple patterns, the following machine has been found to work well in practice. Figs. 720 and 721 are side views, and Fig. 722 is a transverse section of it.

721.



The iron framework a is so mounted upon wheels x, that the whole machine can be moved from one drying-room to another. The motive power is in the first instance communicated to the shaft b, which, in its turn, sets in motion the shafts b_1 b_2 b_3. These shafts carry the cams c_1 c_2 c_3, which serve to depress the blocks as required. The smaller projections on the cams press the blocks down upon the surface of the pads which supply them with paint, while the larger projections lower them to the surface of the cloth to be printed, after the colour-pads have been withdrawn. The frame h_1 h_2 h_3, which bears the blocks g_1 g_2 g_3, slides up and down on the fixed guide bars a_1 a_2 a_3. The rods e_1 e_2 e_3 are furnished with set-screws, by means of which, their length, and consequently the level of the blocks, can be adjusted. The weight of the frames and blocks is counterbalanced by the weights k_1 k_2 k_3. Weighted levers, with adjustable weights, can be advantageously substituted for these hanging weights. The floorcloth upon which the pattern is to be printed, enters the machine over the roller o. At p, it meets two punches, which punch ½-in. holes in the margin of the cloth. A front view of these punches is given in Fig. 723. They descend at the moment when the fabric is stationary, for the purpose of receiving the impression of the blocks. As the cloth progresses, it reaches the roller q, which is provided with holes corresponding with the pegs l^1, upon which the fabric is thus firmly fixed. A preferable method of doing this is by substituting a second couple of hollow punches for the perforated roller q. These punches press the cloth tightly upon the pegs, where it remains until it has passed through the machine. The pegs are fixed in the steel band l, in the manner shown on the left in Fig. 724, which is a transverse section of the band lying in the groove cut for it in the bed of the machine. The illustration on the right of Fig. 724 gives a side view of one of the pegs. The steel bands, one on each side of the machine, afford a means of keeping the fabric rigid while passing through, and enable it to be adjusted accurately at the moment of printing. The forward motion is communicated to the cloth from the shaft b^1, through the rod s^2 and lever s^1. The final adjustment is effected by the plunger t, which enters a recess in the ratchet-wheel r, and remains there while the blocks are descending; t also derives its motion from the auxiliary shaft b^1, through the rod t_1 and lever t_2. The bed of the machine, upon which the cloth is drawn forward, is rendered elastic by means of several thicknesses of flannel, covered with oilcloth or thin linoleum. The printing-blocks g_1 g_2 g_3, which are of the same construction as those for hand printing, but slightly stronger, receive their colour from the pads u. These are padded and covered in the same way as for hand printing, and slide backwards and forwards on the guides u_1. The motive power is communicated to them by the chains v, whose stops v^1 catch the projections u^2 on the framework bearing the pad. The chains are carried by the wheels w_1 w_2 w_3, to which their ends are fixed. The reciprocating motion is produced by the mangle-wheel w, which is driven backwards and forwards by the pinion x. This, in its turn, derives its motion from the wheel y, with which it is connected by a universal joint; x works alternately on the inner and outer side of the mangle-wheel w, and thus causes the pads to advance and retreat as required. The space between the stops v^1 allows the pads to pause at the end of their motion, while the blocks are descending upon them. To diminish the shock caused by the sudden stoppage of the pads and their frames, indiarubber cushions, or metallic springs, are fixed at each end of the slide upon which they move. The colour-pads are supplied with paint from the troughs z, which are provided with two scrapers, capable of adjustment to regulate the flow of colour. The form of scraper used for hand printing (Figs. 717–719) has been successfully adapted to this machine. Where patterns containing large surfaces of colour are to be printed, it is advisable to give the blocks a very slight rocking motion, while in contact with the printed surface; by this means, the paint is evenly distributed. When the cloth has passed through the machine, it is raised, by means of a roller covered with carding-wire, to the top of the drying-stove, in which it is arranged in bights by hand. To avoid the damage occasioned by the wet painted surfaces coming into contact with each other when not racked off accurately, the printing-machine is furnished with a simple apparatus, which makes a mark upon the margin of the cloth, at intervals corresponding with the height of the drying buildings. The men entrusted with the racking-off of the cloth have then only to bring each mark upon the top of a batten, and all loss from the above source is avoided. A machine of this construction for six colours can print 15,000–18,000 sq. yds. weekly, and requires the attendance of two men and a lad, as well as two men for racking-off the cloth when printed.

722.

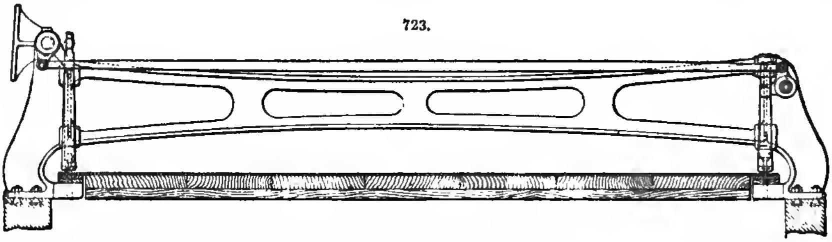


After printing, whether by hand or machine, the cloth is run over rollers into the seasoning stoves, where it is seasoned in the same way as plain linoleum. When sufficiently matured, the printed cloth is removed to the trimming-room, where the edges are cut straight by hand, with the help of straight-edges of iron or steel. The surface is also well washed with soap and water, to remove the dust which has accumulated during the various processes. Each piece is then rolled face inwards upon a round pole, and is ready for use.

In laying down linoleum, it is advisable to cement the edges to the floor. The cement used for this purpose is a thick solution of shellac in methylated spirits of wine. A small proportion of resin is sometimes added; but this does not improve the quality, however much it may diminish the price.

In addition to its use for covering floors, an attempt has been made to employ linoleum as a covering for walls. A compound consisting of linoleum, cement, and wood-fibre (instead of ground cork) has lately been introduced under the names of "linoleum muralis" and "lincrusta." The

723.



ease with which this material can be moulded and embossed would render it peculiarly applicable to decorative purposes, did it not possess grave defects from a sanitary point of view. Wall coverings made of it are quite impervious to air and prevent that infiltration of air through the walls of a room which is so essential to the well-being of its occupants. Besides this disadvantage, linoleum cement has a smell *sui generis*, which will sometimes last for years, and is not adapted to improve the air of a room, whose walls are covered with it. Another objection to the linoleum muralis is the large amount of lead it contains, although this defect might perhaps be remedied.

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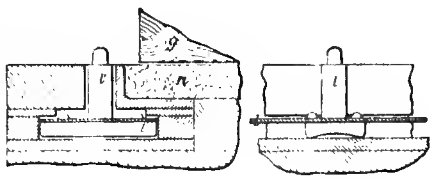

Corticine.—Corticine much resembles linoleum in its composition, the chief difference in the manufacture being the method of oxidizing the linseed-oil. For making corticine, the oil is boiled at a high temperature, until it begins to thicken. It is then mixed with the ground cork, in the same manner as linoleum cement. There are two disadvantages in this method of oxidizing the oil. In the first instance, there is a considerable loss of weight, while there is a gain by the method used in making linoleum. The second and more serious defect in this process is the peculiar, sickly smell acquired by the oil during thickening. This odour is characteristic of corticine, and affords a ready means of distinguishing it from linoleum, from which it differs but little in other respects. Although the disagreeable smell of thickened oil can be easily removed at an early stage of the manufacture, this does not yet appear to have been done on a large scale.

Boulinikon.—Boulinikon is also a kind of floorcloth in which oxidized linseed-oil forms the matrix. It may be described as a coarse felt, made of various fibrous substances, and saturated with linseed-oil. This oil is oxidized by heating the material in stoves at a much higher temperature than that necessary for either linoleum or corticine. During the operation of stoving, very large quantities of acroleïn are given off, while the oil itself becomes tough and hard.

Kamptulicon; Cork Carpet.—These are composed of comminuted cork, cemented together by indiarubber. Waste indiarubber of various kinds is first converted into a paste, by means of the ordinary solvents (see Indiarubber Manufactures). This is then mixed with the ground cork, in ordinary mixing-rollers. The mixture is rolled out into a sheet, which is afterwards vulcanized. Patterns can be printed upon it in the same way and by means of the same apparatus as are used for linoleum or oilcloth. In laying down kamptulicon, the whole of the lower side should be cemented to the floor with indiarubber cement, but even with this precaution, it will sometimes spread under the feet, producing the appearance known as "buckling." Owing to the high price of indiarubber, kamptulicon is being rapidly superseded by those floorcloths in which an elastic cement containing linseed-oil is substituted for the indiarubber.

(See Cork; Oils.) W. F. R.

FOOD PRESERVATION.

The art of preserving food in a fit condition for human consumption has probably occupied men's minds from very early times; but it is only within quite recent years that the subject has attracted scientific attention, and has grown from a domestic to a commercial scale. The curing of bacon, the preserving of fruit, and the making of pickles, are all strictly included under the heading of this article; but the object here will be to avoid such matters as may be found in any handbook of cookery, and to confine attention to the processes which have been devised and executed on a wholesale basis, and which, collectively, exercise a most important influence upon the food-supply of the United Kingdom. For convenience of reference, the subject may be divided into the following heads:—Dairy Produce; Fish; Fruit, Grain, and Vegetables; and Meat.

Dairy Produce.—This heading embraces eggs, milk, and butter.

EGGS.—The best method of preserving eggs in a fresh state for an indefinite period is by the exclusion of air and moisture, and the application of an antiseptic. The eggs, as taken from the nest, are coated with butter (or other sweet animal fat) containing 2–3 per cent. of salicylic acid, applied by a little wool. Each egg is then placed in a box containing sawdust, which has been dried, even to scorching, then poured into the box, and allowed to cool perfectly. The eggs should not touch, and should be quite covered with the sawdust, and the box should be nearly air-tight. Ordinary methods are:—(1) Scalding; (2) short immersion in silicate of soda.

MILK.—Milk may be kept sweet in the pans for a short time by the addition of a little borax. For its preservation for lengthened periods, several processes are in vogue.

Condensed Milk.—The compound known as "condensed milk" is an illustration of the application of the drying or desiccation theory, accomplished by evaporating the excess of moisture, adding sugar, and packing in hermetically sealed vessels. The milk, as received from the dairies, is placed in vessels having a capacity of 750–1000 gal., where it is maintained at a slightly raised temperature, by means of steam-heat, and undergoes evaporation *in vacuo*. The duration of the process varies from 2 to $5\frac{1}{2}$ hours. Refined sugar in powder is added in the proportion of about $\frac{1}{3}$ by weight of the total condensed product; and when the mass assumes the consistency of thick honey, it is put into tin boxes, and hermetically sealed. The proper conduct of the operation is by no means easy. There is much danger of a decomposition of the caseine in the presence of heat and sugar, especially if the milk has been in the slightest degree "turned"; also much of the fatty constituents will distil with the water, if the temperature is allowed to exceed 38° (100° F.). Attention has recently been called, in the *Analyst* and elsewhere, to the fact that these unfavourable conditions do frequently come into play, and that the loss of nitrogenous matter by decomposition, and the loss of equally important fat, partly volatilized, partly decomposed, so generally sustained by condensed milk, render it unfit to replace new milk in the nursery. Small quantities are prepared (almost solely for the American market) without the addition of sugar, in which case the evil is lessened; but the product does not keep so well.

Mabrun's process.—This simple process was probably the foundation of the preceding. The milk is warmed at a moderate temperature, in a tin vessel, furnished with a leaden tube, for the expulsion of the air. The tube is then compressed, and the orifice is soldered up. After 6 months' keeping, the milk is as good as new. The process received a prize of 1500 fr. from the French Academy of Sciences.

Morfit's process.—In 1 gal. of milk at 55°–60° (130°–140° F.), is dissolved 1 lb. of gelatine; the mixture is left to cool to a jelly, when it is cut into slices, and dried. The compound is used to gelatinize more milk, and this is repeated till the gelatine is in the proportion of 1 lb. to 10 gal. of milk.

BUTTER.—The Aylesbury Dairy Co. are the proprietors of a preservative for butter, the composition of which is kept secret. Butter preserved with the compound has remained good for more than a year, under most trying conditions. The process should be the means of introducing large quantities of fresh butter from distant pastoral countries.

Fish.—Before alluding to recent processes for preserving fish in a fresh state, some space may be devoted to the ordinary methods of curing fish.

Herrings.—The fish are spread on a floor, and sprinkled with salt; when sufficiently salted, they are thrown into large vats, and washed. Each fish is then threaded through the gills, on long thin spits, holding 25 each. These are hung upon trestles in the smoking-room, where fires of oak-boughs are kept smouldering. For "bloaters," to be consumed in England, the smoking lasts about 24 hours; "red-herrings" for export are salted more, and are smoked for 3 or 4 to 40 days, usually about 14 days. "Kippers" are taken while fresh, and split up. They are then washed, and thrown into vats with plenty of salt for a few minutes; finally they are spread out on tenter-hooks on racks, and hung up for 8 hours' smoking.

Oysters.—A method of preserving oysters is adopted by the Chinese. The fish are taken from the shells, plunged into boiling water for an instant, and then exposed to the sun till all the moisture is removed. They remain fresh for a long time, and retain their full flavour. Only the fattest can be so treated. Oysters are also largely "canned," much in the same way as salmon.

Salmon.—The fish are beheaded and cleaned, and cut by a series of knives into the right lengths to fill 1-lb. cans. When these have been filled to within $\frac{1}{4}$ in. of the top, the covers are put on and soldered. In an air-tight condition, the full cans are passed to the boilers, vats measuring 5 ft. × 4 ft. × 4 ft., where they are steamed for 1 hour. They are then taken out and cooled. A small hole in the centre of each lid, hitherto remaining soldered up, is opened by applying a hot iron, and the air and cooking-gases are allowed to escape. The cans are then instantaneously made air-tight again, and are boiled for two hours in a bath of salted water, the salt being added to raise the boiling-point. They are then left to stand till quite cool.

Sardines.—The beheaded and cleaned fish are spread upon sieves, and plunged for 1–2 minutes beneath the surface of boiling oil in coppers. After draining a little, the fish are packed closely in tin boxes, which are filled up with pure cold oil, and soldered. The quality deteriorates with every immersion, owing to the matters disengaged by the boiling oil, and the coppers need frequent replenishing with oil.

Shrimps.—To preserve shrimps in a dried state, they are boiled for ½ hour with frequent sprinkling of salt; then spread out on hard dry ground, with frequent turning, to dry and bleach for 3–4 days. They are then trampled to remove the shells, and are winnowed and bagged.

Eckart's process.—This consists in the application of an antiseptic under great pressure. The antiseptic solution is made by adding 33 lb. of salt, and ¾ lb. saltpetre to 100 lb. of water; and ½ lb. of salicylic acid to 100 lb. of water. A mixture is then made of 75 parts of the salt solution and 25 parts of the salicylic acid solution. This is applied under a pressure of at least 12 atmos. The goods are then packed in barrels or cases, and surrounded with gelatine, to exclude the air, and prevent desiccation. The fish keep good and retain their flavour for 10–14 days. The same process is applicable to meat, game, &c.

Refrigeration.—This process, described further on under Meat, is equally applicable to all kinds of fish.

Fruit, Grain, and Vegetables.—For the preservation of grain, no further precautions are necessary beyond gathering it when ripe, and keeping it dry. The preservation of fruit and vegetables may best be studied under the three heads of desiccation, pickling, and cooking.

DESICCATION.—The simplest form of desiccation is by ordinary sun- and wind-drying, as conducted in hay-making. The next step is by radiated sun-heat, as in coffee-drying (see Coffee); a further advance is made by the application of artificial heat, as in hop-drying and tea-drying (see Hops, Tea). The primary object in all these cases is the removal of the water mechanically present, and without whose presence, fungoid growths and decay cannot exist. As a curative agent simply, the application of heat is, however, unnecessary and injurious, causing a partial destruction of the flavour, and more or less fermentative change. Research has proved that, between the limits of 0° and 15° (32° and 60° F.), vegetable substances retain their flavour and all other qualities, while giving up their moisture, no fermentative action being engendered. This has led to the adoption of the

Cold-blast system.—The fruit or vegetables are deprived of moisture by subjection to dried air at a low temperature. The air is compressed in a chamber containing chloride of calcium, or any other compound possessing strong dehydrating qualities. Chloride of calcium is in practice probably the best, as it so readily gives up the absorbed water on being heated. The compressed and dried air is then admitted into a chamber containing the substances to be treated. The expansion lowers its temperature somewhat, which should be maintained between 32° and 60° F. The substances are distributed throughout this chamber on perforated trays, so as to be fully exposed to the current of cold dry air passing through. All the moisture is thus removed, without the least detriment to the flavour, colour, and other virtues of the substance acted upon. The process has a great advantage over hot-drying, both in the cost entailed and the result achieved. Fruit and vegetables thus prepared, and packed with ordinary care, remain good for an indefinite period, and resume their natural shape and dimensions when placed in water.

Hot-air process.—Great quantities of vegetables continue to be prepared by this process, which has been in use for some time by Whitehead, and other well-known firms. A common method of conducting the operation is as follows:—The fruit or vegetable is pared and cored, if necessary, and then finely shredded. The shreds are spread on galvanized-iron wire screens in the evaporator, a 3-storeyed chamber, through which passes a current of air heated to 116° (240° F.). The screens rest on endless chains, that move upwards at intervals of 3–5 minutes, when a fresh screen is put on below, and a finished one is taken off at the top. The evaporation is very rapid. The cores and peelings of apples, &c., are made into vinegar.

Another plan is by means of a vacuum-pan, heated to 49°–77° (120°–170° F.). The air is dried by passage over chloride of calcium. The operation occupies 20 minutes.

Masson and Gannal's process.—Vegetables are submitted for a few minutes to steam at 70 lb. a sq. in., then dried by air at 100° (212° F.), subjected to hydraulic pressure so as to form tablets, and, when required for use, are soaked in cold water for 5 hours.

Carsten's process for Potatoes.—The potatoes are peeled and cut into discs, and are scalded by immersion in nearly boiling water. They are then dried hard in an oven. To preserve the white colour, they are treated with water, acidulated with 1 per cent. of sulphuric acid. They are then washed in cold water, and dried.

Quick-lime for Potatoes.—For preserving potatoes in store, the floor is sprinkled with fine quick-lime; this is covered with a layer (4–5 in. thick) of potatoes; this by a sprinkling of quick-lime again, and so on, using the lime in the proportion of about 1 measure to 40 measures of potatoes. This method checks disease when it is present, and improves the potatoes if they are watery or waxy. Layers of straw and powdered plaster of Paris may be substituted for the lime.

Sacc's process.—Sacc's process for preserving vegetables is as follows:—The vegetables are warmed to destroy their rigidity, and are then packed in barrels, and surrounded with ¼ their weight of acetate of soda in powder, by which their moisture is absorbed. In summer, the action is immediate; but in winter, it may be necessary to put the barrels into a room heated to 20° (68° F.). After 24 hours, the vegetables are removed, and kept in a dry atmosphere. For use, they are soaked in cold water for 12 hours.

Cooking.—The preservation of vegetables by cooking them in sealed cases is dependent upon the destruction of all organic germs by the heat of the boiling, and the perfect exclusion of air. An example of the simplest form is the

Canning of Tomatoes.—The fruits are scalded to loosen the skin, and then dipped in sieves into water, heated by injection of steam, for ½ minute. They are then skinned, and picked over, and passed into the steamer. Thence they fall into the hopper, and are fed by the "stuffer," a cylinder worked by a treadle, into the cans. The filling of these is adjusted by boys, and they are sealed up. The cans are then boiled for 2 hours, then partially cooled, the air is let out by a pin-hole, and they are immediately soldered up, and the cooling is completed.

Many other vegetables are canned in a similar manner. Those which have a green colour lose it during the operation, by the destruction of the chlorophyl. The same remark applies to those dried by heat. The green colour may be replaced by adding a solution of chlorophyl, exhausted from other plants; or the natural colour may be retained by treatment with alkaline earths, according to Possoz, Biardot, and Lécuyer.

Pickling.—In pickling vegetable substances, advantage is taken of the curative properties of acids, alcohol, sugar, saltpetre, salt, &c.

By Acids.—Curing by means of acids, as acetic acid, vinegar, &c., is the process commonly known as "pickling." In the ordinary way, the vegetables are kept soaking for a long time in brine, and are then pickled by acetic acid. An improved method, by which months of time are saved, is to exhaust them under an air-pump, and then to force in spiced vinegar under a pressure of 45 lb. a sq. in.

By Alcohol.—This is too expensive for commercial purposes. An example is the preservation of cherries in brandy.

By Sugar.—Sugar is very largely used for preserving fruit in an edible condition, either in bulk, or in separate pieces.

Marmalade.—The manufacture of marmalade is a type of the process carried on in bulk. The peel is removed from the oranges, and their pulp is squeezed, to liberate the juice. The peel is softened by steaming, and is then sliced by revolving knives. The pulp is boiled, and then passed through a "searcher," to remove the tough skin and pips. The juice and sliced peel are then mixed and boiled with lump sugar in steam-jacketed copper pans. Wherever possible, the appliances used are of oak.

Candied Fruit.—The "candied-peel" of citrons, lemons, and oranges, is thus prepared. The fruits are placed in vats, and boiled till soft enough to absorb the sugar. The pulp is then entirely removed, and wasted, no attempt having been made to utilize it for the production of essences, or vinegar. The peel is put into tubs, and treated with hot syrup of sugar for 10–14 days. It is then dried on sieves, in a room heated to 38° (100° F.). It is finally candied by immersion in a boiling limpid syrup of sugar, left to drain on a sieve over the pan, and again hot-dried and packed. Whole fruits are prepared in a similar manner.

Meat.—Dr. Richardson says that putrefactive changes in meat are due to the decomposition of the water contained in the tissues. The means which have been found to arrest this decomposition are (1) a low temperature; (2) a high state of desiccation; (3) the application of antiseptics; (4) the exclusion of air.

Refrigeration.—Subjection to a low temperature is a thoroughly effective way of preserving meat, but it can be considered only as temporary, decomposition ensuing when the cold state is abandoned. Nevertheless, its effects are sufficiently lasting to serve practical ends, and the process seems most likely to solve the problem of conveying large quantities of fresh meat to this country. Numerous plans have been devised, all aiming at the production of a sufficiently low temperature at a remunerative cost. The principal are:—

Harrison's.—The meat is first frozen, and is then packed in a chamber on board ship, the air of which is maintained in a thoroughly dry state, so as to keep up a slow but constant evaporation from the surface of the meat. The meat is placed in tanks, which are kept cool by directing a stream of brine among ice, and regulating the strength of the brine so as to produce the desired degree of cold. The ice and brine are kept in tanks above the meat, and from them streams constantly trickle over and around the meat-tanks. The consumption of ice is less than 50 tons for 50 tons of meat, and the proportion decreases with larger quantities. The meat retains its full flavour, and will keep good in a temperature of 17°–20° (63°–68° F.) for 70–80 hours after removal from the tanks. The drawback is the bulk of ice required.

Tellier's.—The joints of meat are placed in a chamber, through which is passed a current of air charged with ether, or other volatile substance, so as to reduce the temperature sufficiently low to preserve the meat, without freezing its juices.

Mort and Nicolle's.—In this process, the freezing agent is ammonia solution, under a pressure of 50–70 lb. a sq. in. The freezing-room is kept below 0° (32° F.), and the meat is frozen quite hard.

Poggiale's.—A low temperature is maintained by the evaporation of methylic ether, and circulation of chloride of calcium.

Bell and Coleman's.—This process is, perhaps, the most completely successful of all that have been introduced, and is equally applicable to the preservation of fresh meat during transport by land or sea, and while being stored. The meat is placed in a chamber, made as nearly air-tight as possible, and of the best-known non-conducting materials. The air which is made to circulate in the meat-chamber is cooled so as to maintain a temperature never exceeding 10° (50° F.), and never so low as to actually freeze the meat. The cold is obtained by the re-expansion of compressed and cooled air. Cold-producing machines on this principle are by no means new, but a great difficulty hitherto met with in applying this system has been the formation of particles of ice during the re-expansion. This is avoided by a more effectual cooling of the compressed air, and by subsequently treating the air so as to separate moisture from it, by subjecting it, before re-expansion, to an atmosphere cool enough to ensure the deposition of any remaining moisture that would be liable to freeze; moreover, care is taken that the air shall not be so highly dried as to have a desiccating effect upon the meat.

The compression of the air is effected in the apparatus shown in vertical section in Fig. 725. The air enters by pipes *a* above the cylinders, and through valves *b* in the upper parts of the cylinder ends; it passes out through valves *c* in the lower parts of the cylinder ends, and by pipes *d* beneath the cylinders. At each end of each compressing-cylinder *e*, is fitted up a small pipe *f*, for injecting water to absorb some of the heat developed during compression; this water drains into the discharge-pipes *d*, and is led away by pipes *g*. The compressed air passes from the discharge-pipes *d* into the apparatus for completing the cooling and separation of the moisture. This apparatus is shown in vertical section in Fig. 726. It comprises two vertical cylinders *a b*, and a set of pipes *c*. The first vessel *a* is formed with an inlet *d* at its lower part, for admitting the compressed air, which passes upwards through *a*, then by a connecting-passage *e*, to the top of *b*, in which it descends, and thence passes into the pipes *c*. At the top of *a*, is a pipe *f* for the introduction of water of ordinary temperature (or colder when conveniently obtainable), such water being forced by a pump so as to overcome the internal pressure of the compressed air. This injection-pipe is fitted with a rose-nozzle *g*, for spreading and distributing the water over the area of the vessel, it being important that the air and water should mingle intimately. To ensure complete contact and action between the water and air, so that the water may abstract as much as possible of the heat rendered sensible by the compression of the air, the vessel *a* is provided with a number of perforated metal diaphragms *h*, which are fixed across the lower part of the vessel, but above the air-inlet, and are arranged with the holes in each opposite the solid metal of the next above and below, in order that the subdivided currents of air may have their directions continually changed, and be made to impinge upon the wetted surfaces of the diaphragms. Similar diaphragms *i* are fitted in the second vessel *b*, for separating from the air any moisture it carries over from *a* into *b*. The jets of air, passing through the perforations in each plate in succession, impinge on the next plate, and deposit the suspended moisture. At the bottom of each vessel, is a casing *j k*, to receive the water ready for drawing off.

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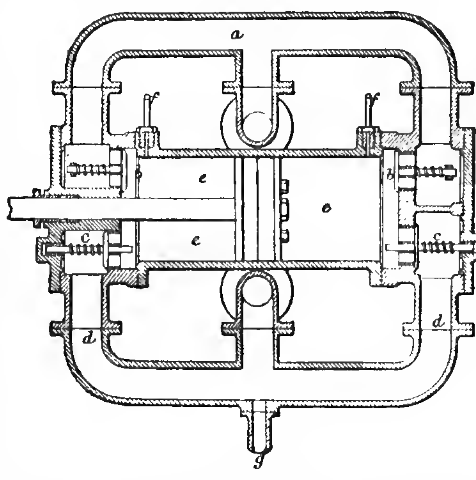

Assuming that the water employed is of the ordinary temperature, it cannot reduce the air below that temperature, and the air will still retain some moisture, both mechanically suspended and invisible, which will be precipitated, and possibly congealed, on the air being subsequently expanded, and becoming of considerably lower temperature. It is the purpose of the pipes *c* to cause the separation and deposition from the air, before it reaches the expansion-cylinders, of any moisture which would thus tend to congeal. These pipes are placed in an atmosphere below the ordinary temperature, and, being inclined upwards from *b*, the moisture deposited in them, in consequence of the additional cooling of the air in passing through them, drains back into *b*. The pipes are best placed in the chamber in which the meat is preserved, the temperature there being always kept above the freezing-point. They should be of considerable length, the precise length in each case depending upon the temperature intended to be maintained in the chamber, and other circumstances. Where several chambers are to be kept cool, e. g. a number of vans composing a railway-train, or several separate compartments in a ship, the pipes may be arranged in only one compartment. At their higher ends, the pipes communicate with a single pipe, which leads the air to the expansion-cylinders; after the air has been expanded, it is led to the chambers, where it is discharged in its expanded and cool state, being distributed by pipes fitted with valves, which can be adjusted so as to secure a temperature as uniform as possible throughout.

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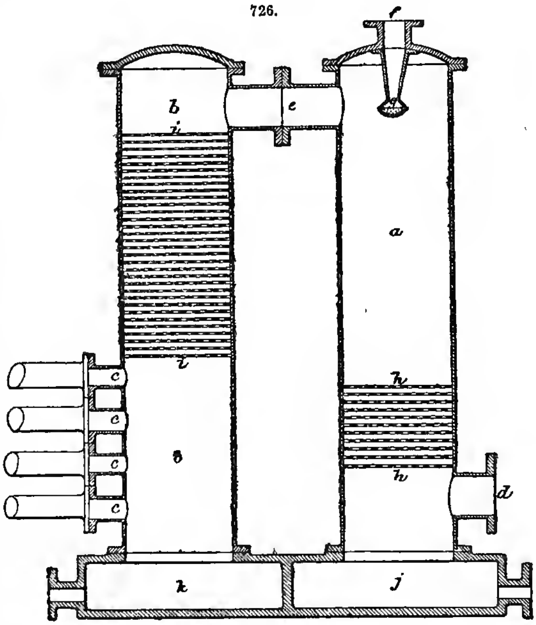

The air drawn into the compressing-cylinders *e* by the pipes *a* will generally be led from the chambers, so that the same air continually circulates through the entire apparatus, and has to be deprived only of the heat which it absorbs each time it passes through the chambers. The cooling action of the machinery depends on the power developed by the steam-cylinders, and the temperature in the chambers can consequently be regulated by suitably adjusting the steam throttle-valve. (See Ice.)

Knott's and Kent's.—In Knott's refrigerating-car, air is cooled by passage over a freezing-mixture, or ice alone, and a constant circulation of it is kept up, the temperature being best maintained at a little above the freezing-point, say at 33° F. The air is both dried and cooled. Kent's well-known refrigerator-safes are made upon much the same principle, the great feature being a downward draught. Importations of meat from America have been made by this system, the meat being sewn up in bags and suspended in a chamber, surrounded by a temperature of about 3° (37° F.), the draught being produced by a steam-fan worked over the ice-tanks.

Desiccation.—Animal matter, preserved by the absorption of its moisture, loses its flavour, and becomes tough and indigestible; the fat becomes rancid, and, in damp weather, the meat absorbs moisture, and turns mouldy and sour. These tendencies are corrected by adding absorbent substances with fat food—as sugar and spice, to form "pemmican," and farina, to produce "meat-biscuits." Altogether, the process seems ill-adapted for preserving meat in a fresh state, and two methods only need be mentioned.

Tellier's.—The meat is placed in vessels, whose air is repeatedly exhausted, and replaced by carbonic acid gas, which latter is finally absorbed by a concentrated solution of potash. The meat loses 18–20 per cent. by weight, and is kept *in vacuo*.

Sacc's.—This process has been described above, under Fruit. When applied to meat, the brine produced furnishes an extract of meat on evaporation, the acetate of soda crystallizing out. This extract is added in the proportion of about 3 per cent. to the preserved meat. The latter, before use, requires to be steeped for 12–24 hours in water containing about $\frac{1}{2}$ oz. sal ammoniac to the pint.

Antiseptics.—The use of chemical antiseptics has long been known, common salt being a very generally employed agent of this class. The difficulty seems to be to ensure the meat retaining its freshness, and to avoid its acquiring any unpleasant flavour. From among the very various processes devised, the following are selected as being most noteworthy.

Herzen's.—The quarter-carcases are soaked for 24-36 hours in a solution composed of 3 parts borax, 2 parts boracic acid, 3 saltpetre, and 1 salt, in 100 parts water; they are then packed with some of the same. Before use, they need 24 hours' soaking in fresh water.

Reynoso's.—The meat is subjected to the action of compressed nitrogen, carbonic oxide, &c. After being kept in this state for 40 days, the freshness has been so maintained that blood has flowed from the joints.

Richardson's.—Dr. Richardson made some test experiments with meat treated with various antiseptics, under a temperature varying from 7° (45° F.) to 43° (110° F.), for a period of 75 days. The results may be summarized thus:—Methylene: preservation, good; colour, imperfect. Methylal: faint taint of decomposition. Cyanogen: preservation, excellent; colour, perfect; structure, firm. Sulphurous acid: some tainted; colour, dark. Sulphurous acid and lime-juice: some tainted; colour, indifferent. Sulphurous acid and glucose: some tainted; structure, dense. Nitrate of methyl: preservation, good; colour, yellowish; structure, firm. Formates: entirely fresh, and excellent in colour.

Estor's.—This consists in treatment with sulphurous acid and chlorine in succession.

Gamgee's.—The animals are killed by inhaling carbonic acid, &c., and the carcases are kept in an atmosphere of carbonic or sulphurous acid. This does not prevent decomposition where bruises exist.

Medlock and Bailey's.—The meat is immersed in a solution composed of equal parts of water and bisulphite of lime, of 1·05 sp. gr. It acquires no unpleasant flavour. This is one of the most successful of the antiseptic processes.

Pelletier's.—The meat is covered with a coating of gum, then immersed in acetate of alumina, then in solution of gelatine, allowing the whole to dry on the surface. The antiseptic acetate of alumina forms an insoluble compound with the gelatine.

Pagliare's.—Gum benzoin is boiled in a solution of alum. The meat is immersed in this compound, and excess moisture is driven off by a current of hot air, leaving the antiseptic on the meat.

Jones and Trevethick's.—The meat is put into tin canisters, which are hermetically closed, except two holes in the lid. These are plunged into a vessel containing water, and after the air has been exhausted by an air-pump through one hole, sulphurous acid gas is admitted through the second, and this alternation is continued till all the air is out. The sulphurous gas is then replaced by nitrogen, and the holes are closed.

Exclusion of Air.—As the presence of oxygen seems to be essential to the existence of decomposition, many plans for the preservation of meat have been based upon the exclusion of air from it. By far the most important are the numerous modifications of cooking in air-tight cans, called "canning," which have been conducted for years with great success. The heat of the cooking destroys any microscopic germs, if such be present, and, at the same time, expels all air from the receptacle and from the substance itself. The preservation is complete, but over-cooking is unavoidable, and the meat is rendered soft, fibrous, and insipid.

"Canning."—There are three chief modifications of the canning process:—(1) "Aberdeen"; (2) "steam-retort"; (3) "chloride calcium bath." The Aberdeen process probably originated with Appert, whose plan was brought into use during the Crimean war. The meat is placed in vessels nearly closed; these are then put into a close boiler, and the heat is raised to 112° (234° F.). After about 3 hours' cooking, the vessels are hermetically sealed. McCall's improvement upon this consists in the addition of a little sulphite of soda. Jones' improvement lies in the fact that the water is first driven off at 110° (230° F.) *in vacuo*, and the heat is then raised to, and kept at, 132° (270° F.). The special feature is the vacuum, all the oxygen being extracted by means of tubes connecting the tins with the vacuum-chamber; this greatly reduces the time. By the steam-retort plan, the meat is canned up, leaving a pin-hole, and the cans are put into a retort under steam at 110° (230° F.), and kept there for 1½–2 hours; they are then taken out, and the pin-holes are soldered up while steam is issuing from them. The cans are again steamed at 116° (240° F.), and cooled. The object of the chloride of calcium bath is to obtain a higher temperature. The raw meat is put into cans having a pin-hole, as before. The cans are placed for half their depth in a solution of chloride of calcium, boiling at 127°–132° (260°–270° F.). The heat is gradually raised from 82° (180° F.) to 110° (230° F.), and the steam is allowed to blow off for 4 hours, during which time the meat is being cooked. The holes are then closed by a drop of solder, the heat is raised to 127°–132° (260°–270° F.) for ½ hour, and the cans are withdrawn and cooled. Ritchie's deviation from this consists chiefly in desiccating the meat first in an oven at 204°–216° (400°–420° F.), and then packing it in cans, with the addition of meat jelly to create steam, before subjection to the chloride of calcium bath.

Naylor's process.—The meat is cooked, and then packed in cases, and covered with stearine (tallow).

Redwood's process.—The meat is immersed in melted paraffin at 115° (240° F.), to concentrate the juices, and expel the air. Thus condensed, the meat is covered with a coating of paraffin. Before use, it is placed in boiling water, which removes the paraffin; it can only be used in its cold state, not bearing re-cooking.

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FRUIT (Fr., *Fruit*; Ger., *Obst, Frucht*).

The scope of this article embraces only the chief foreign fruits which form objects of commerce. The extent of this commerce may be judged from the fact that the value of our total imports of fruit in 1879 amounted to about 6,750,000*l.* The only kinds of fruit distinguished in the Customs Returns are almonds, currants, figs, nuts (see Nuts), oranges and lemons (collectively), plums, and raisins. Of the unenumerated varieties, the imports of those preserved without sugar, in 1879, were:—From Italy, 8,597,468 lb., 52,039*l.*; United States, 3,592,925 lb., 51,418*l.*; Spain and Canaries, 1,743,863 lb., 14,876*l.*; British W. Indies, 751,701 lb., 7480*l.*; British E. Indies, 608,623 lb., 3347*l.*; Sweden, 498,425 lb., 2587*l.*; France, 381,218 lb., 7211*l.*; Portugal, Azores, and Madeira, 195,717 lb., 3181*l.*; other countries, 515,080 lb., 6253*l.* Our imports (in bushels) of unenumerated raw fruits, in the same year, were:—From Belgium, 962,983, 268,914*l.*; United States, 734,904, 315,814*l.*; Holland, 598,952, 251,313*l.*; France, 477,473, 264,902*l.*; Spain and Canaries, 429,116, 252,968*l.*; Germany, 418,778, 131,367*l.*; British N. America, 213,783, 102,495*l.*; Portugal, Azores, and Madeira, 182,755, 105,015*l.*; Channel Islands, 47,034, 29,704*l.*; British W. Indies, 24,671, 16,552*l.*; other countries, 129,502, 7892*l.* In the same year, our receipts of unenumerated dried fruits (in bushels) were:—From Turkey, 252,606, 106,097*l.*; Bombay and Scinde, 16,211, 11,373*l.*; Egypt, 12,130, 10,076*l.*; United States, 8590, 10,946*l.*; France, 2231, 5334*l.*; other countries, 9279, 10,113*l.* The imports of enumerated fruits will be given under their separate heads below.

Almonds (Fr., *Amandes*; Ger., *Mandeln*).—These are the fruit of *Amygdalus communis* (*Prunus Amygdalus*), a tree of moderate size. Its indigenous growth probably extended from Persia, through Syria and Asia Minor, to Algeria; at a very early date, it spread throughout the Mediterranean region, and even penetrated into the continent of Europe in favourable localities. The fruit ripens in S. England, but frosts destroy the tree in many parts of Central Europe. The tree ascends to 3000 ft. in Mesopotamia, 4000 ft. in Anti-Lebanon, and 9000 ft. in S. Kurdistan. The fruit is of two distinct kinds:—"sweet" (var. *dulcis*), and "bitter" (var. *amara*). No permanent botanical difference is noted in the trees yielding the two varieties, nor in their geographical distribution. The sweet almond is of numerous kinds, showing marked changes in shape, size, and firmness of shell. The most esteemed are the so-called "Jordan" almonds (a corruption of *jardin*—"garden"), which come from Malaga. These are usually imported without the shell, and differ from all others in being oblong and of large size. Their approximate value in the London market, when new, is 160–285*s.* a cwt. The other kinds best known here are "Valencia," 100–120*s.*; "Sicily," about 102*s.*; "Barbary," 60–90*s.* These sorts are all used as dessert fruits. The bitter almond also exists under several forms and sizes. The best are "French"; next come "Sicily"; and "Barbary," 60–85*s.* "Soft shell" almonds are only worth about 55*s.* The bitter kinds are used for the preparation of the "essential oil of almonds" (see Oils—Almond).

In 1860, we imported 19,638 cwt. of sweet almonds, and 7361 cwt. of bitter; in 1870, the figures were 36,189, and 7618; in 1872, the total import had grown to 70,270 cwt., value 204,592*l.* Of this, Morocco contributed 33,500 cwt.; Spain and Canaries, 22,000; and Italy, Portugal, France, &c., the remainder. In 1876, the total was 77,169 cwt., value 244,078*l.* The figures for 1879 show a great falling off in quantity, and rise in price:—Italy, 13,615 cwt., 62,476*l.*; Spain and Canaries, 12,999, 73,062*l.*; Morocco, 12,863, 52,148*l.*; Portugal, 3862, 13,594*l.*; other countries, 2980, 11,625*l.*; total, 46,319 cwt., 212,905*l.* Large quantities are shipped from the Persian Gulf to Bombay. The exports from Chefoo, in 1878, were 1035 *piculs* (of 133⅓ lb.), 2957*l.* In the same year, Tangier exported 4 cwt., 12*l.*, to Great Britain; Malaga shipped 22,099 boxes, and 3001 bush.; Bagdad despatched to Europe and India 260 cwt., 1797*l.*; and Mogador exported 3782 casks, 27,600*l.*, to Great Britain, and 1429 casks, 9200*l.*, to France, the total weight being 10,870 cwt. In 1879, Tangier exported 10 cwt., 30*l.*, to Great Britain, and 8 cwt., 24*l.*, to France and Algiers.

Bananas.—The terms "banana" and "plantain" are applied to the fruits of many species and varieties of the genus *Musa*, which is found throughout the tropics and subtropics. The kinds yielding edible fruit are cultivated as far north as Japan, Madeira, Syria, N. Africa, and even parts of S. Europe. They bear at an elevation of 4590 ft. in a temperature of 16° (61° F.), but the cultivation is not profitable. Many varieties are found in India, China, the E. Archipelago, Persia, Asia Minor, Arabia; some are cultivated in Guinea, Madagascar, Abyssinia, Nubia, Egypt, Greece, Sicily, and Spain; but its greatest development seems to be attained in Equatorial America: Mexico, Central America, Colombia, Peru, Brazil, the Guianas, the W. Indies, and even in Louisiana and Florida. The plants like a warm, moist soil, and prefer the neighbourhood of the sea. They are propagated by slips about 8 in. long, frequently as "shade" for other crops. They require 5–20 months to mature, according to the variety and the locality. The fruit seldom reaches this country in perfection, and is little appreciated. In the tropics, it forms the chief food of several millions of people. In 1879, the United States imported 305,094 bunches of bananas from the W. Indies, chiefly Baracoa; and 240,000 from Panama. In 1878, we imported 1829 bunches from St. Michael's (Azores); in 1879, 564 bunches. The leaves afford a valuable fibre (see Fibrous Substances—Musa sp. div.).

Citrons (Fr., *Citrons;* Ger., *Citronen*).—Citrons are the fruit of *Citrus medica*, an evergreen tree, about 8 ft. in height. It thrives in the open air in India, Burma, China, Persia, the Mediterranean region, Florida, and the W. Indies. Its cultivation is confined within narrow limits, having given way before the more prolific lemon. The trees are still scattered along the Western Riviera, about Paola and Pizzo on the western coast of Calabria, in Sicily, Corsica, the Azores, and Greece. The fruits, weighing several pounds, are chiefly used for making candied peel. Leghorn was the great seat of the candied citron-peel trade, exporting about 5000 boxes (1000–1100 tons) in good seasons. This trade has declined, and the peel is now largely shipped in brine to England and Holland. Statistics of this trade are very meagre and unreliable, no trouble being taken to distinguish citrons from lemons. The values of the exports from Syra in 1878 were:—To England (including figs and raisins), 1448*l.*; Turkey, 307*l.*; Austria, 60*l.*; Danubian Principalities, 18*l.* The orangeries of Florida produced 23,789 citrons in 1879.

Coconuts. *See* **Nuts—Coconuts.**

Currants (Fr., *Raisins de Corinthe;* Ger., *Korinthen.*)—Imported currants are the seedless fruit of a variety (*corinthiaca*) of grape-vine, *Vitis vinifera*, peculiar to Greece. The plant is cultivated chiefly in Zante, Cephalonia, Ithaca, and near Patras. Until the independence of Greece, the culture was insignificant, and confined to Patras, Egialée, and Corinth; but in 1860 the area occupied by it was 15,300 hectares (of 2½ acres); and in 1875, 36,631 hectares, of which, 29,138 were in the old kingdom, and 7493 in the Ionian Isles. The total crop shows an average production of about 16 cwt. an acre. The currant-vines prefer the littoral districts and the lowlands, leaving the higher lands to the grape-vine. Gypseous and calcareous marls are preferred to limestone, as they favour deep penetration of the roots, and do not allow of too rapid escape of moisture. The vines are planted 3–4 ft. apart in rows 6 ft. apart. They are propagated by grafting upon grape-vine stocks, or by planting out, in the spring, young shoots taken at the end of the previous year from old currant-vines cut off below ground. The grafting stock is cut down at 1 ft. below the surface, and 2–3 shoots are inserted in perpendicular chisel-cuts near the bark. Moist marl is then applied to the wounds, and wrapped on with leaves and rushes, after which, the earth is filled in around, leaving 2–3 eyes above the surface. Grafts bear fruit in 3 years; slips, in about 6. The plantations are irrigated from October to the end of the year, and are subsequently kept constantly moist; in December, they are cleared of dead and weak wood; in February, they are pruned, and the median shoots are removed from the buds, leaving only the lateral ones; in February–March, basins of earth are hoed up around the stems, to facilitate watering; in April–May, when the leaves show, the ground is well turned, manured if necessary, and re-leveled; in June, the new shoots are broken back; in July, the fruit begins to ripen; and in August, it is harvested. An operation, known as "ring-cutting," or peeling a circle off the vines which are in blossom, is much practised; it is said to concentrate the sap in the young forming berries, producing more heavy, thin-skinned and delicate fruit. The trees are very liable to attacks of oïdium, against which, a dusting of brimstone is applied while the fruit is ripening. Recently a new malady, called *Anthracnose*, has done much temporary damage, especially near Pirgos: the young shoots were affected by a rough excrescence, followed by the leaves and fruit withering and dropping off; it was checked by the hot weather, and does not seem to have left permanent effects. After 7 years, the vines do not yield profitably. When ripe, the currants are gathered, and spread on a drying-ground, in layers ½ in. thick, exposed to the sun. Rain at this time is disastrous, damaging, and even destroying, the crop. No precautions are taken to prevent rain causing fermentation during the drying, beyond the occasional turning which is done to detach the fruit from the stems. The dried currants are packed in large butts for exportation. Besides their well-known culinary application, they were largely used by French wine-makers last season, to replace the deficiency of the grape vintage. For this purpose, the currants are shipped in bulk or in bags. The approximate values of the various brands known in this market are:—Vostizza, 34–43*s.* a cwt.; Cephalonia, 24–34*s.*; Zante, 24–31*s.*; Patras, 23–34*s.*; Gulf, 25–42*s.*; Provincial, 21–31*s.*; Pyrgos, 21–34*s.*; old, all kinds, 16–33*s.* In 1879, the shipments from the Morea were (in tons):—To United

Kingdom, 52,102; France, about 14,000; United States, 7470; Trieste, 1439; N. Europe, 397; Canada, 277; Russia, 195. About 1000 tons were exported from the Ionian Isles. The value of the exports from the provinces of Calamata and Messenia was 107,184*l.*, being a middling crop; $\frac{3}{5}$ went to France, and the remainder to England, Germany, and Russia. The produce exported from Nauplia was valued at 19,740*l.* The crop in the Pirgos district reached 24,000 tons, value 360,000*l.* In 1877, Syra exported 6183*l.* worth to France, and 451*l.* to Austria. Our imports in 1879 were:—From Greece, 1,136,957 cwt., value 1,461,252*l.*; other countries, 11,555 cwt., 14,176*l.* The import duty is 7*s.* a cwt. The cultivation of currants has recently assumed some importance in S. Australia.

Dates (Fr., *Dattes;* Ger., *Datteln*).—The name dates is applied to the fruit of the date-palm (*Phœnix dactylifera*), a handsome tree, 60–80 ft. high, found from the Canaries, through N. Africa, to India and S.-E. Asia. Although the countries where the date flourishes best are characterized by absence of rain, the tree will not fruit unless its roots are well watered. The best trees are produced from slipped plants; those raised from seed are much slower in maturing, and generally poor. The slip is taken from the foot of the stem of an adult tree; when first planted, it must be watered daily for 6 weeks, and on alternate days for another 6 weeks, after which, the trees are watered once a week in summer, and every month in winter. The nut does not commence to germinate for 6–12 months after planting, and grows very slowly for the first 2 years. The trees yield fruit in 5–6 years, but do not come into full bearing for 20–25 years, after which, they continue fruitful for about 150 years. Trees in full bearing produce 8–10 bunches, each containing 12–20 lb. of fruit; taking an average of 144 lb. a tree, and 100 trees a hectare (2½ acres), the product is about 50 cwt. an acre. One tree has been known to yield 4 cwt. The dates of N. Africa are superior to any others. The region of Ziban, south of the province of Constantine, in Algeria, is conspicuous for extended and careful culture and superior fruit. Laghouat, in the province of Alger, is another centre. Tunis possesses about 2,000,000 trees. In Egypt, there are 4,000,000 female trees, yielding annually about 5,000,000 cwt.; those of Upper Egypt and the Oasis are the most delicate. Bussora (Turkey) has enormous date-groves, stretching along both banks of the Euphrates and Shat-el-Arab for a distance of over 140 miles, yielding 40,000–60,000 tons in good seasons, about half of which is exported. The best fruit is that which is gathered just before it is ripe, and is exposed to the sun for several days, to mature. The crushed dates, which arrive here in bulk, are inferior and damaged, having ripened on the trees, and fallen. Of the numerous varieties of the date locally distinguished, that best known in Europe is called *Beglet nour.* The approximate comparative values of the sorts imported into England are:—Tafilat, 70–84*s.* a cwt.; Egyptian, 28–45*s.*; Bussora, 13–21*s.* Our imports are not enumerated. The most recent statistics concerning exports are as follows:—Mogador, in 1878, exported 2 casks, value 5*l.*, to Portugal; Tripoli shipped 500*l.* worth in 1878, and 3500*l.* in 1879; Tangier, in 1878, sent 816 cwt., value 1836*l.*, to Great Britain and Colonies; Bagdad, in 1878, despatched 23,617 cwt., value 8588*l.*, to Europe; the values of all Egyptian exports in 1879 were 11,800*l.* to Austria, 9000*l.* to Great Britain, 6050*l.* to Turkey, 680*l.* to Greece, 660*l.* to France, and 3080*l.* to other countries.

Figs (Fr., *Figues;* Ger., *Feigen*).—The edible fig is the fruit of *Ficus Carica*, a small tree, 15–20 ft. high. Its native country extends from the steppes of the E. Aral, along the S. and S.-W. coasts of the Caspian, through Kurdistan, to Syria and Asia Minor. It is found on the plains of N.-W. India, and on the outer hills of the N.-W. Himálaya, up to 5000 ft., as well as in the Deccan, Afghanistan, and Beluchistan. In Asia Minor, it is met with wild at 4800 ft. The tree was early introduced into Mediterranean Europe; and in the United States, with protection in winter, succeeds as far north as Pennsylvania. Commercial supplies of figs come most largely from Asiatic Turkey, especially the country in the vicinity of Smyrna. Although the tree flourishes in nearly every part of Greece, it is cultivated on a considerable scale only in the provinces of Messenia, Calames, Andros, Carystie, Tenos, and Pylie. In 1875, the plantations occupied 6348 hectares (of 2½ acres), and produced about 242,000 cwt., or an average of 1700 lb. an acre. Several districts in Italy and Spain also furnish minor quantities, and Majorca has recently commenced an export trade with France. The soil and climate south of the Dividing Range, in Victoria, are well adapted to fig culture.

There are a great many varieties of the tree. Under cultivation, two crops yearly are generally produced—one in early summer, from the buds of the last year; another in autumn, from the buds of spring growth. The latter is the more important. The aid of hymenopterous insects is necessary for the fertilization of the flowers. When ripe, the figs are not left to dry and shrivel on the trees, but are plucked, and placed on light trays, exposed to sun and air, great care being taken to protect them from rain and dew. They become either "natural," or "pulled." The former are left to dry in their natural form, and are packed without compression; the latter, which are the finest, are kneaded and flattened during the drying, and are packed "in layers," with considerable compression, in small boxes, or rush baskets. The flattening process is carried to an unreasonable degree, and often causes the fruit to split, when its quality deteriorates. The best Smyrna figs are labelled "eleme," a corruption of a Turkish word meaning "hand-picked." The merits of a good fig are a thin skin, the seeds visible through it, and the pulp dark and luscious. The quality seems rather inclined towards retrogression. Figs grown elsewhere than in Turkey are inferior in size, flavour, and packing. The saccharine efflorescence is of natural origin.

The exports of figs from Bagdad in 1878, were 35 cwt., value 700*l.*, to Europe and India. The crop in Thessaly fell from 653,000 *okes* (of 2¼ lb.) in 1877, to 225,000 in 1878, and 46,000 in 1879. The exports from Syra in 1877 were:—To Great Britain (including raisins) 689*l.*; Austria, 125*l.* The Calamata crop in 1878 went chiefly in barrels to Taganrog, Odessa, and Trieste. The exports seawards from Brindisi in 1878 went principally (about 700,000 kilo.) to Austria, to be roasted and ground, for the purpose of adulterating coffee. In 1879, the Brindisi exports were 993,917 kilo. to Austria, 19,716 kilo. to France, besides other shipments. Malaga exported 14,217 cwt. of figs in 1878. Huelva, in 1877, shipped 2100 boxes, value 525*l.*, to Great Britain. Our imports in 1879 were:—From Asiatic Turkey, 85,295 cwt., 183,127*l.*; Spain, 9088 cwt., 9606*l.*; other countries, 10,944 cwt., 11,878*l.* The duty is 7*s.* a cwt. The approximate relative market values are:—Turkey, layers, new, 33–100*s.* a cwt.; natural, 30–35*s.*; Spanish, &c., 20–24*s.*

Lemons (Fr. *Limons, Citrons*; Ger., *Limonen, Citronen*).—Lemons are the fruit of *Citrus Limonum*, a tree of 10–15 ft. in height, indigenous to the forest of N. India, Kumaon, and Sikkim, found scattered in gardens in many sub-tropical countries, and cultivated industrially in Italy, Sicily, Corsica, Spain, Portugal, and Florida.

The cultivation of the lemon is carried on in combination with orange-growing, and the rules adopted with the one are equally applicable to the other (see Oranges). The lemon bears fruit twice yearly. It flowers with the orange in May, and again, but not so plentifully, in the autumn. The fruit may be plucked and used at any time after it has attained a fair size, though it may be green; but for convenience, it is gathered with the orange crop in September, for exportation, another lighter harvest being made in early winter. Many varieties are produced. The most remarkable is the *lustrato*, which is obtained by gathering, while yet green, all but a few lemons from the tree. Those which are left monopolize the fruit-producing powers of the tree, and thus attain unusual size. They preserve their flavour for a long time, and bear sea voyages well. Statistics concerning the lemon trade are meagre, and generally confounded with oranges. Sicily takes the lead. The exports from Palermo in 1878 were 463,977 boxes, each containing about 350. Malaga, in 1878, shipped 31,930 boxes. Syra, in 1877, sent 120*l.* worth to the Danubian Principalities, and 124*l.* to Austria. Tripoli, in 1878, exported 500*l.* (including oranges). Mogador, in 1878, despatched 54 cases, value 60*l.*, to Great Britain. Our imports are classed with oranges (*q. v.*). The United States, in 1879, received at New York, 315,176,750 lemons, of which, 113,463,620 perished on the voyage. This enormous loss, and the low prices caused by a glut in the market, were the ruin of many producers and shippers in Sicily, whence America is chiefly supplied. The Florida orangeries are now supplying considerable numbers of lemons, the crop of 1879 being estimated at 344,498. The approximate London values are:—Naples, 20–30*s.* a case; Malaga, 28*s.*–32*s.* 6*d.* a box. The fruit yields a useful oil (see Oils—Lemon).

Limes (Fr., *Limons*).—Limes are the fruit of *Citrus Limetta*, a member of the orange family. The tree grows wild in the tropics, but does not flourish so far north as the Azores. It attains the greatest perfection in the W. Indies. The island of Montserrat has long had a reputation for the product, and the lime estates of Dominica are now yielding greater profit than any other kind of culture. The tree flourishes best in good light soil, near the sea, and needs much moisture; yet it is fruitful in soils that prove too poor and dry for cocoa or coffee. Protracted drought is particularly fatal to it. In Trinidad, it rarely recovers from a drought which is severe enough to cause a curling of the leaves. The means of irrigating in dry weather are, therefore, essential to success in lime-growing. The trees are generally planted about 15 ft. apart. They require regular pruning, and to be freed from parasites during their early growth. They come into full bearing about 7 years after planting the seed. In Trinidad, the trees do not, as a rule, remain fruitful over 15 years; but in Dominica, they may last longer. The harvest is heaviest in September–January; but the Montserrat plantations yield more or less throughout the year. The extraction of the juice is very simple. The fruit is carried to the manufactories, there sliced by water-power, and passed through squeezing-rollers. The extracted juice from choice fruit is at once put into casks; that of inferior fruit is boiled down to ⅛ its original bulk, and sold for making citric acid. In 1874, Dominica exported 12,462 gal. of lime-juice, value 1600*l.*; Jamaica, 107,558 gal., 5378*l.*, and 475 barrels of limes, value 190*l.*; and Montserrat, 400–500 puncheons of juice yearly. New York, in 1879, imported 988 barrels of limes. The fruit-gardens of Florida produced 3739 bush. of limes in 1879; and, in the same year, the South Sea Islands exported 13,406 gal. of lime-juice, locally valued at 447*l.* Lime-juice is worth about 1*s.* 3*d.*–1*s.* 9*d.* a gal.

Oranges (Fr., *Oranges*; Ger., *Pomeranzen*).—The orange family (*Aurantiaceæ*) is a large and important one. Three of its members, the lemon (*Citrus Limonum*), the lime (*C. Limetta*), and the citron (*C. medica*), have been already described. The bergamot (*C. Bergamia*) is cultivated for the sake of its essential oil (see Oils—Bergamot). The shaddock or pompelmousse (*C. decumana*) and the forbidden fruit are varieties produced in small quantities for their edible fruits. Lastly there is the common orange (*C. Aurantium* [*vulgaris*]), whose culture will now be described. There are two marked varieties of the common orange—the bitter, Seville, or bigarade orange (var. *amara*); and the sweet, Portugal, or China orange (var. *dulcis*). Of the former, some 32 varieties are distinguished; of the latter, 43.

The orange is said to be a native of N. India. A wild orange, growing in Sikkim, Gurwhal, and Khasia, is thought to be the parent of both sweet and bitter varieties. However that may be, the fruit is now commonly grown throughout the tropics of both hemispheres. In Europe, its limit crosses the northern part of Spain and the extreme south of Provence, traverses Italy a little above Florence, descends nearly to Greece, and, passing Cyprus, enters Asia. Throughout the Mediterranean basin, and the Azores, orange-culture flourishes. W. Africa has recently taken up the industry. China and Japan produce some of the choicest varieties. In several of the Australian Colonies, and in Fiji, the culture is well established. The W. Indies are now producing very large quantities; and the Gulf States, California, Mexico, and Brazil, must not be omitted.

The tree needs a humid soil, with a warm, somewhat moist, regular, and calm climate; sudden changes of temperature are especially injurious. The best method of propagating is by young plants produced from wild seed, upon which are grafted shoots of cultivated trees, when they are about 8–9 years old. Meantime the land must be kept clean, and manured. At 4 years, the plants are removed to 2 ft. apart, and, at 7–8 years, to 3¼ ft. After 2–3 years more, the grafting takes place; 2 years later, the trees are finally transplanted; and 3 years afterwards they should yield a first crop. The distance apart at the last planting varies from 13 ft. in the Neapolitan Provinces, to 25 ft. in Trinidad. In the Azores, 25–30 ft. is the common figure, the intervening space being occupied by melons, &c. Much depends upon the amount of pruning, the object being to admit plenty of air and light. When the tree has borne fruit for 6 years, it is considered full grown, and may then be expected to continue prolific for 60–70 years. Plantations require digging over twice a year, taking care not to injure the surface-feeding rootlets. Hollows are left at the feet of the trees, to receive manure, and collect moisture. Bees should always be kept on orangeries, as the honey is superior. The trees bear fruit once a year. At least 6 months are required to ripen the fruit; but it is usually gathered while yet green, packed separately in very thin paper, and stowed into boxes, ready for shipment, as it ripens after being picked. The trees are principally valued for the fruit, that of the sweet kind being eaten fresh, while that of the bitter is made into marmalade (see Food Preservation). Orange-flower water (see Perfumes—Orange-flower) is made when the trees are sufficiently numerous; another perfume (see Perfumes—Orange-zeste) is made from the rind of the sweet orange; and the leaves are frequently used for scenting rooms. The timber is much valued for inlaid work.

In the Neapolitan Provinces, the blood orange is chiefly grown, the trees yielding 500–2000 fruit annually. Salerno is noted for its mandarin oranges. Sicily is a very large producer; the exports from Palermo (in boxes of 350) were:—in 1875, 379,421; 1876, 432,549; 1877, 295,373; 1878, 320,482. Spain has an important position in the trade. Seville, in 1877, exported 5,500,000 kilo., value 55,000*l.*, to Great Britain; 3,293,000 kilo., 32,930*l.*, to France; and 87,000 kilo., 870*l.*, to Belgium. Huelva, in 1877, exported 5590 boxes, 4472*l.*, to Great Britain. Malaga, in 1878, shipped 27,250 boxes of oranges, and 5858 cwt. of orange and lemon peel. Oporto, in 1877, sent 228,000,000 oranges, of inferior quality, to Great Britain. The Azores, in 1878, shipped from St. Michael's to the United Kingdom, 410,101 *malotes* (or half-boxes, containing about 400) of the native orange, and 4577 *malotes* of tangerines, a variety of the mandarin orange. In 1879, the figures were reduced to 263,205 and 3485 respectively. The orange-groves in the valley of the Soller (Balearic Isles) have recovered their usual condition, and promise large crops again. Some parts of N. Africa, especially the Algerian province of Alger, grow oranges largely. Algeria, in 1865, exported 14,285,580; Morocco, in 1873, shipped 1,577,700; Tripoli, in 1878, despatched 500*l.* worth (including lemons); and Tangier, in 1879, exported 30,000 to Great Britain, and 4000 to Germany. The orange-gardens of Jaffa number about 400, and are irrigated by wells. The exports in 1879 were:—to Turkey, Egypt, and Syria, 17,500,000; Europe, 8,750,000; total value, 26,250*l.* On heavy soils in New South Wales, oranges and lemons thrive admirably. The orangeries at Paramatta supply quantities of the fruit to other portions of the continent. Most members of the *Citrus* family grow luxuriantly in the valleys of the Humber and the Clarence, and along the coast districts. In S. Australia, especially around Adelaide, the trees flourish extremely well. The same may be said of some parts of Queensland. There are good prospects of our receiving supplies from these colonies before long. Orange-culture has taken a great start in the W. Indies. The average annual crop is 500 oranges a tree, sometimes reaching 1000; the trees are 25 ft. apart, or 65–70 an acre. An important feature for the industry is that the crop comes in generally 8 weeks before the Mediterranean crop, so that it takes the market at a favourable time. Meantime New York is a very large customer. In 1879, that port received 16,399,421 oranges from the W. Indies, nearly half being from Kingston (Jamaica). The losses amounted to 44 per cent. Oranges, lemons, and limes grow wild and abundantly in Florida, and south of the lakes in Louisiana and Mississippi. Some of the finest groves are on the St. John's, Indian, and Oclawaha rivers. The district included between 27° and 29° 40′ N. lat., and 80° 30′ and 82° 40′ W, long., seems to be peculiarly adapted to oranges and lemons. In 1879, the Florida orange-groves contained 20,481,541 trees, of which 18,821 were in bearing. The crop produced was 16,034,558; while that of 1880 is estimated to reach 100,000,000. This immense production will no doubt stop the importation from the W. Indies, &c., to New York. In California, oranges and lemons grow well. The county of Los Angelos produced 5,280,000 oranges in 1879; the trees numbered over 90,000 in 1874. In Brazil, the industry is not yet of much importance. Ceará, in 1878, exported 8017 cases to England, and 817 to New York. Tahiti, in 1878, shipped 4,207,000 oranges, value 4207*l.*, and in 1879, 2,148,000, value 2148*l.*, principally to San Francisco. Hankow, in 1878, shipped 1592 *piculs* (of 133⅓ lb.) of orange-peel; and Wenchow exported 4400 *piculs* of fresh oranges. Our imports of oranges and lemons in 1879 were:—From Portugal, 2,084,896 bush., 832,696*l.*; Italy, 717,867, 252,940*l.*; Azores, 370,629, 128,605*l.*; Portugal, 235,947, 92,465*l.*; Brazil, 3950, 2343*l.*; other countries, 19,770, 8912*l.* The approximate prices of the best-known kinds are:—Valencia, 16*s.*–22*s.* 6*d.* a box; Lisbon, 13–16*s.*; Palermo, 7*s.* 6*d.*–12*s.*

Pineapples (Fr., *Ananas*; Ger., *Ananase*).—These are the fruit of *Ananassa sativa*, a plant found in a wild state in most parts of India and Ceylon, the Malay Peninsula, Straits Settlements, China, and the E. Archipelago; also in the Azores, W. Indies, Tropical America, and the W. coast of Africa. It has recently been introduced into the Australian colonies. The plant is propagated by suckers, which bear fruit in 12–18 months. Sometimes the crown of the fruit is planted, but this takes 3 years to mature. They are set out in rich soil, about 18 in. apart, and weeded every 3 months. In the Bahamas, 20,000 suckers are planted on an acre; but in Jamaica, the distances are 3½ ft. × 2½ ft., or 4840 to the acre. The latter plan gives 4000 fruit an acre in 16–18 months after planting. The W. Indies are the chief seat of pineapple culture. It is mostly carried on in Eleuthera, Abacos, and San Salvador. Two kinds are grown: "sugar-loaf," the best, principally shipped to England; and "Spanish" or "red pine," for the American market. New York, in 1879, imported 2,740,002 of which 26 per cent. perished. In 1874, the value of the total shipments from the W. Indies was 40,066*l.* Pineapples grown in the Azores are much finer than W. Indian, and are more carefully packed. Great quantities of the fruit are produced in Assam, and the gardens of Malacca and Singapore yield enormous specimens; but these do not enter into commerce. In 1876, Queensland had 86 acres under this crop. The fruit is picked while green, and allowed to ripen on the voyage; hence the inferiority of imported pineapples to our own hothouse productions. Large quantities of the canned fruit now arrive from the W. Indies. The plant yields a most valuable fibre (see Fibrous Substances—Ananassa).

Plums (Fr., *Prunes*; Ger., *Pflaumen*).—The various kinds of plums and prunes now met with under cultivation are supposed to be derived from *Prunus domestica*. It is believed to occur truly wild in Greece, the S.-E. shores of the Black Sea, the Caucasus, and the Elburz range (N. Persia). The culture of the tree on a really large scale is now confined (1) to the valley of the Loire, where the very superior "French plums" are grown; (2) throughout Germany, where a variety termed *Quetschen* (*Prunus œconomica*) is largely cultivated, and supplies the English market with dried prunes when the French crop fails; (3) in Bosnia, Servia, and Croatia. In the three last countries, the plum crop is the most important, the Possavina district, in N. Bosnia, producing 15,000–20,000 tons in a good season. The best are grown on the sides of the low valleys descending into the great plain of the Possavina. The culture and drying of the fruit is rudely conducted, yet the latter process is so well understood that the peasants are hired for the purpose into Servia and Austria. The Servian and Croatian plums are inferior to the Bosnian, and readily undergo fermentation. The Bosnian plums go by the Save to Sissek for Trieste, and by the Save and Danube to Budapest. The Servian plums are very extensively used for making a spirit termed *sligovitch*. Servia is estimated to have about 155,000 acres under plums. Both Bosnian and Servian plums are largely exported to Germany and the United States. The crop of 1877 was reckoned at 1800 tons Bosnian, and 2500 tons Servian, besides 1000–1200 tons Slavonian plum jam, consumed mostly in Bohemia and Germany. The exports from Fiume to the United States in 1878 were 415 tons. The import duty discourages shipments to this country. Our imports in 1879 were:—French plums and prunelloes: from France, 7230 cwt., 42,880*l.*; other countries, 44 cwt., 234*l.* Prunes: from France, 8102 cwt., 11,824*l.*; other countries, 675 cwt., 1160*l.* Dried or preserved plums: from Portugal, 437 cwt., 4377*l.*; other countries, 405 cwt., 1513*l.* The import duty is 7*s.* a cwt. The value of French prunes is 22–45*s.* a cwt.

Raisins (Fr., *Raisins*; Ger., *Rosinen*).—Raisins are the dried fruits of the common grape-vine (*Vitis vinifera*). They are not, as might be supposed, produced wherever the vine is cultivated; on the contrary, their preparation is a specialty of certain districts. One of the most important of these is a strip of Spanish territory bordering the Mediterranean, about 100 miles long, and 5–6 wide. Two kinds of raisins are here produced: the muscatel or dessert-raisin, chiefly in the neighbourhood of Malaga; and the common pudding-raisin, peculiar to Valencia. Unfortunately, the phylloxera has made such ravages throughout this district, that the industry is almost threatened with extinction. The region next in importance has its outlet at Smyrna. Here the small stoneless or Sultana raisin is grown, not only on the mainland, but also in the island of Chesme, which gives its name to a portion of the crop. There are large districts in Persia where raisins are produced, but the expense and difficulty of transport cause them to be consumed locally. Greece furnishes small supplies of sultanas. California is becoming a large producer of muscatels, for consumption both in the E. States, and in China. The decay of the Cape wine trade has driven the growers to convert much of their grapes into raisins. Finally, S. Australia is rapidly developing a raisin trade.

The vines begin to bear in the 2nd year, but are not in full bearing till the 5th; they continue productive for 50–75 years. The sultana vines are planted in rows 6–7 ft. apart; they are productive in the 3rd year, and are in perfection at the 4th–6th year. The matured fruits do not fall off, but remain attached to the plant, where, with sufficient heat, they wither and dry. The drying is an operation requiring the greatest care. It is usually hastened by one of the following methods. In Spain, the ripe bunches are clipped off one by one, and placed on sloping floors, covered with small pebbles, to cure in the sun. Perhaps the finest kinds are obtained by partially severing the stalks, and leaving the bunches hanging on the vines, the leaves being at the same time removed, so as to admit the sun. In Asia Minor, the plucked fruit is slightly sprinkled with oil during the curing, to prevent too rapid evaporation, and to favour the preservation of the fruit in transit. Occasionally, the bunches are dipped into warm water, or a lye of wood ashes and lime, especially in Valencia. Of course, it is essential that damp shall be rigidly excluded during the drying period. When dry, the fruit is carefully assorted. The muscatels are classed as layers (neatly packed in fancy boxes), bunch, and loose, the last being picked off the stems. The best are for the London market; the worst, chiefly for Scotland and America. Of Valencia raisins, about half come to London, a large proportion of the remainder going to the United States and Canada. Sultanas are very largely consumed in Germany, and in our Midland Counties. The "eleme" (or hand-picked) are specially packed for our colonies, and for ships' stores, and come chiefly from Karabourna and Vourla (Asia Minor). The Chesme growth, unpicked and unselected, form the great bulk of the German importations, and are popular in our Eastern Counties. The approximate relative values are as follows:—Muscatel: layers, 40–150*s.* a cwt.; loose, 30–42*s.* Valencia: 25–34*s.*; good and fine, 28–49*s.* Smyrna: red, 23–35*s.*; eleme, 30–45*s.*; sultana, 30–56*s.*; Belvidere, 30–31*s.*

The exports from Malaga, in 1878, were 2,134,518 boxes, 28,006 frails, and 19,343 barrels; in 1879, 1,984,183 boxes, 23,000 frails, and 18,442 barrels, of which, 1,520,000 boxes, and 22,832 frails were sent to the United States, and the remainder chiefly to Great Britain, France, and Germany. The boxes contain about 25 lb.; the frails and barrels, 50 lb. Bagdad, in 1878, exported 477 cwt. of black raisins, value 459*l.*, to Europe and India. Trebizonde exported 550 cases (of 1¾ cwt.), value 2200*l.*, in 1877, and 623 cases, 1272*l.*, in 1878, of Persian raisins to Great Britain. In 1877, Syra shipped 689*l.* worth of raisins and figs to Great Britain; and Nauplia, about 220 tons of sultanas. In 1878, Syra exported 33*l.* worth of raisins to Turkey, 1448*l.* (including figs and citrons) to Great Britain, 261*l.* to Austria, 137*l.* to France, 127*l.* to Russia, and 26*l.* to Italy. The values of the exports of raisins from Samos in 1879 were:—To France, 60,000*l.*; Austria and Germany, 15,000*l.*; Holland, 3000*l.*; England, 1500*l.*; Turkey and Egypt, 1200*l.* Our imports in 1879 were:—From Spain, 339,294 cwt., 586,023*l.*; Asiatic Turkey, 220,078, 380,441*l.*; Greece, 8788, 15,314*l.*; other countries, 17,378, 23,850*l.*

Tamarinds (Fr., *Tamarins;* Ger., *Tamarinden*).—Tamarinds are the fruit of *Tamarindus indica*, a tree of 60–80 ft. in height. It appears to be truly native in Tropical Africa, between 12° N. and 18° S. lat., and is found abundantly from the Upper Nile regions to the Zambesi. It occurs in Tropical Australia, throughout India, in Java, Brazil, Ecuador, Mexico, and largely in the W. Indies. Commercially, the fruit is divided into three kinds: E. Indian, W. Indian, and Egyptian. The first consists of the fruits deprived of their outer shell, and pressed into a mass, usually without the addition of sugar. The second class, when shelled, are placed in layers in a cask, and covered with a layer of boiling syrup, the cask being closed when this has cooled. A better sort, rarely found on sale, is prepared by packing the fruit with alternate layers of sugar, in stone jars. The third or Egyptian kind, prepared in Arabia, Darfur, Kordofan, Sennaar, and Abyssinia, is kneaded into discs, 4–8 in. wide, and 1–2 in. thick, dried in the sun. The W. Indian, brown, or red, tamarinds are those usually found in our shops. They are shipped from several of the W. Indies, and from Guayaquil. E. Indian, or black, are used in the manufacture of tobacco, and medicinally (see Drugs) on the Continent. Bombay exported 6286 cwt. in 1871–2. Egyptian are largely consumed in Egypt and Central Africa, and occasionally reach S. Europe. E. Indian tamarinds are worth about 8–15*s.* a cwt.; W. Indian, about 10–20*s.*

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FUR (Fr., *Pelleterie;* Ger., *Pelzwaaren*).

The term "furs" is applied to the hairy coating attached to the skins of many animals, when prepared; before preparation, the skins are called "peltry." On the living animal, the fur proper, which is short, soft, curly, and barbed, is prevented from becoming matted by the interposition of longer, straight, smooth, and stiff hairs, collectively termed the "overhair," and which often lends additional beauty and value to the pelt. Furs may be divided into two classes:—(1) Fancy furs—those used for ornament, and having a high value; (2) Staple furs—those employed industrially for various purposes, and of humbler price. The best furs come from the coldest regions. The fur of water-animals is finest and shortest on the belly, longest on the back: that of land-animals is finest and longest on the back, and fine, long, and flowing on the belly. Though several orders of the *Mammalia* furnish pelts, the *Carnivora* and *Rodentia* are the most important. Many animals afford skins which are marketed with the hair on, but cannot properly be called furs; therefore, this article should be read in connection with those on Hair, Skins, and Wool.

Furs are now largely collected by private trappers, though the Hudson's Bay Co., the Alaska Commercial Co., and a few minor combinations, still maintain an extensive trade. The first object of the collector is to secure the animal without injury to its fur. The next step is to remove the skin from the flesh. This is commonly done by ripping up the belly, and then drawing the skin off; but "cased" skins, or those which are not cut down the belly, fetch much better prices, particularly those of the mink, musk-rat, otter, fox, fisher, opossum, and skunk. A good plan is to puncture the skin where no injury will result, and to insert a quill, by which air can be blown in between the flesh and the skin. When stripped, the pelts are cleaned from adherent fat, and are hung up in a cool place to dry and harden, nothing being applied to them. They are occasionally beaten, to dislodge worms, and, when thoroughly dry, are packed in bales, care being taken that they shall not heat. The only exception to this rule is the fur seal, which is best preserved by salting, and packing in barrels. A little carelessness at this stage may ruin the contents of a whole bale; as the slightest putrefaction suffices to condemn the fur.

The principal centres where furs are collected for sale and transport are:—New York, Boston, Montreal, and St. Louis, in N. America; Victoria (Vancouver's Island), for the region drained by the Hudson's Bay Co.; Nijni Novgorod, for European Russia; Irbit and Kasan, in Siberia; Kiachta, on the Siberio-Chinese frontier; Leipsic, for the interchange of American, European, and Asiatic furs; while London is a great market for almost every kind, and its fur sales, especially those of the Hudson's Bay Co. in January, March, and September, are perhaps the most important of all.

The imported raw peltries of the fancy class are subjected to the following treatment. The skins are first softened by the application of unsalted butter or sweet oil; the pelts are then placed in vats containing fine sawdust of hard wood (e. g. mahogany), kept at blood-heat by means of steam, and are here trampled by foot for about 1 hour; when sufficiently worked, they are drawn over a sharp knife, to remove every particle of flesh; and finally are trampled again in clean sawdust. This operation is termed "leathering"; by it, the pelts become soft and supple like glove-leather. The furrier then receives the skins, assorts them according to colour and overhair, and cuts them up to form the articles required. When the pieces have been stitched together with extreme care and nicety, the article is damped, stretched and secured upon a pine-board according to pattern, and left to dry; on removal, it is trimmed, and softened by rubbing, and is then ready for lining. Great judgment is required to properly economize the materials, and fur piecing is a distinct branch of the trade. Remnants and cuttings are largely imported into Greece, for making rugs and linings, while large quantities go to the hat-makers, for transformation into felt. Much ingenuity is exercised in dyeing and dressing furs, to improve the appearance, and conform with the demands of fashion, as well as to enable inferior specimens, and even the pelts of other species, to fetch an artificial price. The secrets of these processes are, of course, jealously guarded by the trade.

Staple furs receive a very different treatment, the object in their case being first to separate the hair from the skin, and then to convert the former into felt. These operations are described under Hats and Woollen Manufactures, the bulk of the hair being used for making felt hats. Quite recently, F. Fenton, of York, has patented a process for spinning rabbit and hare fur into yarn, suitable for making woven and knitted fabrics.

The trade in fancy furs is subject to great changes and risks, owing to the vagaries of fashion; while that in staple furs is fairly constant. The supply increases rather than decreases, and the variations of fashion preserve the rarer species from extermination. The imports of furs into this country are very large; in 1879, they were:—From Australia, 8,137,997, 94,645*l.*; United States, 2,433,980, 324,787*l.*; France, 794,201, 83,309*l.*; Russia, 601,185, 22,378*l.*; British N. America, 483,638, 93,623*l.*; Holland, 385,929, 47,474*l.*; Belgium, 285,104, 31,618*l.*; Germany, 231,614, 14,626*l.*; Brazil, 201,474, 10,974*l.*; other countries, 438,693, 36,036*l.*; total, 13,993,815, 759,470*l.*

The following notes convey an idea of the sources, estimated animal production, principal characteristics, approximate values, and chief uses, of the furs of commerce:—

Badger.—European and Asiatic (*Meles Taxus*), 50,000; American (*M. labradoria*), 5000. Size, 2 ft. × 3 ft.; European (German are the best) have woolly fur, with overhair coarse, and black with silver spots; American have finer fur, with overhair 3–4 in. long, fine and soft, and coloured purplish-brown at the roots. Values, 2–7*s.* for 1sts, 8*d.*—3*s.* 6*d.* for 2nds and 3rds. Used for covering trunks and horse-trappings in France, and the hairs for superior shaving-brushes and artists' pencils.

Bear.—Europe and Asia, 4000; America, 15,000. Black bear (*Ursus americanus*): large numbers in Minnesota, Alaska, &c. Size, 3 ft. × 6 ft.; overhair, 6–8 in. long, fine and brilliant; fur, thin. At the best when animals just quitting their winter lair; cubs finest; American superior. Values, 64–95*s.* for 1sts, 36–64*s.* for 2nds, 15–34*s.* for 3rds, 3*s.* 6*d.*–12*s.* for 4ths, 22–60*s.* for small and cub 1st and 2nd, and 3–18*s.* for ditto 3rd and 4th. Uses, saddle-cloths, robes, foot-muffs, grenadiers' head-dress, &c. Brown bear (*U. arctos* of Europe, and *U. ferox* and *U. Richardsonii* of America): a few in the wildest Alps, Pyrenees, Carpathians, and mountains of Norway and Lapland, Siberia, and the Altai, with varieties in the Himálayas, Thibet, Persia, Afghanistan, Caucasus, and Armenia; and in the Hudson's Bay territory. Size, 3 ft. × 6 ft.; overhair, very fine. Values, 17–68*s.* for 1sts and 2nds (a few very prime, 15*l.*), 3–14*s.* for 3rds and 4ths. Uses, muffs, &c. Grizzly bear (*U. horribilis*): in the Rocky Mountains. Size, 4 ft. × 8 ft. and upwards; overhair, coarse; fur, thick and heavy. Value, 1–2*l.* Use, robes. White bear (*U. maritimus*): in the Arctic regions of both hemispheres. Size, larger than the others; overhair, short and stiff; fur, thick. Values, 10–20*l.* for best pure white, 20–70*s.* for 1st and 2nd grey, and 3–12*s.* for 3rd and cub grey. Uses, robes.

Beaver (*Castor fiber*).—Asia, 20,000; America, 200,000. The best come from Labrador and Moon Fort. Size, 2 ft. × 3 ft.; overhair, 3 in. long, coarse, brown; fur, fine, thick, dark-grey. Usually come as "parchment," i. e. cut open, stretched to a hoop, and dried; when made up by the Indians, are called "beaver coats," and bring good prices. Values: in America, 4–12*s.* a lb. for "raw parchment"; London, 24–42*s.* each for 1st large, 19–32*s.* for 2nds, 12–17*s.* for 3rds, 9–17*s.* for 1st and 2nd small, 4*s.* 6*d.*–9*s.* 6*d.* for 3rd small and cub. Uses, very varied; much prized in Russia and China; no longer appreciably employed in hat-making.

Cat.—Domestic, 1,000,000; wild, 10,000. In wild cats, the overhair and fur are thin and coarse; colour, grey. Domestic are superior, and of various colours; the best come from Holland, where they are fed on fish, and bred for their skins; the worst are Russian. Great numbers are collected in Holstein, Bavaria, Switzerland, &c. Civet cats (*Viverra sp. div.*) furnish a few skins of no great note. The Formosan wild cat (*Felis viverrina*) furnishes a pretty, soft fur, much in demand in China at 4*s.* 6*d.* each. Shanghae, in 1878, shipped 1380 cat-skins to foreign countries, and 8400 to Chinese ports. Values, 4–8*s.* for best black, 2–5*s.* for common 1st, 10*d.*–1*s.* 9*d.* for 2nds and 3rds. Uses, very general for lining, trimming, &c.

Chinchilla (*Chinchilla lanigera*).—Peru and Chili, 100,000. Two kinds, real and bastard. Real: size, 8 in. × 12 in.; overhair and fur, 1½ in. long, very fine: colour, silver-grey and dark-grey; best from Peru. Values, 160*s.* a doz. for large, 100*s.* for middling, 16*s.* for small, 46–86*s.* for dry damaged. Uses, muffs, tippets, linings, trimmings, &c. Bastard: smaller; short, weak fur; come from Chili. Value, 13*s.* 9*d.*–16*s.* 3*d.* a doz. In 1879, the Chilian province of Caldera shipped 601 doz. to England, and 30 doz. to the United States; but the trade is dying out, owing to the increasing scarcity of the animals. The province of Coquimbo exports considerable numbers to Great Britain, France, and the United States, the local value ranging from 5*s.* to 9*s.* a doz.

Ermine or Stoat (*Mustela erminea*).—Asia and Europe, 400,000. Common in most countries, but it is only in Russia, Sweden, Norway, and Siberia that the coat becomes pure white in winter. Size, 4 in. × 10 in.; overhair and fur, fine, soft and close; colour, pure white, with black-tipped tail; skin, thin and tough. Best come from Barabinsk and Ischim, in Siberia. Value, 6*d.*–6*s.* Uses, muffs, cloaks, and linings.

Fisher, Pekan, or Wood-shock (*M. americana* [*canadensis*]).—America, 12,000. Size, 15 in. × 30 in.; overhair, 2 in. long, very fine, glossy, dark, and durable; fur, close; tail, 12 in. long, bushy and dark, much valued in Russia. Best from Canada. Values, 40–80*s.* for 1st, 30–40*s.* for 2nds and pale, 22–32*s.* for 3rds. Used for ornament.

Fitch or Polecat (*Putorius fœtidus*).—Europe, 600,000. Size, 5 in. × 15 in. to 8 in. × 20 in.; overhair, 1½ in. long, fine, with dark points; fur, golden-yellow. Peculiarly odorous. Best from Germany, Denmark, and Holland; smallest from Russia. Value, 2–6*s.* Uses, ladies' muffs, &c.; the long overhairs are employed in artists' pencils.

Fox.—Silver or Black fox (*Vulpes argentatus*): America and Asia, 2000. Size, 2 ft. × 4 ft.; overhair, 3 in. long, thick and fine: colour, pale-silver to brilliant blue-black; fur, fine and curly; tail, very handsome; considered one of the finest fancy furs; choicest are from Labrador and Moon Fort; Russian are woolly and inferior. Values, 200–800*s.* for 1sts, 120–280*s.* for 2nds, 35–130*s.* for 3rds. Used for robes, muffs, &c. Cross fox (*V. fulvus* var. *decussatus*): Asia and America, 10,000. Size, somewhat less than the silver fox; overhair, fine, but shaded with red at the points, and forming a distinct cross on the shoulders. Best from Hudson's Bay territory. Values, 35–140*s.* for 1sts, 20–50*s.* for 2nds, 9–34*s.* for 3rds. Blue or Sooty fox (*V. fuligonus*): Europe and America, 7000. Size, same as the cross fox; overhair, grey-blue; fur, woolly. The finest are from Archangel, Greenland, and Iceland; very few come from America. Values, 50–80*s.* for 1sts, 35–55*s.* for 2nds, 15–30*s.* for 3rds. White or Arctic fox (*V. lagopus*): Arctic regions, 75,000. Size, same as the cross; overhair and fur, pure white. The best are from Labrador, the worst from Siberia. Values, 12–18*s.* for 1sts, 7–15*s.* for 2nds, 3–10*s.* for 3rds. Grey fox (*V. virginianus*): United States, 30,000. Overhair, grey, sprinkled with silver on the back; sides, yellow; tail, ashen-grey; fur, coarse. Values, 4–8*s.* for 1sts, 2*s.* 6*d.*–3*s.* 9*d.* for 2nds, 1–2*s.* for 3rds. Kitt fox (*V. volez* [*cinereo-argentatus*]): America, 40,000. Found in N.-W. America, and in Tartary. Smallest of the foxes. Overhair, fine; back, pure grey; sides, yellow; belly, white; fur, coarse. Values, 2*s.* 6*d.*–3*s.* for 1sts, 1–2*s.* for 2nds and 3rds. Red or common fox (*V. fulvus* and *V. vulgaris*): Europe and Asia, 300,000; America, 60,000. Abundant in all northern countries, but the American fur is much superior to the European; the best are from Labrador. Large numbers, the produce of the Caucasus, are sold at Tiflis. Shanghae exported 2106 fox-skins in 1878. Values, 9–20*s.* for 1sts, 8–15*s.* for 2nds, 3*s.* 6*d.*–10*s.* 6*d.* for 3rds.

Hamster (*Cricetus vulgare* [*Mus cricetus*]).—Europe, 200,000. Size, 3 in. × 5 in.; hair, short and close; back, grey; sides, yellow; sometimes nearly black. Abundant in Germany. Value, nominal. Use, for linings.

Hare (*Lepus sp. div.*)—Europe and Asia, 4,500,000. Size, various; overhair, fine; fur, fine, abundant, strong and very long; colour, grey and white; skin, weak. Best from Arctic Russia. Shanghae exported 29,175 (including rabbit) in 1878. Value, 5*d.*-1*s.* Used largely for linings, cloaks, &c., and about the best hair for hat-makers' purposes.

Kolinski or Tartar Sable (*Mustela siberica*).—Siberia and Tartary, 80,000. Size, 5 in. × 15 in. to 8 in. × 20 in.; overhair, 1½ in. long; golden-red colour. Value, 2–4*s.* Uses, dyed to imitate dearer sables, and tails for artists' brushes.

Lion (*Leo africanus, L. asiaticus*, &c.).—Found throughout the greater part of Africa, and in some parts of Asia. Total, about 500. Best from Asia. Value varies much. Use, ornamental.

Lynx.—Europe and America, 50,000. Size, 2 ft. × 3½ ft.; overhair, 3–4 in. long, fine and flowing, clear silver-blue, sprinkled with black. In Europe, *Felis Lynx* (*Lyncus virgatus*), and *L. pardinus* further south, cheap and abundant at Tiflis. Fur, dark-grey, tinged with red, and having dark spots and patches. The winter robe is variously employed. The American Bay Lynx or Wild Cat (*Lyncus rufus* [*Felis canadensis*]) has shorter fur, and longer ear tips; and the fur of a variety (*L. maculatus*) is spotted with brown. The pelts of Bay Lynxes from the Columbia River go mostly direct to China. The fur is light but warm; grey or rusty-brown, spotted with dark and rufous. When dyed, it is much used by the Chinese, Greeks, Persians, &c., for cloak linings, robes, and muffs. Best from Sweden and Labrador. Values, 11–21*s.* for 1st large, 9–12*s.* for 2nd and middling, 6–9*s.* for 3rd and small.

Marten.—American or Pine Marten or Common Sable (*Mustela leucopus*): America, 130,000. Size, 5 in. × 15 in. to 8 in. × 20 in.; overhair, 1–2 in. long, fine and flowing; fur, close and thick; colour, dark coffee-brown to pale-yellow. Finest from Great Whale River and Labrador. Values, 30–110*s.* for dark selected, 15–30*s.* for 1sts, 10–30*s.* for small, 7–18*s.* for pale and seconds, 3–13*s.* for small pale and 3rds. Use, for ornament; tips of tail valued for artists' brushes. Beech or Stone Marten, or French Sable (*Mustela saxorum* [*Martes albogularis*]): Europe, 150,000. Overhair, coarse; fur, woolly; colour, dull-grey. Throughout Europe; best from Hungary and Turkey; common at Tiflis. Cleverly dyed by the French to imitate real sable. Value, 8–12*s.* for best prime. Baum or Wood Marten (*Mustela abietum*): Europe and Asia, 60,000. Overhair, fine; fur, woolly; colour, brownish; tail, long and bushy. Value, 20–40*s.* True Marten or Russian Sable (*Martes zibellina*): Russian Empire, 100,000. Size, 5 in. × 15 in. to 8 in. × 20 in.; overhair, very fine and flowing, of rich bluish tint, and 1½–2½ in. long; pelt, very soft, tough and durable. Best from Yakutsk (Siberia), next from the Lena, worst from the Lower Amoor; while very choice specimens, of browner hue, are obtained from Kamschatka. Values, from 600*s.* for darkest from Okotsk, to 4–8*s.* for poor Saghalien. Uses, ornamental trimmings.

Mink (*Putorius vison* [*Vison lutreola*] *P. ingrescens, P. Cicognanii*, and *P. Richardsonii*): America, 250,000; Russia, 50,000. American mink: size, about 6 in. × 18 in.; overhair, shorter and more rigid than that of the pine marten, but having almost the same degree of bluish lustre. Most abundant in Middle and N.-W. States; best from Nova Scotia, Maine, and Labrador. Value, 12–40*s.*

for 1sts, 5–10*s.* for 2nds and small, 1–5*s.* for 3rds. The Russian mink is smaller, and in all respects inferior. Value, 2–6*s.* for 1sts. Uses, ladies' victorines, capes, &c.

Monkey.—Africa, 40,000. The fur of the White-thighed Colobus, from Gaboon (W. Africa), is almost the only kind utilized. The hair is long, thin, and flowing, chiefly black and dun-grey. Value, 2–6*s.* Used for ladies' muffs.

Musk-Rat or Musquash (*Fiber zibethicus*).—America, 3,000,000; Russia, 100,000. Size, 8 in. × 12 in.; overhair, coarse and light-brown; fur, fine, thick, and silky. The American animal is very prolific in cultivated places; the best skins come from New England and New York, and a highly prized black variety from Delaware and Maryland. The European is most numerous about the Volga, and the adjacent lakes, from Novgorod to Saratov. Values (subject to great fluctuations), 1*s.* 6*d.*–2*s.* for black 1sts, 1*s.* 3*d.*–1*s.* 9*d.* for ditto 2nds, 4–10*d.* for ditto 3rds and kitts; 7*d.*–1*s.* 4*d.* for ordinary 1sts, 5–10*d.* for 2nds, 2–5*d.* for 3rds and kitts. Used for cloaks, &c.; dyed and plucked, it closely resembles fur seal.

Nutria (*Myopotamus coypus*).—S. America, 3,000,000. Overhair, coarse, rigid, and ruddy; fur, soft, fine, and of a brownish-ash colour; pelt, frequently unsound. Shipped from Buenos Ayres. Value, dried skins, 1–2*s.* a lb. Used chiefly for hat-making.

Opossum.—America, 250,000; Australia, a lesser number. Those found in the S. States of America have long, coarse, and whitish-grey overhair, and woolly fur. The best come from Ohio. Values, 1*s.* 9*d.*–3*s.* for 1sts, 10–18*d.* for 2nds, 1–5*d.* for 3rds. The Australian black opossum gives a handsome fur, and its felting qualities should make it valuable to hatters.

Otter.—All northern countries, 40,000. The European otter (*Lutra vulgaris*) is much smaller than the American (*L. canadensis*), which attains to 2 ft. × 5 ft. Overhair, thick and close; colour, brown-black. The best are from Labrador and Canada. Large numbers are brought to Tiflis from the Caucasus. Values, 37–56*s.* for 1sts, 29–48*s.* for 2nds and small, 12–30*s.* for 3rds, small and cub. Uses, general. Largely employed by Russians, Chinese, and Greeks.

Otter, Sea (*Enhydra marina*).—N. Pacific, 5000. Occurs on the coasts of Alaska, Kamschatka, and Japan, and was formerly abundant as far south as California, till exterminated by hunters. Size, 6 ft. × 2–4 ft.; overhair, exceedingly fine, and but little longer than the fur; fur, very thick, close, fine, and silky; colour, dark-brown, sometimes with silver points interspersed on the belly and throat; pelt, pliable and firm. Value, from 1*l.* or so up to 30–100*l.* Prime specimens are the most highly prized of all furs. The tails are sold separately. The Russians and Chinese are great admirers of this fur. Used for ornamenting habiliments.

Rabbit (*Lepus cuniculus*).—Europe, 5,000,000; Australia and New Zealand are developing a great trade in rabbit fur, the animals having become a most serious nuisance. The best skins are English, the purest are Polish. The Australian fur is of two kinds: the ordinary wild variety, worth 2*s.* 4*d.*–2*s.* 6*d.* a doz. here; and a silver-grey description, of which about 200,000 are annually shipped to London, and bring 4*s.*–5*s.* 6*d.* a doz. The furs are valueless if taken in summer. Size, 10 in. × 16 in.; fur, thick and fine; pelt, weak; colour, all shades between black and white. The best are used by furriers, and it is said that the Belgians have devised a method of making them resemble the fur seal. The ordinary are deprived of their hair by a machine, consisting of four revolving cutters, working against a fixed knife. The fur, or "coney wool," is used in making felt hats (see Hats), and valued at 7*s.* a lb.; the coarse hair, for stuffing purposes; the pelt, for size- and glue-making; the refuse, for manure. The fur, when removed, is packed in boxes containing 5 lb., and is in great demand in England, France, Germany, and America.

Raccoon (*Procyon lotor*).—America, 500,000. Size, 1 ft. × 2 ft.; overhair, 3 in. long, coarse, bright-coloured, thick and flowing; fur, resembles that of beaver, coloured silver-blue to grey-brown and coffee-brown. Some specimens approach the fisher, others the silver fox, in beauty of shade, each bringing 1–4*l.* The animal is peculiar to the United States, flourishing most in cultivated regions. Best furs from Michigan, next best from Ohio. Values, 7–40*s.* for selected dark, 2*s.* 6*d.*–7*s.* for 1sts, 1*s.* 6*d.*–4*s.* for 2nds, 1–2*s.* for 3rds, 2*d.*–1*s.* for 4ths. Used for lining travelling coats, especially in Russia and Germany; the inferior qualities are employed for felt hat making.

Seal, Fur.—Pacific, 200,000. Several members of the *Otariadæ* afford a valuable fur; they are chiefly *Otaria* [*Callorrhinus*] *ursina*, *O. Gillespii*, and *O.* [*Eumitopius*] *Stelleri*, in the N. Pacific; *O. jubata* and *O. falklandica*, in the S. Pacific, around Cape Horn, and in the S. Atlantic as far north as the Rio de la Plata; *O. pusilla* [*antarctica*], at the Cape of Good Hope and on the adjacent islands; *O. Hookeri* and *O. lobata*, in Australia and New Zealand; *O. gazella* in Kerguelen's Land. The pursuit of the animals has been carried to such a degree in most places as to cause their extermination, and supplies are now mainly afforded by the Prybilov Islands, especially St. Paul's and St. George's, in Alaska, though incomparably the finest furs come from the South Shetland and South Georgian Islands, in the Antarctic Ocean. The capture of the animals in Alaska is monopolized by the Alaska Commercial Co., and is limited to 100,000 annually. They will probably soon become extinct everywhere else. Sizes: wigs, 4 ft. × 8 ft.; large, 3 ft. × 6 ft.;

middling, 2½ ft. × 5 ft.; small, 2 ft. × 4 ft.; pups, 2–4 ft. long. Overhair, coarse and rigid; fur, fine, thick, silky, and very uniform; pelt, thin, pliable, and light. Values, salted, of the Antarctic, 2–10*l.*; N. Pacific, wigs, 85–90*s.*; middlings, 85–120*s.*; small, 70–105*s.*; large pups, 65–95*s.*; middling do., 60–85*s.*; small do., 50–70*s.*; extra small do., 50–60*s.*; grey do., 16*s.*; black do., 14–16*s.* Used principally for ladies' jackets. A cloth imitation is made from mohair (see Hair Manufactures).

Skunk, or American Polecat (*Mephitis americana*).—America, 350,000. Size, 10 in. × 16 in.; overhair, 3 in. long, fine, dark-blue to coffee-brown, thick, flowing and glossy. Many have two white stripes from head to tail. Best are from New York and Ohio. Values, 4–10*s.* for 1sts, 4–7*s.* for 2nds and striped; 3*d.*–3*s.* for 3rds and white. When the coarse white hairs have been removed, the fur is much used on ladies' apparel.

Squirrel.—Siberia, 6,000,000. Size, 3 in. × 6 in.; overhair and fur, fine; colour, pale-blue to clear dark-blue; bellies, white; tails, long and bushy; pelt, pliable and tough; fur, fine, close and durable. Best are from E. Siberia; those from European Russia are much poorer and paler, while the American are worthless as fur. In universal demand for cuffs, tippets, and linings; the tails are used for boas and brushes. Weissenfels, in Saxony, is a great centre for the dressing of squirrel skins.

Tiger (*Felis Tigris*).—Bengal and N. China, 500. Size varies up to 10–14 ft. long. The Bengal have short hair, but are well marked; the Chinese have hair 2–3 in. long. Value of the latter, 10–20*l.* Used for rugs.

Wolf (*Canis occidentalis*, &c.)—Europe and America, 25,000. Size, from 4–6 ft. long downwards; overhair, long, flowing and coarse, chiefly greyish-brown. The largest are from Labrador; the finest furs are from Fort Churchill; the prairie wolf is inferior in every respect. Numbers are taken to Tiflis from the Caucasus. Values, 30–65*s.* for white and dark 1sts, 10–30*s.* for do. 2nds and 3rds, 14–18*s.* for grey 1st large, 5–7*s.* for do. middling and 2nd, 1*s.* 6*d.*–4*s.* 6*d.* for do. small and 3rd.

Wolverine, or Glutton (*Gulo luscus*).—Russia, Norway, and Hudson's Bay, 3500. Size 1½ ft. × 2½ ft.; overhair, coarse, 2–4 in. long; colour, dark-brown, passing almost into black; fur, soft and long. Values, 15–25*s.* for 1sts, 5–15*s.* for 2nds and 3rds. Used for muffs and sleigh robes.

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GAS [COAL] (Fr., *Gaz à la Houille*; Ger., *Steinkohlengas*).

In the present article, it is proposed to give a brief resumé of the chemistry and general physics of the manufacture and purification of coal-gas, avoiding, as far as possible, descriptive details of the mechanical appliances by which such manufacture and purification are practically carried out, accounts of the various appliances used at a gas-works, belong more properly to the domain of engineering, and the reader desirous of acquainting himself with that branch of the subject is referred to Spons' 'Dictionary of Engineering' and its 'Supplement,' in which all the desired information will be found.

The production of illuminating-gas from coal may be considered as a rearrangement of the elementary constituents of the coal, under the influence of heat, this rearrangement being so conducted as to afford the particular products which are most valuable to the gas-maker. Apart from the composition of the original coal, there are many conditions which affect the quality and general character of the gas produced, chief among which may be mentioned the following, viz.:—(1) whether the coal has been carefully stored, or exposed to a long continuation of atmospheric changes; (2) whether the coal at the time of distillation is wet or dry; (3) the temperature at which the distillation is carried out; and (4), the general perfection of manufacturing details and subsequent purification. Briefly stated, the conditions most favourable to success may be thus enumerated:—The coal should be of good quality, rich in hydrogen, and with a low proportion of sulphur and ash; it should be used for gas manufacture as soon as possible after its removal from the pit, or be carefully stored under cover until required; at the time of its distillation, it should be as dry as possible, and the temperature used should be a full cherry-red heat, approaching to whiteness; the gas should be removed from contact with the heated retort as soon after its generation from the coal as can be conveniently effected; and lastly, the purification of the gas should be efficiently carried out, more especially with regard to the removal of carbonic acid, sulphuretted hydrogen, and ammonia. In discussing the general character of the physical and chemical changes which take place from the manufacture of the gas to its final storage, the subject naturally divides itself into three heads, viz.:—(1) The changes which occur during the distillation of the coal; (2) the character of the crude gas; and (3) the subsequent purification of the crude material. The discussion of the subject under the three divisions named will now be proceeded with.

Distillation of the Coal.—The coal used for the manufacture of gas contains as its elementary constituents, carbon, oxygen, hydrogen, sulphur, and nitrogen, together with a small but varying quantity of mineral matter. When large masses of such coal are subjected to destructive distillation in heated retorts, a variety of hydrocarbons are formed, some solid, some liquid, and some gaseous; while, at the completion of the distillation, a large percentage of the original carbon is left in the retorts in the form of coke, which, in addition to carbon, contains the whole of the mineral constituents of the coal, and a portion of the sulphur. The character of the hydrocarbons produced depends principally upon the temperature to which the coal is exposed. At a low red heat, liquid and solid hydrocarbons are produced in large quantity, with comparatively little gas, which, however, is of high illuminating value. At a stronger heat, the amount of permanent gases formed increases, and the quantity of liquid products decreases in proportion; while, at a full cherry-red heat, the liquid products are small in quantity and the yield of permanent gases is very large. The chemical changes which occur during the distillation are somewhat complex, especially when an elevated temperature is employed. The oxygen of the coal unites with a portion of the hydrogen to form water (H_2O), which is evolved in the form of vapour; part of this water-vapour passes away unchanged, and part is decomposed by contact with carbon, carbon dioxide (CO_2), carbon monoxide (CO), and free hydrogen being formed. The greater part of the hydrogen of the original coal which has not entered into combination with oxygen, passes off, partly in union with carbon, as various solid, liquid, and gaseous hydrocarbons, and partly in the free state. The nitrogen is evolved, chiefly in union with hydrogen, as ammonia (NH_3), and combined with carbon as cyanogen (CN), while the sulphur passes off mainly as sulphuretted hydrogen (H_2S), a minor quantity forming carbon disulphide (CS_2), and other compounds, whose exact nature and composition is not known.

With regard to the hydrocarbons produced from the destructive distillation of large masses of coal in closed retorts, there is little doubt that a large percentage of the compounds first generated are in great measure decomposed before the products leave the retort. It is well known that the higher the temperature to which organic substances are exposed, the simpler are the products of decomposition which are formed; while at comparatively low temperatures, compounds of a more complex nature are produced. Thus, when a mass of coal is placed in a heated retort, the material is some time in acquiring the same temperature as that to which it is exposed. The exterior of the mass comes first under the influence of the heat, and the produced gas, if quickly removed from contact with the heated surfaces, is of high illuminating value, and rich in olefiant gas (C_2H_4), and other hydrocarbons containing a high percentage of carbon. After some time, the exterior of the mass of coal becomes thoroughly charred, its temperature equals that of the retort, and it is completely decomposed; the interior of the mass is, however, at this stage, still at a comparatively low temperature, and, as the heat travels further and further inwards, the hydrocarbons which are first produced, having to pass through the surrounding casing of heated carbon, become more or less decomposed in transit, a deposition of carbon taking place, and compounds containing a larger proportion of hydrogen and less of carbon being produced. At this stage of the distillation, the gaseous products contain much marsh-gas (CH_4). As the whole bulk of the coal becomes more and more heated, the hydrocarbons generated in the interior of the mass have to traverse a gradually increasing layer of spent carbonaceous material at a high temperature, and their decomposition becomes more and more complete, until at the close of the distillation, the evolved gas is nearly pure hydrogen. It will, therefore, be clearly understood why the richest gas, that is to say the gas which contains the greatest proportion of carbon, and possesses the highest illuminating value, is produced during the first period of the distillation; also why the gas becomes poorer and poorer in light-giving constituents as the distillation progresses, until towards the completion of the process, the gaseous products are altogether destitute of illuminating power. It follows also that the method at present in use for the production of illuminating-gas is, from a scientific point of view, unsatisfactory in the extreme, as a large proportion of those constituents which possess the greatest illuminating value are decomposed during the carbonization of the coal. Better results would no doubt be obtained by the use of large flat-bottomed retorts, in which the coal could be rapidly carbonized in thin layers; but there are practical objections to the use of such vessels. The perfection of carbonization would be attained by the use of a mechanical process, by which the coal in a moderately fine state of division could be introduced into a heated retort, and then be rapidly carbonized, the spent material being discharged at the opposite extremity. Such a process was patented some years since by Porter and Lane, and the gas produced was superior in illuminating qualities to that made by the ordinary method; but the scheme was not commercially successful, owing, it is said, to two causes:—Firstly, the working parts could not be maintained intact for any length of time at the high temperature which it was necessary to employ; and, secondly, the coke produced was more or less broken and friable, and consequently of less commercial value than that made in the ordinary way.

Having explained the actions which occur during the destructive distillation of the coal, the next part of the subject to be dealt with is the character and subsequent treatment of the crude gas.

Character of the Crude Gas.—At the moment of leaving the retort the crude gas contains a mixture of true gases with water vapour, and various solid and liquid hydrocarbons. The following list gives the names and formulæ of the principal compounds which are present:—

Gases.			Liquids.				Solids.			
	Name.	Formula.		Name.	Formula.	Boiling-point.		Name.	Formula.	Boiling-point.
						C.				C.
	Hydrogen ..	H		Water	H_2O	100°	Hydrocarbons.	Naphthalene	$C_{10}H_8$	216°
Hydrocarbons.	Marsh gas ..	CH_4	Hydrocarbons.	Benzol ..	C_6H_6	81°	Hydrocarbons.	Anthracene	$C_{14}H_{10}$	360°
Hydrocarbons.	Olefiant gas	C_2H_4	Hydrocarbons.	Toluol ..	C_7H_8	111°	Hydrocarbons.	Chrysene ..	$C_{18}H_{12}$	—
Hydrocarbons.	Acetylene ..	C_2H_2	Hydrocarbons.	Xylol	C_8H_{10}	140°				
Hydrocarbons.	Propylene ..	C_3H_6	Hydrocarbons.	Isocumol ..	C_9H_{12}	170°				
Hydrocarbons.	Butylene ..	C_4H_8	Hydrocarbons.	Amylene ..	C_5H_{10}	35°				
	Carbonic oxide ..	CO		Aniline ..	C_6H_7N	182°		Carbolic acid or phenol	C_6H_6O	184°
	Carbonic acid	CO_2		Carbon disulphide ..	CS_2	46°		Cresylic acid, or cresol .	C_7H_8O	199°
	Sulphuretted hydrogen.	H_2S								
	Ammonia ..	NH_3								
	Cyanogen ..	CN								

Of these constituents, the greater part of the solid and liquid hydrocarbons naturally separate from the gas as its temperature decreases; but some of the more volatile bodies are partly or wholly retained by the gas, and become an integral portion of the purified product. Of these, amylene and carbon disulphide are probably wholly retained by reason of their low boiling-points, while water, benzol, toluol, and naphthalene are in part retained in the form of vapour. The heavier hydrocarbons are deposited in the hydraulic main, while those of lower boiling-point are separated by the action of the condenser. Of the gases proper, ammonia, carbonic acid, and sulphuretted hydrogen are considered as impurities, which have to be removed during the process of purification; while the carbon disulphide has also, as a rule, to be partially eliminated from the gas supplied to London and the metropolis before it is considered sufficiently pure for consumption. The purification of gas from the impurities mentioned may be said to commence at the condensers, and it is to the changes which there occur, together with those suffered by the gas during its subsequent treatment, that attention will now be directed.

Gas Purification.—*Effects of Condensation.*—The term "condensation" as applied to gas manufacture signifies the reduction of the temperature of the gas to about that of the surrounding atmosphere, in order to eliminate condensable substances, and to ensure the eventual product being of a permanent nature before it leaves the works. The gas enters the condensers at a temperature of about 38°–49° (100°–120° F.), and leaves them at a temperature of 10°–21·5° (50°–70° F.). During the cooling process the gas deposits a large amount of tarry matter, containing various hydrocarbons, benzol, toluol, &c.; a large amount of aqueous vapour is at the same time condensed, carrying with it ammonia, carbonic acid, and sulphuretted hydrogen, in combination as ammonium carbonate and sulphydrate. Part of the cyanogen present also combines with ammonia, to form ammonium cyanide, which, by the reaction of sulphuretted hydrogen, becomes ammonium sulphocyanide. Small quantities of ammonium sulphide and sulphocyanide are also no doubt formed at the same time from the mutual reaction of ammonia and carbon disulphide. The present system of condensation is by no means perfect, for the separation of tar by a simple cooling process involves the separation from the gas of light hydrocarbons, which, if retained, would add materially to the illuminating power. The condenser tar contains as much as 7 per cent. of light naphtha, which is separated from the gas, not by the cooling process alone, but by reason of the absorbent power which is possessed by the heavy hydrocarbons over the light ones, and by which the latter are precipitated. Although the light naphthas of coal-tar have a boiling-point not far removed from that of water, ordinary gas can permanently retain a considerable quantity of such hydrocarbons in the form of vapour at ordinary temperatures. It has been proposed to restore to the gas the light hydrocarbons which have been abstracted from it by the action of the condensers, by bringing the gas leaving the condensers into contact with the tar heated to a sufficient temperature. A patent for effecting this by means of suitable apparatus has been taken out by H. Aitken (No. 2587, 24 July, 1874), and the result stated to be obtained by the use of his process is a gain of at least three candles in illuminating power. The value of the process must not, however, be estimated simply by the gain to the gas, but by the net difference between gain to gas and loss to tar, the tar being deprived of its benzol and toluol, and being therefore of less commercial value. The best process for the removal of the heavier hydrocarbons without affecting the lighter ones would be to pass the crude gas into a large vessel, where, owing to the greater area, the velocity of the gas would be so reduced that the particles of heavy tar would be naturally deposited by gravitation, the separation being completed by passing the gas through some straining medium, such as wire gauze. By such a process, tar could be separated from gas without reducing the temperature sufficiently low to cause the precipitation of light hydrocarbons.

Turning to the effect of condensation upon the substances in gas which are considered as impurities, reference may be made to a paper recently read at the Institute of Civil Engineers, by Harry Jones, C.E., Engineer to the Commercial Gas Co., and in which are given figures showing the amounts of the impurities present in the gas at different stages, from analyses made by the company's chemist. Gas made from ordinary Newcastle gas coal was found, on entering the condensers, to contain as a mean of several experiments the following amounts of impurities:—

	Ammonia (NH_3).	Sulphuretted Hydrogen (H_2S).	Carbonic Acid (CO_2).	Sulphur in other forms than H_2S.
Gr. per 100 cub. ft.	370	1000	1105	39

At the outlet of the condensers, the amounts of the respective impurities were as follows:—

	NH_3.	H_2S.	CO_2.	Sulphur in other forms than H_2S.
Gr. per 100 cub. ft.	285	674	1034	39

From these figures it will be seen that a considerable reduction takes place in the amount of all impurities, except sulphur in other forms than as sulphuretted hydrogen, upon which no action is exerted. The partially purified gas then passes to the scrubbers and washers, by the action of which the impurities become still further reduced.

Effect of Scrubbing and Washing.—The portion of the purifying plant which comprises the various forms of scrubbers and washers has for its primary object the elimination of ammonia from the gas, in such a way that a solution of ammonia is formed, of sufficient strength to be of commercial value. The effect of this portion of the plant is, however, not limited to the simple removal of ammonia, but also comprises a considerable reduction in the amounts of sulphuretted hydrogen and carbonic acid. The apparatus used simply consists of various mechanical contrivances, by which the gas is brought at a reduced velocity into intimate contact with water, or with wetted surfaces. The effect of this treatment will be best comprehended by giving the amounts of the various impurities in the gas at its entrance to the apparatus and at its exit:—

	NH_3.	H_2S.	CO_2.	Sulphur.
Gr. per 100 cub. ft., inlet	285	674	1034	39
„ „ outlet	nil	625	645	39

It will be seen that the ammonia has entirely disappeared, while the proportions of sulphuretted hydrogen and carbonic acid have been considerably reduced, the greatest reduction having taken place in the amount of the last-named compound. The reduction of the two impurities (H_2S and CO_2) during the passage of the gas through the scrubbers and washers is due to the same cause that effects a diminution in the amounts of these impurities in the condenser, viz. combination with ammonia. The solutions of ammonia produced in the condenser, the washers, and the scrubbers, constitute, when mixed, the "ammoniacal liquor" of commerce; its strength, that is, the quantity of ammonia which it contains, varies with the character of the coal, and the amount of water used in the scrubbers. From ordinary Newcastle gas-coal, the yield of a ton may be taken as about 28 gal. of "7-oz. liquor," i. e. liquor containing a sufficient amount of ammonia for 1 gal. to neutralize 7 oz. of sulphuric acid (sp. gr. 1·85).

The following Table shows the composition of ammoniacal liquors of different strengths:—

Where from.	"Ounce" strength.	Total ammonia.	Ammonia shown by acid.	Fixed ammonia.	Carbonic acid.	Sulphuretted hydrogen.
		Percentage.	Percentage.	Percentage.	Percentage.	Percentage.
Average of 20 commercial samples	7·0	1·74	1·510	0·23	1·28	0·60
Extra strong sample from washer	21·5	4·73	4·674	0·054	5·18	1·84
Ditto ditto	13·75	3·04	2·989	0·054	3·75	1·07
No. 1 scrubber (nearest crude gas)	5·75	1·28	1·248	0·032	1·34	0·44
No. 2 scrubber	1·56	0·34	0·330	0·010	0·37	0·18
No. 3 do.	0·18	0·06	0·047	0·013	0·06	0·03

The "fixed ammonia" shown in the last Table is that part of the total ammonia which does not exist in the form of volatile compounds, such as the sulphydrate and carbonate, and which is consequently not shown by an ordinary estimation by standard acid. The "fixed ammonia" consists principally of hyposulphate and sulphocyanate, with a little sulphate. The sulphocyanide is chiefly derived from the mutual reaction of cyanogen, ammonia, and sulphuretted hydrogen. The hyposulphate and sulphate are most probably formed from the oxidation of ammonium sulphydrate by the oxygen dissolved in the water supplied to the scrubbers, and by the small quantity of air as an accidental impurity present in the gas. An abnormal amount of hyposulphate and sulphate is sometimes produced on first starting a scrubber containing fresh coke, probably owing to the oxygen condensed in the pores of the material. A similar production would occur if any crack or orifice existed in the retorts, through which, by the action of the exhauster, furnace-gases charged with sulphurous acid were drawn in.

The gas, as it leaves the scrubbers, should be practically free from ammonia. Sometimes, however, difficulty is experienced in attaining the desired result, coincident with the employment of such a limited amount of water as to produce ammoniacal liquor of saleable strength. In such cases, supplementary means for removing the small amount of residual ammonia are sometimes adopted, chief among which may be mentioned the use of the material known as "carbon" or "acid carbon," the employment of sawdust moistened with weak sulphuric acid, and the use of crude sulphate of iron (copperas). The material known as "carbon" is sawdust which has been mixed with strong sulphuric acid, and subsequently subjected to heat, by which more or less complete carbonization has been effected. The action of this material as a purifying agent for the removal of ammonia is the same as that which takes place when sawdust moistened with weak sulphuric acid is used, and consists in the simple union of the sulphuric acid and ammonia to form ammonium sulphate, thus—$H_2SO_4 + 2NH_3 = (NH_4)_2SO_4$. In the case of copperas, the action is as follows:—

$$\underset{\text{Sulphate of iron.}}{FeSO_4} + \underset{\text{Ammonia.}}{2NH_3} + \underset{\text{Water.}}{H_2O} = \underset{\text{Ammonium sulphate.}}{(NH_4)_2SO_4} + \underset{\text{Ferrous oxide.}}{FeO.}$$

The sulphate of iron and the ammonia thus form sulphate of ammonia and protoxide of iron (ferrous oxide). The ferrous oxide then reacts on the sulphuretted hydrogen, sulphide of iron (ferrous sulphide) and water being produced, thus—$FeO + H_2S = FeS + H_2O$.

It remains to describe the changes which occur during the subsequent purification of the gas from the residual sulphuretted hydrogen and carbonic acid, as well as from carbon disulphide.

The gas, as it leaves the scrubbers, supposing those vessels to be thoroughly efficient, may be taken as containing the following average amounts of impurities:—

	NH_3.	H_2S.	CO_2.	Sulphur in other forms than H_2S.
Gr. per 100 cub. ft.	nil	625	645	39

Of these impurities, the carbonic acid and sulphuretted hydrogen have to be completely removed, while the sulphur in other forms than H_2S has (in all the London gas-works) to be reduced to less than 20 gr. per 100 cub. ft. For the sake of brevity, the sulphur in other forms than H_2S will for the future be spoken of simply as "sulphur." The removal of sulphuretted hydrogen and carbonic acid is comparatively simple, reduction of the amount of sulphur being attended with the greatest difficulty. For the removal of sulphuretted hydrogen the best material is the hydrated sesquioxide of iron ($Fe_2O_3\,3H_2O$), known technically as "oxide," and which is found native in many localities. It is best mixed with sawdust before being used, in order to lessen its density and permit the gas to pass through the mass with greater facility and with less "back pressure." For the removal of carbonic acid, slaked lime is invariably employed; lime will also absorb sulphuretted hydrogen, but is objectionable for this purpose, by reason of the nuisance arising from the spent material. For the removal of sulphur, lime is also used, but in a special way.

Effects of Oxide Treatment.—The action which takes place when the hydrated sesquioxide of iron is brought into contact with sulphuretted hydrogen is the formation of ferrous sulphide (protosulphide of iron), free sulphur, and water, thus—

$$Fe_2O_3, 3H_2O + 3H_2S = 2FeS + S + 3H_2O.$$

When the material has become thoroughly saturated with sulphuretted hydrogen, it is removed from the purifier and spread out in a layer about 6 in. thick, moistened with water, and turned over frequently in order to thoroughly expose it to the action of the air. The material then heats, by the absorption of oxygen, the ferrous sulphide becoming converted into hydrated sesquioxide of iron, and its sulphur is set free, thus—

$$2FeS + 3H_2O + 3O = Fe_2O_3, 3H_2O + 2S.$$

This process is termed "revivification," and the regenerated material is then ready for further use. It is thus alternately employed and revivified a great number of times, before it is so surcharged with sulphur that it is desirable to substitute a charge of fresh oxide. The spent product is of commercial value, chiefly on account of the quantity of free sulphur which it contains. The composition of a good sample of spent oxide should be: moisture, 13·40; free sulphur, 58·65; ammonia salts (chiefly sulphocyanate), 7·85; oxide of iron, with a little siliceous matter, 10·30; organic matter, 9·80. In this analysis the amount of cyanogen is not shown; it would be comprised in the organic matter, and exists in the oxide as cyanide, or possibly ferrocyanide of iron. The great merit of oxide as a purifying agent consists in its capacity for regeneration, and in the comparatively odourless character of the material when removed from the purifiers after exposure to sulphuretted hydrogen.

Effects of Lime Treatment.—The lime used for gas purification should be in a particular condition, in order to ensure good results. Besides being thoroughly slaked, sufficient additional water must be subsequently added to make the material wet enough to cake when pressed in the hand; small lumps should not be excluded, as they tend to make the mass more pervious to the gas. The action of carbonic acid on slaked lime (calcium hydrate, $CaOH_2O$) is the formation of carbonate of lime and water, thus—

$$CaOH_2O + CO_2 = CaCO_3 + H_2O.$$

The action of lime on sulphuretted hydrogen consists in the formation of the compound $CaSH_2S$ (calcium sulphydrate) and water, thus—

$$CaOH_2O + 2H_2S = CaSH_2S + 2H_2O.$$

Considering that "oxide" is the best material for absorbing sulphuretted hydrogen, and lime the best for carbonic acid, it would seem on first consideration most desirable to free the gas first from H_2S, by oxide, and then from CO_2, by lime. The objection to this system is, that when lime absorbs carbonic acid without sulphuretted hydrogen being present, the material becomes dense, and the gas passes through it with difficulty. Where, however, the lime is placed before the oxide, and is consequently exposed to the action of sulphuretted hydrogen, this difficulty does not arise, and if exposed for a sufficient period to the action of the gas, the whole of the lime becomes eventually converted into carbonate, and can be removed from the purifier without nuisance. This arises from the fact that carbonic acid is capable of decomposing the calcium sulphydrate, carbonate of lime being formed, and sulphuretted hydrogen set free, thus—

$$CaSH_2S + CO_2 + H_2O = CaCO_3 + 2H_2S.$$

The first action of carbonic acid and sulphuretted hydrogen on lime may be assumed to be the simultaneous formation of carbonate and sulphydrate of calcium. As the action proceeds, the sulphydrate becomes decomposed by carbonic acid, and the sulphuretted hydrogen is driven forward, so that the last-named compound becomes gradually in advance of the carbonic acid, and makes its appearance first at the outlet of the purifier. The following diagrammatic section may be supposed to exhibit the condition of a lime purifier which has been exposed for some time to the action of CO_2 and H_2S:—

Outlet. ← Gas free from CO_2 and H_2S.	Clean lime.	
	Calcium sulphydrate.	
	Mixture of calcium carbonate and sulphydrate.	
	Calcium carbonate.	← Inlet. Gas contains CO_2 and H_2S.

After the action has continued for some time, the contents may be illustrated as follows:—

Outlet. ← Gas free from CO_2, but contains H_2S.	Calcium sulphydrate.	
	Mixture of calcium carbonate and sulphydrate.	
	Calcium carbonate.	
	Calcium carbonate.	→ Inlet. Gas contains CO_2 and H_2S.

A further stage in the process is the advance of the carbonic acid, so that the whole contents of the purifier have become carbonate. The diagrammatic sections do not, of course, accurately delineate the condition of a lime purifier; they are simply intended to illustrate the order in which the various substances present would be arranged. In practice there are many reasons why even an approximation to any definite division between the various compounds in the purifier should not exist. The velocity of the gas is invariably so rapid that complete and instantaneous combination cannot take place, and the action is not, therefore, limited to the first surfaces of contact, but extends for some distance upwards in the direction of the current of gas. Again, however carefully the purifying material may be arranged, there are sure to be, in practice, some portions which are less dense than others, and in the direction of which the gas will have a tendency to pass, as affording less resistance, a condition which will give inequality of action over any given area.

It now remains to describe the usual means adopted for the removal of sulphur. Fresh lime appears to exercise little or no action upon this form of impurity; but when the lime has been previously exposed to the action of sulphuretted hydrogen, it becomes capable of removing the sulphur to a large extent, reducing the total quantity normally present in unpurified gas to an extreme limit of 5-7 gr. per 100 cub. ft. The particular lime compound which is active on sulphur is not known, but it is generally assumed to be calcium sulphide (CaS). It is difficult to understand how this compound can be formed; this much, however, is known, firstly, that after lime has been thoroughly exposed to the action of sulphuretted hydrogen, it will remove sulphur from gas; and secondly, that carbonic acid must be excluded from the lime which has been used for this purpose, as otherwise the sulphur which was taken up will be expelled. The compound formed when sulphur, presumably existing as carbon disulphide, is removed by sulphuretted lime, is probably calcium sulphocarbonate ($CaSCS_2$). The action of carbonic acid on this compound would be to form carbonate of lime, carbon disulphide, and sulphuretted hydrogen, thus—

$$CaSCS_2 + CO_2 + H_2O = CaCO_3 + H_2S + CS_2.$$

Various systems of using purifying materials are in use at different gas-works, the exact method adopted depending on the particular experiences of the engineer, and on the necessity for avoiding nuisance. The simplest system by which sulphuretted hydrogen and carbonic acid can be removed, coincident with a reduction in the amount of sulphur, is the ordinary "rotation system," as it is usually termed; but this system cannot be adopted in places where the works are situated in a populous district, and have consequently to be conducted with as little nuisance as possible. In this process, a series of four vessels of sufficient size (about 0·4 sq. ft. area for every 1000 cub. ft. of gas passing in 24 hours) are employed, and charged entirely with lime. It will be remembered, that when speaking of the use of lime, it was shown that by the continued action of foul gas containing CO_2 and H_2S, the H_2S was always in advance of the CO_2 at the outlet of a vessel. The effect of this in a series of vessels is that there is always sulphuretted lime in advance of the lime which is taking out CO_2, and this sulphuretted lime is capable of absorbing carbon disulphide. At the outlet, therefore, of the set of vessels, the gas will not only be free from CO_2 and H_2S, but the amount of sulphur will be materially reduced, viz. to about 12 gr. or less. The conditions for successful working would occupy too much space to describe in detail, but consists chiefly in taking off the first vessel in the series, sufficiently often to effect the desired result, the vessel when recharged taking its place as the last or No. 4. It is best, in practice, to have an additional vessel charged with oxide, as No. 5 in the series, its function being to stop any small quantity of H_2S that may occasionally pass from No. 4. The nuisance occasioned by the use of this system is the chief drawback to its more extended employment, as the vessels have to be discharged while their contents contain much sulphuretted hydrogen. The lime in this condition heats rapidly when exposed to the air, and evolves a portion of its sulphuretted hydrogen, occasioning a corresponding amount of unpleasant smell. One of the best methods of purification, and one which creates the minimum of nuisance is that employed by H. Jones at the works of the Commercial Gas Co. A series of four vessels are used for the removal of H_2S and CO_2. Each of these vessels is charged with a certain quantity of lime, above which is placed a certain quantity of oxide, the comparative amounts of each material being so proportioned that the lime is sufficient for the carbonic acid, and the oxide for the sulphuretted hydrogen. Each impurity is thus removed in the least offensive way, viz. the carbonic acid as calcium carbonate, and the sulphuretted hydrogen as ferrous sulphide. The gas leaves this set of vessels free from CO_2 and H_2S, the sulphur being on the average somewhat less than 30 gr. per 100 cub. ft. The gas then passes to a special series of four vessels, two only of which are as a rule in use. These vessels contain lime which has been well "sulphided," i. e. saturated with H_2S. Here the sulphur is reduced to about 10 gr., frequently to even less than that amount. Finally, the gas passes through a purifier charged with fresh lime and oxide, to absorb any traces of sulphuretted hydrogen that might otherwise pass unarrested. The "sulphide" vessels are kept in action as long as the contents will absorb sulphur, and, when thus worked, occasion practically no nuisance on being discharged. The spent lime heats but very slightly, and does not throw off any sulphuretted hydrogen.

Many attempts have been made to effect the purification of gas in closed vessels by means of liquid reagents; but although they have been attended with some degree of success, success in the commercial sense has not yet been attained. The best results have been obtained by Leigh, of Manchester, whose process consists chiefly in the preparation of the polysulphides of ammonium, from gas-liquor and sulphur, for employment in the removal of carbon disulphide; and Hill's process, which is mainly for the purification of gas from CO_2 and H_2S, by means of a solution of ammonia, prepared by heating ordinary ammoniacal liquor to a temperature of about 82° (180° F.). At this temperature, the ammonium carbonate and sulphide in the liquor are decomposed, CO_2 and H_2S passing off in the gaseous state, together with a small quantity of ammonia, while the bulk of the ammonia present is left in the liquid. The cool liquor is used for absorbing fresh quantities of CO_2 and H_2S from the gas, and, when saturated, is again purified. The process was in use for some time at the works of the South Metropolitan Gas Co., under the direction of Livesey. It is to be hoped that the purification of gas by liquid media will yet be accomplished, as the facility of working, and freedom from nuisance, would be much greater than where solid purifying agents are used, as at the present time.

Bibliography.—See Bibliography, at end of article on Coal-tar Products (p. 684); also lists of works relating to gas, at the end of articles on Gas Manufacture, in Spons' Dictionary of Engineering, and Supplement.

(See Alkalies—Ammonia; Coal-tar Products.) H. L. G.

GEMS (Fr., *Gemmes, Pierres fines*; Ger., *Gemmen, Edelsteine*).

The term "gems" or "precious stones," is applied to a very limited number of minerals conspicuous for their brilliancy and beauty of colour, and for their rarity and durability. They occur as druses in veins and fissures in the earth's crust, as geodes in the igneous rocks, and as accidental or accessory crystals in the older metamorphic formations. They are never met with in great profusion, and only a small proportion of those found possess purity and brilliancy in the highest degree. Consequently, their value is subject to but slight changes, and a remunerative market is always ready for them.

In this article, will be described only the most esteemed gems, numbering less than a dozen; the description will include their chemical and physical characteristics, their geographical and geological distribution, the modes of obtaining them, and such statistics of their production as may be available.

Artificial Gems.—The fabrication of compounds in imitation of gems has assumed the importance of an industrial art, and is prosecuted with skill and capital. It is carried on principally in France, in the Jura, Franche-Comté, the communes of St. Claude, Septmoncel la Meure, les Molunes, and surrounding districts. The basis of these imitation products is a pure, fusible, brilliant, transparent and dense variety of glass, termed "paste," or *strass*, appropriately tinted by the addition of metallic oxides. The proportions (by weight) of the ingredients of this paste are:—Pure pulverized silica, 45·7 parts; pure dry carbonate of soda, 22·8; calcined borax, 7·6; saltpetre, 3·4; pure red-lead (minium), 11·8. The source of the silica is rock-crystal; flint contains impurities. Each ingredient is separately reduced to an impalpable powder; they are then intimately mixed in due proportion, and placed in a Hessian crucible heated by charcoal; the temperature is raised gradually till fusion has commenced, and is then maintained with the utmost uniformity for 20–30 hours; they are finally cooled very slowly. The density and beauty of the product depend upon the regularity of the fusion, the intimacy of the combination, and the slowness of the cooling. The cooled compound, without any further treatment, is cut up, polished, set and foiled, in imitation of the diamond. Counterfeits of the other gems require the addition of pigments, in which some variety prevails. Thus imitation topaz is made by fusing 40 parts of glass of antimony, and 1 of purple of Cassius, with 1000 of the paste. From this compound at its opaque stage, ruby may be simulated, by melting 1 part with 8 parts of paste, in a Hessian crucible, for 30 hours, in a glass-furnace; the product is a yellowish crystal, which, remelted by the blowpipe, yields a mass resembling the finest ruby. Another colouring agent for topaz is 1·59 per cent. of oxide of uranium; and another for ruby is 5 parts of peroxide of manganese, and a trace of purple of Cassius, to 1000 of paste. Emerald is imitated by 1000 of paste, 8 of oxide of copper, and 0·2 of oxide of chromium; or, 0·53 per cent. of oxide of iron. For sapphire, mix 1000 of paste and 15 of oxide of cobalt; or, 0·106 per cent. of carbonate of cobalt. Spurious emeralds, totally different from the above, have recently appeared in the market. Bryce Wright states their composition to be:—Silica 35·70; lime, 41·66; soda and potash, 13·00; "beryelia" (? beryllium, or berzelin), 9·54; with traces of iron, chromium and lead; alumina is not present. They are readily known by their high sp. gr.—3·402—and by their optical properties; but their colour exceedingly well imitates the true gem, and they are flawed with remarkable faithfulness. None of the above compounds display the optical properties, the hardness, the sp. gr., nor the chemical constituents of the true gems. Another system of fraud, more difficult to discover, is the facing of pieces of worthless transparent material with thin slices of the real gem, affixed by means of an invisible cement; but this is not commonly practised. (See Glass.)

In quite another category from the above-described tricks, intended only to deceive the eye, and thus to palm off rubbish at a very fictitious value, must be placed recent discoveries permitting the synthetic production of several gems, differing in no essential respect from their natural prototypes. The first success of the kind was achieved by Frémy and Feil, in the artificial formation of ruby and sapphire, differently coloured and crystallized forms of corundum. The process is as follows:—A fusible aluminate is formed by calcining equal weights of alumina and red-lead in a double fire-clay crucible at a bright-red heat for 20 days. During the operation, the lead salts attack the silica of the crucible. On cooling, two layers of matter are found: one is vitreous, and composed chiefly of silicate of lead; the other is crystalline, and consists of alumina or corundum. To produce ruby-coloured corundum, 2–3 per cent. of bichromate of potash is added to the ingredients in the crucible; the blue of sapphires is obtained by using small quantities of oxide of cobalt and bichromate of potash. Another method of producing rubies is by calcining equal weights of alumina and fluoride of barium, with 2–3 per cent. of bichromate of potash, in a covered crucible. In these manners, are produced large masses of a substance having all the hardness of natural ruby, and probably capable of wide industrial application, even though it should not possess the brilliancy of true gems.

Perhaps even more important from a scientific point of view, is J. B. Hannay's discovery resulting in the artificial formation of the diamond. For the many unsuccessful preliminary experiments, the reader is referred to his interesting paper read before the Royal Society. The only successful result was obtained in the following manner. A coil-tube of Lowmoor iron, measuring 20 in. long, 4 in. diameter, and ½ in. bore, was ¾-filled with a mixture containing 90 per cent. of bone-oil (the nitrogenous distillate obtained in the manufacture of bone-charcoal), taking only the portion boiling at 115°–150° (239°–302° F.), and rectified over solid caustic potash, and over sodium; 10 per cent. of paraffin spirit boiling at 75° (167° F.); and 4 grm. of lithium. The tube was closed by welding, and was then heated in a furnace to a visible red heat for 14 hours, and allowed to cool slowly. On opening the tube, a great volume of gas was given off, and very little liquid remained. At the end which had been uppermost (obliquely) in the furnace, was a hard, smooth, adherent mass, which, when removed and pulverized, disclosed microscopic fragments of crystalline carbon, differing from natural diamond in no respect save brilliancy. Thus, though a great achievement scientifically, the cost and difficulty of the process, and the insignificant value of the product, preclude at present its commercial application.

Diamond (Fr., *Diamant*; Ger., *Diamant, Demant*).—Composition, pure carbon; hardness, 10; sp. gr., 3·515–3·525; varies from colourless transparency to white, grey, brown, red, yellow, green, blue, and even black.

In Europe, diamonds are of rare occurrence. A very doubtful one is said to have been picked up in Ireland, another was found at Dlaschkowitz, in Bohemia, and numbers of small ones, the largest not 8 carats, occur in the gold washings near Bissersk, on the western side of the Urals, in a mica-slate formation.

The diamond-fields of Asia were formerly of considerable importance, notably those of India, and though now almost abandoned, and affording but a poor return to the few diggers engaged, they would probably repay systematic and scientific exploration. Diamonds have been found in the Ganges Valley; are still washed as far north as Sambalpúr, and in the Majnodi, an influent of the Mahanadi; on the Upper Nerbudda; on the line of the Godavery; and on the course of the Krishna. The extreme points of this district would be Masulipatam and the Ganges Valley, embracing some 90,000 sq. miles. The most southern group of diamond strata is about Cuddapah on the Pennar, and at Condapetta and Ovalumpally; also at Landur and Pinchetgapadu, and still farther beyond the Pennar Valley to Gandicotta and Gutidrug. The strata here are:—topmost, 1½ ft. of sand, grit, and loam, followed by 4 ft. of tough blue-black muddy earth, resting upon the diamond bed, 2–2½ ft. thick, consisting of rounded pebbles (much hornblende) and grit, bound together by loam. The next group is 15 miles northwards, on the west side of the Nalla-Malla Hills; the beds here are only about 1 ft. thick. A third group, of greater magnitude, is that of Ellora, on the Lower Krishna, and embracing the so-called Golconda diggings, from the fort of that name, where the stones are brought for sale. The chief finds are at Mallivully, about 6–7 hours W.-S.-W. of Ellora, and at Partiál, near Condapilly, on the N. bank of the Krishna. Here the diamonds occur in alluvium 20 ft. deep. The Sambalpúr group lies in the bed of the Mahanadi, from Chunderpore to Sonepore, about 24 miles. The best is mostly tough reddish clay, with pebbles and a little sand. The Ganges group lies in a sandstone range, southward of that river, principally at Myra, Etawa, Kamaruja, Brijpur, and Baraghari. In India, the dry grounds are worked by sinking shallow pits to reach the diamantiferous stratum, and the latter is broken up before being subjected to the common washing process for removing the earth. Among other Asiatic countries, China possesses diamonds in the streams and sands from the Chiukang-ling range, about 15 miles S.-E. of Yichow-fu, in Shantung. Their size varies from that of a millet-seed to a pin's head. Numbers of diamonds, some of great size and purity, occur in the Ratoos Range, in the S.-E. of Borneo, in a sand and gravel bed about 6 ft. thick, resting on serpentine, and overlaid by 30–40 ft. of red clay; in Landak, in the N.-W. part of the island, they are also found.

Africa recently held the foremost position among diamond-producing countries, and still continues to furnish very large supplies. The fields lie chiefly in the Colony of Griqualand West, in the valleys of the Vaal, Modder, Veit, Orange, and other rivers, draining the Drakenberg (Quathlamba) Mountains. The area proved to be diamantiferous is already very large, though but little has been done to determine its limits. The stones are sought in two distinct formations—in the recent alluvial deposits of the river-valleys; and in "pans" or basins of considerable depth (commonly 100–200 ft.), containing a peculiar igneous conglomerate. Throughout this mass, diamonds are scattered with greatly regularity. It is broken down, suffered to bake in the sun for several days, and then washed in "cradles" or "long-toms," such as are employed in alluvial gold-mining. Great variety of character is to be noticed in the stones from different localities: those from the river-sands are waterworn, but the whitest of any, and bring the best prices; those from Dutoit's Pan are large, off-coloured and yellow; those from Bultfontein are small bevelled octahedrons, pitted on the surface; those from Kimberley are smaller and whiter than those from Dutoit's Pan. About 10 per cent. are of 1st quality, 15 of 2nd, 20 of 3rd, and the remainder merely "bort," and not reckoned as gems. Their colour is classed as "white," "Cape white," bye-water," "off-colour," and "yellow." The total value of the diamonds taken from these diggings is estimated at 15,000,000*l.* The returns of the exports, which, of course, understate the truth, are:—in 1868, 1, value 150*l.*; 1872, 45,830, value 306,041*l.*; falling, in 1877, to 83, value 330*l.*

N. America claims to afford diamonds in California and Oregon, where they are occasionally found in the gold-sluices; their size is very small. They are also mentioned in Arizona, Georgia, N. Carolina, and in the Sierra Madre, near Acapulco (Mexico).

Brazil was the chief source of diamonds at the close of last and opening of this century. The most productive districts are Diamantina (Tejuco), in Minas Geraes, Diamantino, in Matto Grosso; also on the Rio Claro, on the Rio Tibagy, in Sao Pedro do Rio Grande do Sul, and in Sao Paulo. The total area of distribution is yet far from being known. The stones are sought for in the *cascalho*, a loose deposit of gravel, clay, and quartz lumps, containing gold, and supposed to be the detritus of "itacolumite," a quartzoze mica-slate, or metamorphosed sandstone, in which diamonds also occur. This latter is too hard to repay working, and operations are confined to washing the *cascalho*, as if for gold. The stones are mostly small, averaging but little more than 1 carat. The exports from Bahia in 1878–9 were 8269 grm., value 709,324,000 *reis* (1000 *reis* = 4*s.* 5½*d.*), of which, France took 574,854,400; Great Britain, 132,587,200; and Portugal, 1,882,300.

Several of the Australian Colonies yield diamonds, though not of great size nor in large number. The most noted localities are the Macquarie and Mudgee river-valleys, and Bingera, all in New South Wales. The finds are in the auriferous drift of dead rivers, overlaid by Pliocene basalt. They also occur in the Cudgegong River, 19 miles north-west of Mudgee. In South Australia, they are found near Echunga, about 20 miles south-east of Adelaide; in Victoria, at Beechworth and Collingwood Flat. They are reported from N.-E. Gippsland and from New Zealand.

Emerald (Fr., *Émeraude*; Ger., *Smaragd*).—Composition, 65 per cent. silica, 14 alumina, 13 glucina, 3·5 oxide of chromium, 2·5 lime; hardness, 7·5; sp. gr., 2·7; colour, rich deep-green; somewhat brittle, transparent to subtranslucent. Europe is said to possess emeralds in Norway and Austria. In Asia, they have been found in the Urals and Altai Mountains, in Burmah, and on the Siberian frontier of China. African emeralds are found in mica-slate beds in the Sahara, and at the junction of the Harrach and Qued Bouman Rivers, in Algeria. The principal modern source of the gem is in S. America, between the mountains of New Granada (Colombia) and Popagan. The most celebrated mine is that of Muzo, in the Tunka Valley, about four days N.-N.-W. of Bogotá. The formation is a secondary limestone, containing veins of calcareous bitumen, in which the gems are found imbedded. Mining operations are necessary, and the broken-down material is washed in ground sluices. The production is very variable, and no statistics exist. Stray emeralds are reported from Victoria and New South Wales.

Lapis Lazuli (Fr., *Pierre ollaire*; Ger., *Topfstein*, *Lawetzstein*).—Composition, 45–50 per cent. silica, 30–32 alumina, 9 soda, 6 sulphuric acid, with minor quantities of lime, iron, chlorine, and sulphur; hardness, 5·5; sp. gr., 2·4; colour, ultramarine or fine azure-blue of varying intensity, depending, it would seem, upon the proportion of iron and sulphur. The stone occurs in Asia and S. America. A celebrated mine is in the valley of the Kokcha, in Badakhshan; here it is met with in an unstratified limestone, and is extracted by heating the surface of the rock so that it can be flaked off by smart blows till the stone is exposed. Another source is the shores of the Shudauk, near the Baikal Lake; also in many parts of China, and reputedly on the Indus. In the Cordillera of the Andes, near the sources of the Cazadero and Vias, tributaries of the Rio Grande, the gem is found in a thick stratum of limestone, accompanied by small quantities of iron pyrites.

Opal (Fr., *Opale*; Ger., *Opal*).—Composition, 90–95 per cent. silica, 5–10 water, with traces of iron, potash, soda, lime, alumina, &c.; of various colours and many varieties; the noble or precious opal, the only one to be considered here, exhibits a beautiful play of colour by refracted and reflected light. The only two sources of precious opal are Hungary and Mexico, the product of the former being by far the more valuable. The Hungarian mines are situated at Dubrick and

Cservenicza in the Carpathians. The stones occur as druses, irregularly scattered throughout the interstices of an andesite, or trachytic lava, forming the mass of the mountain. These opals vary in value from 1*l.* to 5*l.* a carat, and even higher, and are almost the only ones employed by jewellers. The Mexican and Honduras stones come from Esperanza, Amealeo, and Real del Monte, occurring in a porphyritic formation. They are beautiful when new, but soon lose their beauty, and are worth only a few pence a carat. S. Australia is said to afford a few specimens resembling the Hungarian; and some of particular beauty are reported from Beechworth, Victoria.

Ruby (Fr., *Rubis;* Ger., *Rubin*).—Composition, varies from about pure alumina, to a compound containing 10–20 per cent. of magnesia; hardness, 9; sp. gr., 4·6–4·8; colour, various shades of red. The ruby is essentially an Eastern gem. One celebrated mine is situated about 20 miles from Ish-kashm, in a district called Gharan, on the right bank of the Oxus. The formation is either red sandstone or magnesian limestone, easily worked; the stones occur encased in nodules in seams and spots in the rock. Superior gems are found at Mo-gast and Kyat-pyan, 5 days S.-E. of Ava, the workings being a monopoly of the King of Burmah. Perhaps the finest come from a district between the north-east of Mandalay and the west of the Upper Salween River. Another noted locality is at the foot of the Capelan Mountains, near Sirian, in Pegu, where fine rubies are not rare; also near Kandy, in Ceylon, where good stones are very scarce. One has been found near Mount Eliza, on Port Philip Bay, Victoria; also one in Queensland; and another in New Zealand. Rubies of pure colour and fair size are the most valuable of all gems.

Sapphire (Fr., *Saphir;* Ger., *Saphir*).—Composition, about 98·5 per cent. of alumina, with oxide of iron and other colouring matter; hardness, 9; sp. gr., 4·6–4·8; colour, from translucent yellow or white, to violet. Sapphires of great beauty are found in and near the Iser Mountains, in Bohemia, and in the bed of the River Iser, mostly in quartz sand and granite detritus. In Ceylon, good sapphires are not rare. Quite a rush has recently taken place to the mines of Battambong and Chantubong, in Siam, whence a stone of the finest water, weighing 370 carats in the rough, is credibly reported. Blue and white stones of some value have been found in Dandenong Creek, Victoria; at Ballarat, S. Australia; and in the Hanging-rock caves, near the Pearl River, New South Wales.

Topaz (Fr., *Topaze;* Ger., *Topas*).—Composition, 34 per cent. silica, 57 alumina, 15 fluorine; hardness, 8; sp. gr., 3·5; colours, yellow, blue, and white. In Saxony, is found a pale-violet variety; and in Bohemia, a sea-green. Many occur in the Urals, north of Katharinburg, in granite and albite; and in E. Siberia. In the Brazilian province of Minas Geraes, numbers are met with in the auriferous gravels, especially at Capao. Some fine specimens have been got at Beechworth, Victoria, in Flinders' Island, and in Tasmania.

Turquois (Fr., *Turquoise, Agaphite;* Ger., *Agaphit, Kalait*).—Composition, 47 alumina, 27 phosphoric acid, 3 phosphate of lime, 2 oxide of copper, 1 oxide of iron, 19 water; hardness, 6; sp. gr., 2·6–2·8; colour, blue to blue-green. The Land of Midian possesses three turquois mines: one at Aynuneh, a second near Ziba, and a third, known to the Bedouins as Jebelshehayk. But the stones comes principally from the mountainous district of Nishabor (Neshapore), in N.-E. Persia; the oldest mine is in the Bari Madán *bulúk*, and a second has recently been discovered in the hills to the south, separating Nishabor from Turshiz. Mashhad is the headquarters of the trade. Better stones at lower figures are said to be procurable at Shikárpúr, in Sind.

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GLASS (Fr., *Verre;* Ger., *Glas*).

Glass is an amorphous mixture of various silicates, formed by the fusion of the ingredients. There are, indeed, certain silicates which are themselves commonly known as glasses, and resemble glass in appearance. Such are the potassic tetra-silicate (Fuch's soluble glass), and the plumbic sesqui-silicate. These, however, are deficient in durability, and are useless for those purposes to which glass is generally applied. Silicates are formed by the combination of silica (silicon dioxide) with metallic oxides, in various proportions. Most silicates are fusible. The fusing-point of a mixture of silicates is generally about the mean of the fusing-points of the constituents. Thus the calcic and aluminic silicates are separately fusible only with great difficulty, but in combination fuse readily. Silica (silicon dioxide, symbol SiO_2, molecular weight 60), which unites with metallic oxides to form silicates, and is therefore the principal ingredient of all glasses, is the only known oxide of silicon. Sand is silica mixed with various impurities.

Silicates may be formed directly or indirectly. When sand is heated with the oxide of lead in proper proportions, plumbic silicate is formed: in this case, the silica combines directly with the metallic oxide. If sodic carbonate be substituted for plumbic oxide, sodic silicate will be formed by indirect action, for before the silicate can be formed, it is necessary that the carbonic acid, which is in combination with the oxide of sodium in the carbonate, shall first be expelled. That carbonic acid is expelled from its combinations by silica at a high temperature may be proved thus:—A mixture of sodic and potassic carbonates is melted in a platinum crucible (the mixed carbonates have a lower fusing-point than either constituent); the crucible, whilst still hot, is lowered into a tall glass vessel, and some perfectly dry sand is poured into the molten mixture; carbonic acid escapes with effervescence, and, being retained in the tall glass vessel, may be detected by its reaction with lime-water. By replacing the sodic or potassic carbonate by calcic, plumbic, or baric carbonate, calcic, plumbic, or baric silicate, may be formed. Again, if, at an elevated temperature, silica be added to sodic sulphate, sulphuric anhydride will be expelled, and sodic silicate produced. The decomposition of the sulphate of soda by silica is facilitated by mixing the sulphate with $\frac{1}{10}$ of its weight of charcoal; the sulphate is thus reduced to a lower state of oxidation, and the sulphur escapes as sulphurous anhydride at a lower temperature than is required to decompose the sulphate.

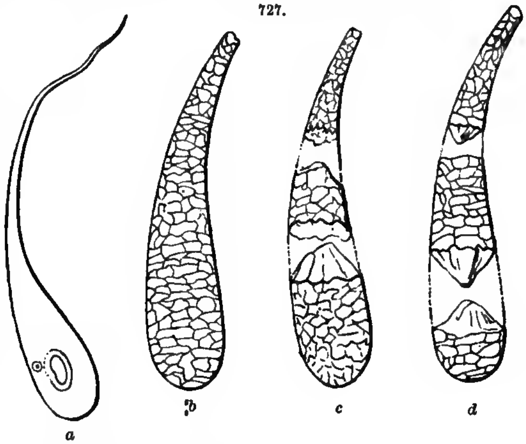
All glasses are mixtures of silicates. Bohemian glass is a mixture of calcic and potassic silicates; sheet-, plate-, or crown-glass, of calcic and sodic silicates; bottle-glass, of calcic, sodic, aluminic, and ferric silicates; flint-glass, of potassic and plumbic silicates. For experimental purposes, many silicates can be obtained, in absolutely correct chemical proportions, by precipitation from solutions. If these precipitated silicates be dried, and two or more be mixed in proper combining proportions, and the mixtures be fused, pure glasses will be obtained. The sodic and potassic silicates, formed by the fusion of silica with excess respectively of sodic and potassic carbonate, can be obtained in solution. If to a solution of sodic or potassic silicate, a solution of calcic chloride be added, calcic silicate will be precipitated; similarly, plumbic silicate will be precipitated by the addition of plumbic nitrate. Bohemian glass may therefore experimentally be produced by the fusion, in combining proportions, of precipitated calcic silicate with potassic silicate; plate-glass, by the fusion of precipitated calcic silicate with sodic silicate; and flint-glass, by the fusion of plumbic silicate with potassic silicate. The following formulæ may be taken as approximately representing the composition of the various glasses which will be considered in this article:—Bohemian, sheet-, plate-, and crown-glass = K_2O (or Na_2O), CaO, $6SiO_2$; lead- or flint-glass = K_2O, PbO, $6SiO_2$; optical lead-glass = K_2O, PbO, $4SiO_2$; optical crown-glass = K_2O, CaO, $4SiO_2$; bottle-glass = $3K_2O$, $27CaO$, $3Al_2O_3$, $2Fe_2O_3$, $45SiO_2$.

Such accuracy of combination as is obtained experimentally by precipitation can hardly be looked for in commercial glass manufacture. In the latter case, the formation of silicates from raw materials, and the formation of glass from the combination or mixture of silicates, have both to come into operation in the crucible. To ensure the production of definite silicates in the crucible, the raw materials must be mixed together in proper combining proportions, for if more metallic oxide be introduced than can chemically combine with the silica, the excess will form an impurity in the glass. To this cause is to be attributed, not only the blemishes visible in common glass, but also the decomposition of the substance of the glass, after long exposure to the action of air and moisture. The surface of old glass is commonly pitted and worn: this appearance is due to the solution, by moisture and carbonic acid, of an excess of material with which the silica has been unable chemically to combine; or, in the first instance, to the materials having been mixed in improper proportions.

The quality which especially facilitates the manufacture of glass on a commercial scale is a curious viscosity or plasticity produced by the agency of heat. When solid glass is heated, it becomes gradually softer and softer, and passes by imperceptible stages into a liquid condition. It may be said to melt at the lowest temperature at which perceptible softening occurs, and to be fully melted when a further elevation of temperature does not make it more fluid; but no precise temperature can be given as its melting-point. At an intermediate stage between liquidity and solidity, which may conveniently be termed the stage of viscosity, glass is in an exceedingly favourable condition for manipulation. In this condition, it can be ladled, or poured, or gathered on a heated iron rod; a solid mass, at the end of a hollow blowing-iron, will expand and become hollow by the pressure of the breath; it can be moulded, pressed, or rolled; so great is its ductility, that hollow or solid masses can be drawn out to immense lengths of tube or cane; so weak is the cohesion of its particles, that a mass will lengthen by the force of gravity, and a contracted cup will expand into a flattened disc under the centrifugal force produced by rapid rotatory motion.

To maintain the glass in this state, it is necessary that glass-furnaces shall be capable of being worked with great regularity: sudden fluctuations of temperature affect not only the physical condition of the glass, but, by disturbing the homogeneity of the molten glass, produce striæ and irregularities in its substance. The action of heat upon bodies is to develop a repulsive force between their molecules, which is continually struggling with molecular attraction. Under its influence, bodies tend to expand, and finally to change their state of aggregation. This theory necessarily assumes the existence of pores or interstices between the molecules of matter, which increase in size with the growth of the repulsive force generated by heat. By this theory, many phenomena in the manufacture of glass may be explained. In glass in a viscous condition, the physical pores are large; and, as it passes from the viscous to the solid state, the pores must be gradually reduced in size throughout the entire mass. If the process of cooling be in any way hurried, the exterior of the mass will solidify sooner than the interior, and the latter will remain in a state of porosity and unstable equilibrium. This will especially be the case with glass, owing to the fact of its being an exceptionally bad conductor of heat. If a small quantity of molten glass be allowed to fall into water, a drop of glass is formed, similar to that represented at *a*, Fig. 727. If the thin end of this drop be cut into, whether by the action of hydrofluoric acid, the cutter's wheel, or a blow, the entire mass will be broken up, as at *b c d*. Until the surface is injured, the drop possesses extraordinary strength. These drops, commonly known as Prince Rupert's drops, afford an excellent illustration of the behaviour of glass too suddenly cooled. The exterior rapidly contracts, whilst the interior molecules are still in a state of mutual repulsion. The repellent molecules are only resisted by the intense solidity of an outer crust; so soon, therefore, as this crust is weakened, the entire mass is disintegrated. Attempts have been made of late years to utilize the solidity and strength undoubtedly possessed by the crust of suddenly cooled glass. This is the principle of M. de la Bastie's invention, to which further reference will be made.

727.



In the manufacture of glass for all ordinary purposes, special provision has to be made to facilitate gradual cooling. This may be effected in either of two ways:—(1) By placing the manufactured glass, whilst still hot, in a closed oven or kiln, and allowing the fire of the kiln gradually to die out; (2) by exposing the manufactured goods to a permanent fire, and then gradually withdrawing them. The process of gradual cooling is technically known as "annealing." The kiln system is probably the better, especially where heavy goods have to be annealed. Its disadvantages are (1) the length of time required to effect complete cooling, in some cases amounting to 1–2 weeks; (2) the space occupied by the kilns, as there must always be at least two; (3) the discontinuity of the process. The withdrawal system is especially suited to flint-glass works, where goods are produced rapidly, and it is essential that the cooling process shall be continuous.

Devitrification of Glass. Réaumur's Porcelain.—If glass, surrounded by sand or gypsum, be heated for a considerable time, but not sufficiently to cause fusion, it will be converted into a porcelain-like mass. This result may also be obtained, but with less regularity, by melting an impure glass, such as ordinary bottle-glass, in a crucible in a furnace, and allowing the furnace to die out. This change of condition is supposed to be caused by the partial separation of certain silicates, especially those of calcium and aluminium, and their assumption of a more or less crystalline form. A mass of these crystals, analyzed by Dumas, gave the formula $18(CaNa)O, 2Al_2O_3, 45SiO_2$; whilst the transparent glass from which they separated contained 3·5 per cent. less silica, 1·4 less alumina, and a proportionately larger quantity of soda. It has been observed that devitrified glass may be vitrified and again devitrified; that from devitrified glass, placed in a moist atmosphere, there exudes a soluble salt; and that apparently the melting-point of devitrified glass is higher than that of the same glass when vitrified. Glass of any kind may be devitrified; but the finer kinds of potash glass only with difficulty. The soluble glass of Fuch is especially liable to devitrifaction by crystallization. Attempts have been made to utilize devitrified glass, but without any marked success.

Badly prepared window-glass becomes opaque on exposure to air. This is due to a devitrification of the surface, brought about by the action of water, carbonic acid, and ammonia, and depends on the fact that the alkalies are separated, and washed away by water, whilst an iridescent coating, consisting of a thin film of calcic silicate, remains on the surface.

Raw Materials.—*Sand.*—Freedom from colour, and transparency, in glass, depend principally upon the quality of the sand used in its composition. The impurities generally present in sand are iron, lime, alumina, and magnesia. Iron is the most detrimental, and the quality of a sand is mainly determined by the quantity of iron contained in it.

Sand of extreme purity has been shipped from America, but that generally used in England is obtained either from Alum Bay, in the Isle of Wight, or from the Forest of Fontainebleau, in France. Fontainebleau sand is obtained in blocks from the quarries in the same manner as ordinary sandstone. The following are analyses of samples of sand from Alum Bay and Fontainebleau, and may be taken as typical of sands suited to the production of the best forms of glass:—Alum Bay: silica, 97 per cent.; alumina, magnesia, and oxide of iron, 2; moisture, 1. Fontainebleau: silica, 98·8; magnesia and oxide of iron, 0·7; moisture, 0·5.

Before admixture with the other ingredients, the sand is washed and burned. The process of washing may remove a certain quantity of extraneous dirt and chalk, but it is doubtful whether it rewards the labour expended. Burning tends to disintegrate the larger lumps, and removes all moisture and organic matter. The removal of organic matter is important, as its presence would tend to reduce a portion of red-lead to the metallic state, or to convert ferric into ferrous oxide. Burning is carried on in a special oven, in which the sand rests upon a fire-clay bed, shelving towards a central trap-door, communicating with a vault beneath. The flame plays over the sand from a fire-place on one side, towards the flue, which is placed on the opposite side to the fire-place, and in such a position that all the sand shall be subjected to the heat. When the sand has become incandescent, the trap-door is drawn, and the sand falls into the vault below. The sand is sifted, both before washing and after burning, through very fine copper-gauze sieves; it should be kept from contact with iron, and be moved only with wooden shovels.

Tests.—The best test for sand is microscopic examination. Pure sand should be perfectly white, and should not effervesce, nor lose colour, when heated with an acid; effervescence shows the presence of chalk; oxide of iron would be dissolved by boiling with hydrochloric acid, and be discovered by the ferrocyanide test. Pure sand is insoluble in all acids except hydrofluoric.

In the manufacture of common wine and beer bottles, the effect of iron is clearly seen; their dark-green tint is due to ferrous oxide, present as an impurity in the sand and some of the other materials. Even in the best samples of sand, there is nearly always a trace of iron. The injurious colouring effect of small quantities can be neutralized by the use of dioxide of manganese, or of trioxide of arsenic. A green colour is due to ferrous oxide; if this be converted into ferric oxide, the green becomes a pale-lemon tint, invisible when the quantity of iron is small. The oxidation of ferrous oxide is accomplished through the decomposition by heat of manganese dioxide. If the latter be added in excess, or if the heat be not continued sufficiently long for its decomposition, the glass acquires a pink tint, and is said to be high-coloured. From fear of producing high-coloured glass, through using excess of manganese dioxide, and from the fact that glass containing it becomes high-coloured by the continued action of sunlight, manufacturers of window-glass prefer arsenic trioxide. If this be heated with ferrous oxide, metallic arsenic volatilizes, leaving its oxygen to convert the ferrous into ferric oxide. When manganese dioxide is used, it should be specially prepared by precipitation, as the natural oxides always contain iron.

Red-lead (see Pigments).—The purity of red-lead may be tested by the microscope and by heat. A sample strongly heated in a covered crucible should leave a residue of yellow tint. The presence of iron may be detected by ordinary tests.

Carbonate of Lime ($CaCO_3$).—Chalk, the form in which carbonate of lime is used, often contains silica, alumina, and oxide of iron, combined in the form of clay, and sometimes magnesia. Chalk should entirely dissolve in dilute hydrochloric acid; any residue remaining undissolved is clay.

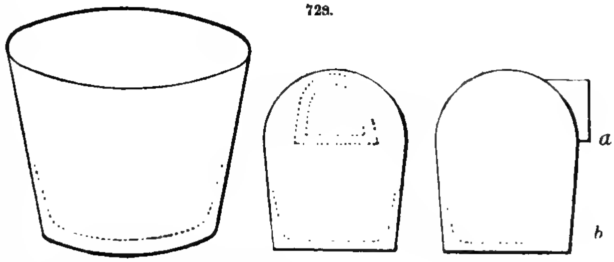
Carbonate of Potash (K_2CO_3).—Sources, (1) wood-ashes, and (2) sulphate of potassium. Commercial carbonate of potash, known as "refined pearl-ash," contains:—Carbonate of potash, 79·17; sulphate, 0·17; chloride, 0·59; carbonate of soda, 3·55; silica, alumina, &c., 0·46; insoluble, 0·01; water, 15·95.

Sulphate and Carbonate of Soda.—(Na_2SO_4) (Na_2CO_3).—Sulphate of soda is very much cheaper and more manageable than carbonate; it was, however, for a long time considered to produce glass of inferior color to that made with carbonate. As the use, whether of sulphate or carbonate of soda, involves their preparation from common salt, attempts have been made to accomplish the direct union of silica and salt in the manufacture of window-glass. At the present time, however, the only glass made from common salt is the black-bottle glass of Newcastle.

Crucibles.—Crucibles are exposed to so many dangers, both from within and from without, and their welfare is so intimately connected with the welfare of the manufacturer, that great care is expended upon their production and preservation. A crucible is exposed to the most intense heat of the furnace, as well as to variations of temperature. At the same time, it is attacked from within by the corrosive action of the raw materials, and, after fusion is completed, it is required to resist the constant pressure of the liquid glass.

The forms of crucibles are regulated by the work they have to do, as well as by the nature of the glass which they are intended to hold. Glass containing lead must always be protected from the reducing action of flame, and is therefore placed in a partially closed crucible, the opening of which is outside the furnace. Glass which contains no lead may be fused in open crucibles, and be subjected (without protection) to the full heat of the furnace. In Fig. 728, two flint-glass crucibles are shown on the right; and on the left, a crucible which can be used for crown-, sheet-, plate-, or bottle-glass. The usual dimensions of a flint-glass crucible are approximately as follows:—Entire height, 40 in.; outside diameter, 36 in.; depth inside, from *a* to *b*, 22–24 in.

728.



The dimensions of open crucibles vary considerably. For some purposes, they have a diameter of 6 ft., and a proportionate depth. In addition to the two principal forms already mentioned, there are a great variety of smaller crucibles, adapted to small furnaces, and for the production of small quantities of coloured glasses.

Crucibles are made of fire-clay; that of Stourbridge is especially noted. Those of Forges-les-Eaux, in France; Namur, in Belgium; Largenau, in Switzerland; and Schwarzenfell, in Bavaria, are also famous. (See Clay.)

A serviceable test of the quality of a fire-clay consists in forming a brick of any fresh sample, allowing it to dry, breaking the brick into two pieces, and exposing one piece in a furnace. If the two pieces unite accurately, the sample may be considered good. The "weathering" or exposure of the clay (see p. 639), in addition to causing the disintegration of the lumps, appears to make the clay more plastic and adhesive in manipulation. After the clay has been ground and sorted, it is transferred from the clay works to the glass manufactory. Here the raw ground clay is mixed with a proportion, varying from $\frac{1}{8}$ to $\frac{1}{8}$ of its weight, of ground burnt clay. The chief object in adding the burnt clay is to make the clay set quicker, and also to add to the power possessed by the clay of resisting the corrosive action of the raw materials. When the raw materials are filled into a crucible, the heat first affects the carbonate and nitrate of potash, the carbonate or sulphate of soda, and especially any borax that may be present. These materials, if in contact with the sides or bottom of the crucible, will attack the silica and alumina in the fire-clay, in preference to the sand with which they are mixed. The result is the formation on a small scale of an infusible compound of alumina, and the corresponding corrosion of the substance of the crucible. This infusible substance is the cause of the white specks, which are at times so annoying to workmen and manufacturers.

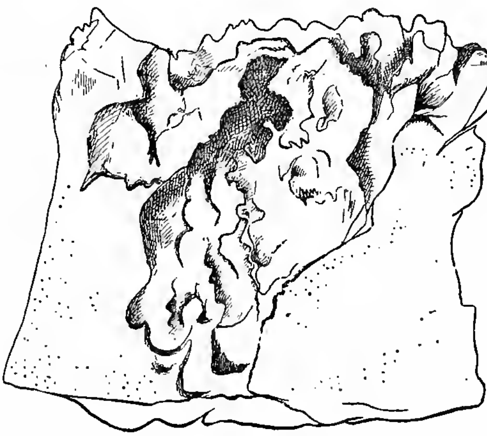
An examination of a small experimental crucible, in which borax had been fused, discovered a succession of rings eaten into the body of the crucible. It is known that if red-lead be heated by itself in a crucible for a long time, it will gradually eat its way through the crucible, extracting from it silica, and forming silicate of lead.

In order to strengthen crucibles against internal corrosion, a curve should be formed at the junction of the bottoms and wall, and sharp angles be carefully avoided. It is also advisable, before filling in the raw materials, to throw into the crucible some broken glass, which melts, and protects the bottom from corrosion. The only legitimate death of a crucible is by gradual corrosion. Fig. 729 is a view of a fragment of a bottom of a crucible, through which the glass has gradually eaten a way. The backs and bottoms of crucibles which have done good service are completely honeycombed.

After the burnt and unburnt clays have been carefully mixed through fine sieves, the mixture is placed in a large bin, and water is gradually added. After the mixture has been thoroughly wetted, it is subjected to the process of "treading." Many machines have been tried for combining the moistened clay, and increasing its tenacity; but none have at present been found capable of competing with the action of the naked feet of men. The "treader" holds on to a rope attached to the ceiling of the clay-room, and, first with one bare foot, and then with the other, presses upon the clay, which is supplied to him little by little, until the whole mass has passed under his feet at least three times. In addition to elasticity, softness, and warmth, the human foot possesses sufficient sensitiveness to detect the presence of any hard foreign matters in the body of the clay. The crucible-maker receives the clay, as he wants it, from the treader, and fashions it into small tapering rolls with the palms of his hands. A stone slab, larger in diameter than the intended crucible, is first covered with a thin layer of sand. Upon this sand, the potter places the foundations of the crucible.

The rolls of clay are carefully pressed together, until one complete layer is formed; the surface of the first layer is scratched across and across by the potter's fingers, so as to make a bond for the second layer, and the process is repeated layer by layer until the bottom is sufficiently thick. The bottom is consolidated by prolonged beating with a wooden mallet, and is finally smoothed with a wooden straight-edge. Ridges are scratched round the edge of the bottom, to form a bond for the walls; and the walls are slowly built up, roll by roll and layer by layer. The chief object in the whole process is to drive out the air from the substance of the clay. The potter presses the rolls principally with his fingers and the cushions of his hands, and works them towards the middle of the wall of the crucible, both from the inside and the outside. If the outside rolls are worked round the circumference from left to right, the inside rolls are worked from right to left. The building of one crucible is not carried on continuously: several crucibles are kept in hand at the same time, and the potter passes from one to the other, leaving one to set whilst at work upon another. However, before leaving one, he takes the precaution to cover the edge with moist cloths. The dome of a flint-glass crucible is made complete; the opening or mouth is cut out, and the lip and hood are put on afterwards. Flint-glass crucibles, although smaller than open crucibles, take longer to make, as the upright wall must be allowed partially to set, before the building of the dome can be commenced. A good potter, with three or four assistants, can finish three or four sheet-glass crucibles in one week, whereas it would not be safe to finish flint-glass crucibles in less than two weeks. Crucibles are allowed to dry in the same room in which they have been built, the temperature being maintained, by means of gas or hot-water apparatus, continuously at about 15° (60° F.). All draughts should be carefully excluded; with this object, the floor, windows, and doors should be double.

729.



When the clay is firmly set, the crucibles are cut from their stone slabs by means of a wire, and are placed upon low wooden trucks, so that they can be readily moved without jarring. Crucibles ought to stand for twelve months or more, before they are fit for the furnace. A crucible, before being placed in the furnace, requires to be gradually raised to the same temperature with the furnace. For this purpose, it is placed in an oven, constructed for the purpose, and is lodged upon three fire-clay blocks, in such a way that a low iron carriage can be thrust under it for its removal.

730.

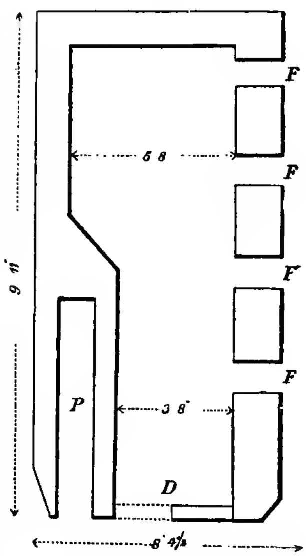
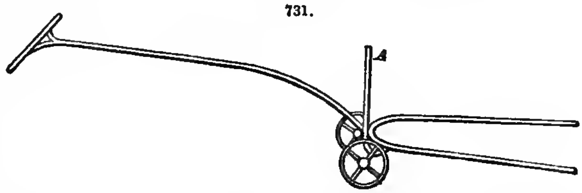


Fig. 730 is a horizontal section of a flint-glass crucible-oven, taken through the fire-place, which stands about 18 in. from the ground: F are the openings to flues; P, the fire-place; D, air-tight doors. Fig. 731 represents the iron crucible-carriage. When the crucible is first placed in the oven, the dampers of all the flues should be closed, and the fire be allowed only to smoulder. After 3–4 days, the flues may be gradually opened, and the fire be increased until on the 7th–8th day; when the heat of the oven is equal to the heat of the furnace, the crucible may be moved into the furnace. Probably more crucibles are broken by carelessness in the management of the flues of the oven than in any other way.

The removal of an injured crucible from the bed of a furnace, the preparation of the bed, and the setting of the new crucible in the place of the old, are operations which require very great presence of mind, and physical strength and endurance. The temporary brick-work, which acts as a screen in front of the crucible, has to be removed piece by piece. Finally, the whole arch, under which the injured crucible stands, is laid open, and the workmen are exposed to the full heat of the furnace. In order to soften any glass which may have found its way on to the bed of the furnace, and which might tend to seal the broken crucible to the bed, the furnace is driven to its utmost heat. The tools, with which the workmen accomplish their task, are of the simplest description, being merely diamond-pointed or chisel-edged steel crowbars, of various lengths and sizes. The arch having been laid open, the crucible loosened and raised from the furnace-bed, and the parts of the bed on each side of the crucible levelled and smoothed, the crucible is drawn forwards by means of iron bars and rakes; it is thrust upon the crucible-carriage, removed, and broken up. The levelling of the bed is effected either by a long iron pointed bar, resting upon a fulcrum, and worked by several men, or by separate blows dealt by relays of men, each man being armed with a light crowbar. Part of the broken crucible is preserved, and ground, for mixing with the raw clay, in the manufacture of crucibles. The remainder is used for building up the screen in front of the new crucible, which takes the place of the one removed. After the old crucible has been removed, it is customary to repair any defects in the furnace-bed with lumps of moist fire-clay, and to spread a layer of sand for the new crucible to rest on. The doors of the oven are now thrown open, and the driver of the carriage thrusts its prongs under the crucible, depresses the handle, raises the crucible from its supports, withdraws it from the oven, and carries it to the furnace. The prongs of the carriage bearing the crucible being half-way within the arch of the furnace, the wheels are blocked, and two men, using the upright post A of the carriage (Fig. 731) as a fulcrum, gradually, by means of bars, force the crucible into the position which it is intended to occupy. The screen is now rebuilt, partly with fire-clay slabs made for the purpose, and partly with the debris of the broken crucible, moist fire-clay, and fire-bricks.

731.



Before the new crucible is fit to receive the raw materials, it requires to be glazed internally with hot glass. If the process of setting has been at all prolonged, or if the crucible, during its passage from the oven to the furnace, has become chilled, or if the crucible has not attained in the oven to the same temperature as the furnace, there is every probability of its being found to be cracked. The duration of crucibles is very uncertain, they may stand for 6–12 months or even longer, and they may crack in the first week after setting. If the furnace becomes chilled, or if the grate is insufficiently covered, and allows cold air to rush upon the crucibles from the cave below, the crucibles run a great risk of being cracked. The crack is not usually discovered until the furnace regains its heat, and the liquid glass finds its way through the crack and on to the grate. The bars of the grate have to be widely separated, to allow the glass to fall through; and if, as usually happens, the air be allowed to rush up through the gap, the breakage of one crucible is very likely to be the cause of the destruction of others. Cracks in crucibles may be stopped by exposing them to the air, and allowing the exuding glass to cool and solidify into an effectual lute.

This remedy applies to the whole circumference of an open crucible, but only to the front of a flint-glass crucible, and in neither case is it of any avail for a cracked base. When a new furnace is to be lighted, new crucibles are sometimes placed in position, and heated with the furnace. Such great losses have, however, been incurred by this means, that there are very few manufactories in which this plan is carried out.

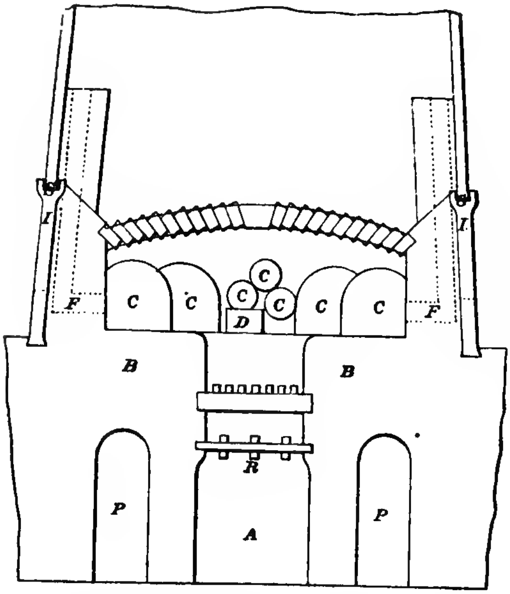
In a glass manufactory, fire-clay is used for a great variety of purposes, in addition to the construction of crucibles. In all building operations, connected with the furnace, kilns, ovens, &c., fire-clay is used in place of mortar, as well as for the bricks. A fire-clay ring, formed of two half-circles, measuring about 2 in. in thickness, forming an internal opening of about 8 in. in diameter, is sometimes allowed to float upon the surface of the molten glass in a crucible, so as to attract impurities, and to secure a space of pure metal for working purposes. The mouth or opening of a flint-glass crucible is always provided with a movable door or stopper of fire-clay, covering the whole aperture, as well as with a collar or horse-shoe of the same material, which is used, when work is being made, or glass gathered, in order to leave the crucible open, and, at the same time, to diminish as much as possible the loss of heat. The slabs and bricks for building the screen in front of the crucible have already been referred to.

Furnaces.—In a glass manufactory, the furnace is by far the most important structure. It is not too much to assert that upon the furnace depends the whole life of the manufactory. A variety of furnaces are employed. The annealing-kilns will be noticed hereafter. In sheet-, crown-, and some flint-glass works, in addition to the main furnaces, annealing-kilns, and crucible-ovens, small auxiliary furnaces for various purposes are largely used. All manipulation of glass requires heat, and it is found to be more economical to erect small separate auxiliary furnaces for manipulative purposes, than to utilize directly the heat of the main furnaces. Where auxiliary furnaces are used, the whole heat of the main furnace can be employed in fusing successive charges of raw materials, and furnishing a continuous supply of molten glass ready for use. Where they do not exist, the workmen stand round the main furnace, and heat the glass which they are manipulating, either at openings over or at the side of the crucibles, or in the mouths of the crucibles themselves. This is the usual arrangement in flint-glass works, where the glass is worked much more slowly than in sheet- or crown-glass works, and where, consequently, it is seldom necessary to recharge the crucibles. It is, however, objectionable, even in flint-glass works, as a workman usually monopolizes the crucible in front of which he happens to stand, and prevents other workmen from gathering glass from out of it. Moreover, for the manipulation of large goods, a proportionately large opening is necessary, and space which ought to be continuously utilized for the production of molten glass is left permanently vacant for the purposes of manipulation, which can only be carried on for a comparatively short time. In the manufacture of sheet- and crown-glass, an intense heat with flame is requisite, a result which can be more conveniently gained at an auxiliary than at a main furnace. The flues of these auxiliary furnaces are usually run into the shaft of the main furnace. The heat and consumption of fuel of auxiliary furnaces can be reduced so soon as the work at them ceases. In crown-glass works, the auxiliary furnaces are known as "nose-holes," and are used for fashioning and expanding the circles or tables. In sheet-glass works, they are used for forming and opening the cylinders. In flint- and bottle-works, for general manipulation, and especially for large work. In some old-fashioned flint-glass furnaces, a wide-mouthed crucible, in which the heat is augmented by burning beechwood logs, is set apart for the manipulation of all large goods of best quality. The heated glass is cut off, by the hood and back of the crucible, from fumes generated by the coke or coal burnt in the furnace, which fumes are apt to mar the brilliancy of the glass, and to interfere with the amalgamation of the various parts of any vessel which is being produced. It is, however, to the main furnace that attention ought principally to be directed. The chief points to be arrived at in building a furnace are—(1) durability, (2) regularity, (3) production and concentration of intense heat, (4) economy of fuel. It must be borne in mind that the heat of a glass furnace is maintained continuously, and that a furnace is expected to last for at least three years. To attain a satisfactory result, great care and experience are required both in the selection of the materials and in the construction of the furnace. Economy of fuel has been placed last, as, although it is a very important point, it is, nevertheless, of considerably less moment than the first three. Good glass cannot be produced by an irregular furnace. There may be intense heat, and fusion may be satisfactorily performed; but if the furnace be irregular, every variation will be registered in the substance of the glass, and an imperfect striated mass will be the result. Variations of temperature are also fatal to the existence of crucibles. If a furnace grows cold, and suddenly picks up and becomes intensely hot, the crucibles are almost certain to crack. There are no troubles more harassing to glass manufacturers than "cordy" glass and broken crucibles. It is essential to the well-being of a factory that the glass shall be ready to be worked at stated times, and this result will be rendered impossible by the irregularity of the furnace. For these reasons, manufacturers and workmen alike look shyly upon innovations.

Fig. 732 is a sectional view of one half of an old-fashioned circular furnace; Fig. 733 is a ground plan of the same taken at the level of the bases of the crucibles. The passage A runs under the grate G of the furnace, and is connected at both ends, either directly or by cross passages, with the outer air. This passage introduces the air necessary for the consumption of the fuel. From this passage, the stoker is able to stir the fire from beneath, and into the passage, fall the cinders and slag, and the lost glass from broken crucibles. P is a small passage, opening at each end of the grate into the main passage, and enabling the stoker to pass from one end of the grate to the other, without going immediately under the furnace. R is an iron rest to support the bars used for stirring the fire. D is a small iron door for charging the grate with fuel, which is thrown in by a shovel, or forced in by a long rake. The crucibles C rest upon the bed B. The clinker, when coke is used, is thrown into the furnace by the stoker, in the form of lumps of broken gas-retorts; but when coal is burnt, it is formed by the coagulation of spent coal. The clinker plays an important part, both in regulating the draught, and in protecting the iron bars of the grate from the heat of the fire. It is one of the stoker's most urgent duties to attend to the condition of the clinker. There must be enough, and not too much; and what there is must be continually moved, in order to prevent the bottom of the furnace becoming impervious to air. Iron staves I, at each side of every opening of the furnace, carry a continuous iron ring s, upon which the cone of the furnace is supported. Flues F stand on each side of the charging-door and of all the large crucibles. These flues can be cleaned through small doors opening outwards. They are arranged so as to draw the heat, after it has struck the crown of the furnace, all round the lower part of the crucibles. The dome or crown Z is kept as flat as possible, in order to economize heat.

Furnaces are usually built of moulded fire-clay blocks; shaped blocks, for building complete furnaces, are kept in readiness at clay-works. The blocks are dried, but not burnt, and are therefore comparatively yielding; every block is rubbed against its immediate neighbours, until an impervious joint is formed. In building the crown, the work commences at the outside, and no supports or centres are used. So soon as the blocks forming the outermost ring of the crown have been rubbed into position, they are firm enough to support a man's weight. The blocks for the next

732.



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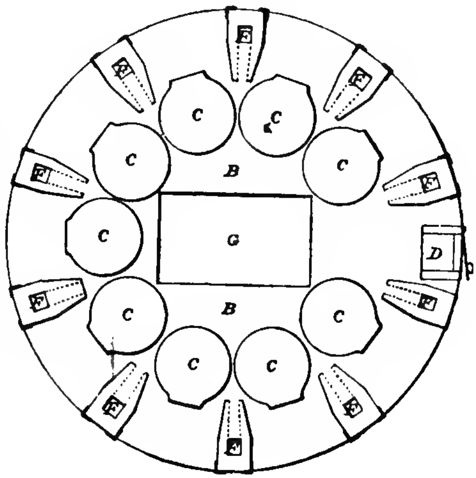


ring are one by one fitted with clips at top and bottom. A man, standing on the outside ring, holds the upper clip, and a man on the base of the furnace the lower. The block is then sawed up and down against the outer ring, and seems to adhere to it more and more, until it becomes permanently fixed. In this manner, the crown is built concentrically block by block. In furnaces in which open crucibles are used, great care must be exercised in the selection of the blocks of which the crown is formed. If use be made of a material which, when exposed to intense heat, crumbles, even to a small extent, the glass in the crucibles is liable to be spoiled. In sheet- and plate-glass works, it is common to employ Dinas' silicate blocks, which appear to be practically indestructible. In building a furnace, the only cement or medium is a mixture of finely ground fire-clay and water. After the furnace has been built, it requires to be gradually warmed, before it is fit to withstand the intense heat necessary for the complete fusion of glass. For this purpose, the whole of the eye of the furnace, from the grate-bars to the surface of the bed, is tightly packed with coal or coke dust, which is lighted at the top, and allowed to smoulder. It takes 4–5 weeks to raise a furnace with safety to its full heat.

The crown and the base of the furnace are the parts most liable to wear out. The crown, especially when it is very flat, sometimes "gives," and one or more of the crown blocks fall in. When this happens, the opening must be temporarily covered with large fire-clay slabs and moist clay, and another furnace must with all speed be lighted and prepared to receive the crucibles. Dirt and soot accumulate on the outside of the crown, and, by keeping the crown unnecessarily hot, assist the corroding action of the flames within. For this reason, the crowns should be kept clean. The base or bed of the furnace must gradually wear away, and the duration of the bed usually determines how long the furnace shall remain at work. A point must sooner or later be reached when the base will be so reduced in width as no longer to afford a safe resting place for the crucibles. It is unwise to shirk the expense and trouble of lighting a fresh furnace, when there arises the slightest risk of losing crucibles and glass. It is customary, whenever a new crucible is set, to effect repairs in a damaged bed, by means of lumps of wet fire-clay, applied at the end of long iron shovels. It is, however, doubtful whether such repairs afford sufficient advantage to compensate for the labour expended on them.

Figs. 734, 735, and 736 are respectively a vertical section, a ground plan, and a horizontal section through its bed, of a furnace, the arrangement of which is intermediate between those of an old-fashioned furnace and a gas-furnace. The fuel is introduced at the ports A, and makes its own way down to the grate-bars B. By the fuel passing through and under the base, crucible space is gained. The partial combustion of the fuel upon the grate-bars generates a gas, which burns with intense heat, when brought into contact with the air, introduced by the passages P cut through the base, Fig. 736. By reason of the combustion of the fuel taking place beneath the base, it is possible to reduce the size of the eye of the furnace, and, in this manner, to increase the width of the base, and consequently the duration of the furnace. The heat is directed by the flues in such a manner as to surround the crucibles C, as in the furnace just described.

734.

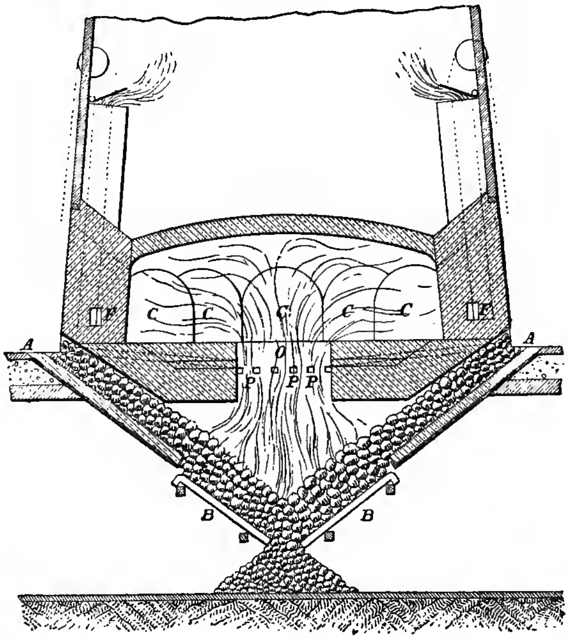
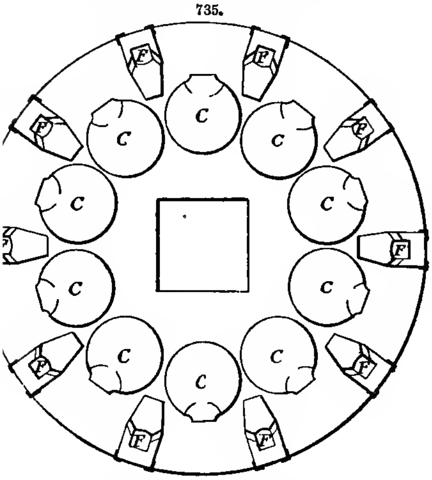


Fig. 737 represents an arrangement known as Boetius' furnace. It was the forerunner of the last, and is very similar to it. The chief difference is that air is introduced through a perforated column *b*, as well as through the air-passages *a* in the base. The gas and air unite and burn at *c*. The disadvantage of the central column is that any glass which may escape from a broken crucible is retained by the column, and can be removed only with great difficulty.

Frisbie's Feeder. — Frisbie's patent feeder provides a method of stoking from beneath the fire, and effects a considerable saving in the consumption of fuel. By this principle of feeding from below the fire, the igniting of the fresh coal is a gradual process, and all volatilized coal, combustible gas, and carbonaceous matter pass from below, through the live coals above, and break at once into flame; thus perfect combustion, and great intensity of heat, are secured. The heat of the surface of the fire is not abated,

735.



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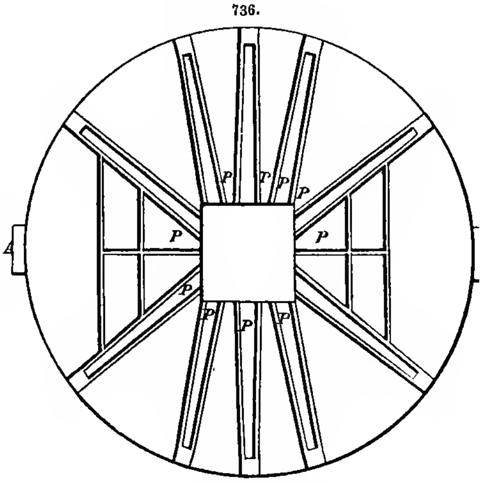
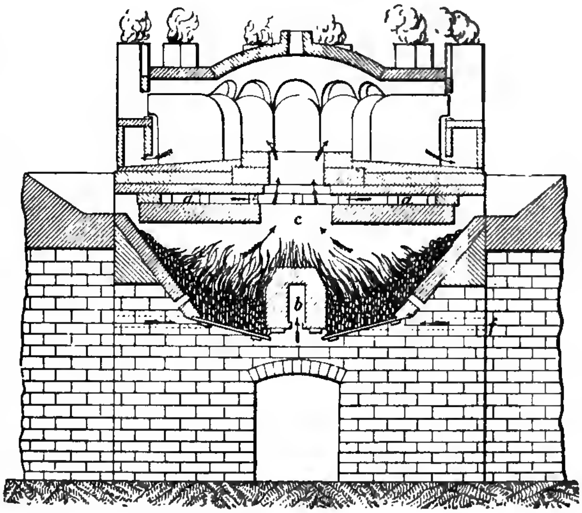


nor is cold air admitted into the furnace while supplying fresh fuel, so that a perfectly uniform heat is maintained; and, as the hottest portion of the fire is constantly at the top, all the heat is utilized, and the grate-bars are preserved from burning and from clinker. The coal is pushed up and outwards equally from the centre of the grate, and the whole fire is stirred and broken up at each fresh supply of fuel, so that no raking is required, and the coal is evenly consumed, leaving little refuse, except fine ashes which drop down through the grate-bars without raking. Figs. 738 and 739 show, in vertical section, the respective positions when feeding and not feeding: A is the opening through the grate; B, hopper; C, movable bottom; D, plunger to feed-hopper; E, plunger-lever; F, apron sustaining coal while the hopper is being refilled; G, rocking-bar, attached to H and K; H, rocking-shaft; I, hand-lever for working H; K, lever carrying hopper backwards and forwards; L, catch; M, arm supporting hopper and apron; N, shaft supporting M.

737.



Siemens' Regenerative Gas-Furnace.—The gas-producer is shown in Figs. 740 and 741; the former is a section, and the latter a front elevation, of a pair of gas-producers. The producers are entirely separate from the furnace where the heat is required, and may be made sufficient in number and capacity to supply several furnaces. The fuel is supplied at intervals of 2–4 hours, through the charging-boxes A, and descends gradually on the inclined plane B, which is set at an inclination to suit the fuel used. The upper portion of the incline B is made solid, being formed of iron plates covered with fire-bricks; but the lower portion C is an open grate formed of flat horizontal steps. The large opening under the lowest flat step is convenient for drawing out clinkers, which generally collect at that point. The small stoppered holes F at the front, and G at the top, of the producer, are provided to allow the insertion of an iron bar to break up the mass of fuel, and detach clinkers from the side wall. Each producer is capable of converting daily about two tons of fuel into combustible gas, which passes off through the "uptake" H leading to the furnaces. The action of the gas-producer is as follows:—

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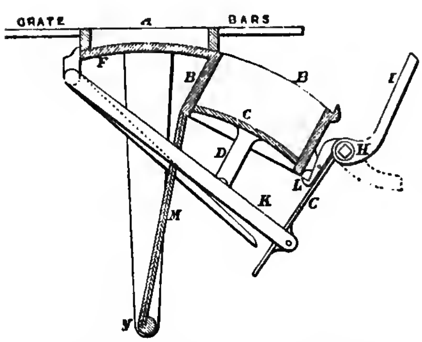

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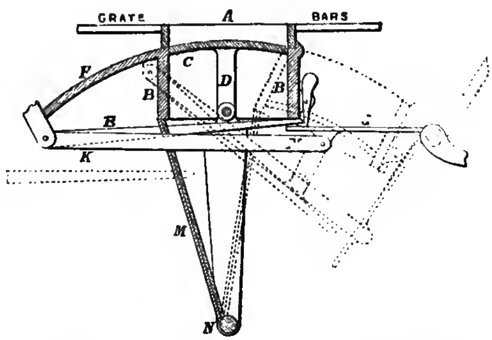
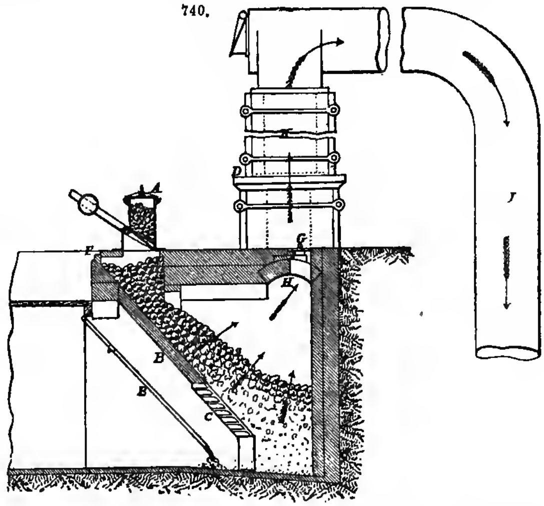


The fuel, as it descends, becomes heated, and parts with its volatile constituents,—namely, the hydrocarbon gases, water, ammonia, and some carbonic acid. There now remains 60–70 per cent. of purely carbonaceous matter to be disposed of, which is accomplished by the action of a current of air slowly entering through the grate C, producing regular combustion immediately upon the grate. The carbonic acid thereby produced, in passing slowly through a layer of incandescent fuel, takes up another equivalent of carbon, and becomes carbonic oxide, which passes off with the other combustible gases to the furnace. Water may be brought to the foot of the grate by the pipe E; this water, absorbing the spare heat of the fire, is converted into steam, which, in its passage through the incandescent fuel, may be decomposed into its elements, after having performed the useful office of disintegrating the clinkers. The total production of combustible gases varies with the admission of air, and since the admission of air depends upon the withdrawal of the gases, the production of gases depends upon the demand for them. A damper D can be inserted in the "uptake," so as to shut off any gas-producer at pleasure.

Fig. 742 is a diagram of a regenerative gas-furnace. Underneath the heating-chamber K, are placed four regenerative-chambers L, which are filled with fire-bricks, built up with spaces between them. The regenerative-chambers work in pairs, the two under the left-hand end of the furnace communicating with that end of the heating-chamber, while the other two communicate with the opposite end. The gas enters the heating-chamber through the passage M, and the air enters through the passage N, whereby they are kept separate up to the moment of entering the heating-chamber, but are then able immediately to mingle intimately, producing at once an intense and uniform flame. From the air-flue, the entering air is directed by the reversing-valve P into the air-regenerator, and there becomes heated ready for entering the furnace; at the same time, the gas entering from the gas-flue is directed by the reversing-valve R into the gas-regenerator, where it also becomes heated to the same temperature as the air. The products of combustion, on leaving the opposite end of the furnace, pass down through the second pair of regenerators (as shown by the arrows), and, after being there deprived of their heat, are directed by the reversing-valves P R into the chimney-flue. When the second pair of regenerators have become heated by the passage of the heated products of combustion, and the first pair cooled by the entering of gas and air, the valves P R are reversed by hand-levers, causing the currents to pass through the regenerators in the contrary direction, whereby the hot pair of regenerators are now made use of for heating the gas and air entering the furnaces, while the cool pair abstract the heat from the products of combustion escaping from the furnace. The supply of gas and air to the furnace is regulated by the stop-valves S S^1, whereby the nature of the flame in the furnace may be varied at pleasure, whilst a chimney-damper T is used to regulate the amount of pressure in the furnace in relation to the atmosphere, so as to allow the opening of the doors or working-holes of the furnace.

740.



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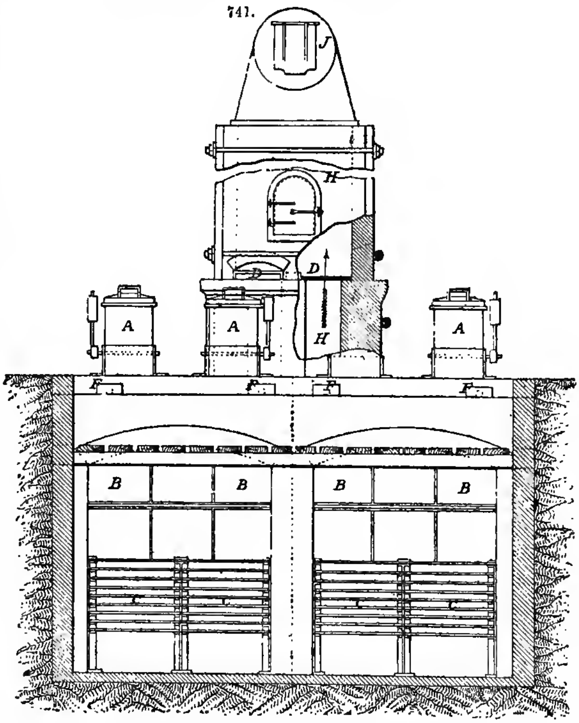

Fig. 743 shows the application of the regenerative gas system to a flint-glass furnace. The advantages of the regenerative gas-furnaces are:—(1) saving of fuel, both in quantity and quality; (2) great cleanliness in the manufactory; (3) complete command of the heat.

Annealing-ovens.—The simplest and oldest arrangement for annealing is a tunnel, about 30 ft. in length, either provided with a lateral fire at one end, or heated (as at the Murano works) by the waste heat from the melting-furnace, and having a tramway, with movable trucks for the goods, running down the centre. The trucks are mounted on small solid iron wheels, protected from the

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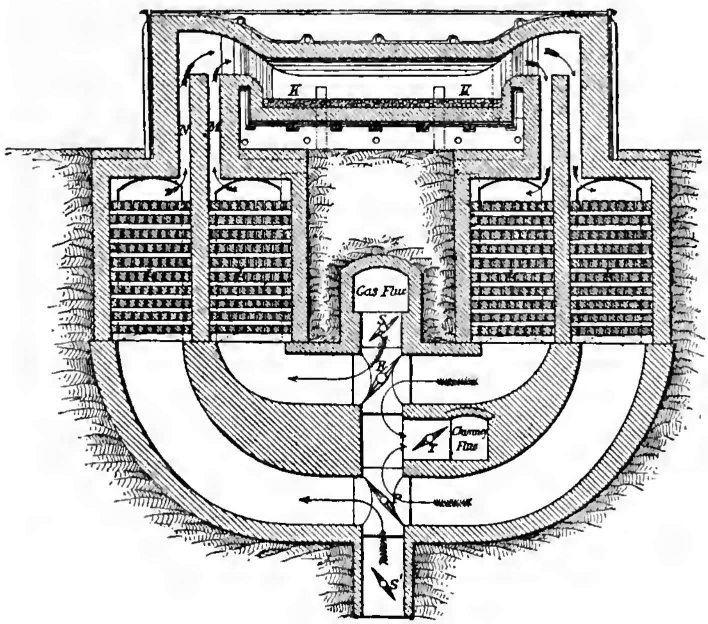

fire by the projection of the body or pan of the truck, and are moved by an endless chain and a windlass; the pans are provided with hooks, so that they can be fastened together, to form a continuous train. Figs. 744 and 745 are different views of such an arrangement. Fig. 746 is a section, showing a tramway, beneath the main tramway, on which the pans or trucks, after they have been emptied at the end of the tunnel farthest from the fire and the glass-house, are returned to the glass-house by means of an endless chain. The pans are piled one upon another, and the lowest is hooked into the endless chain, by which they are drawn from one end of the tunnel to the other.

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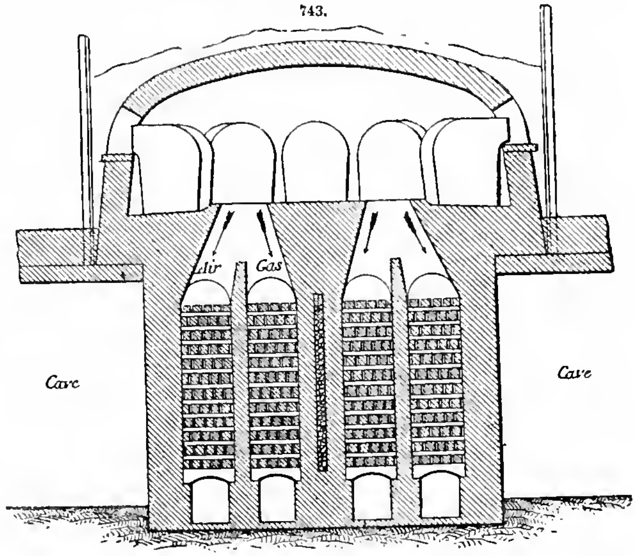
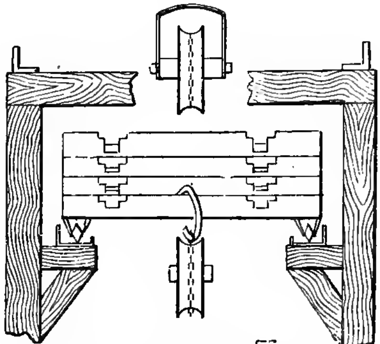


Another arrangement for accomplishing the same purpose, of which Fig. 747 is a bird's-eye view, is a flat, horizontally-revolving iron wheel, worked upon the same principle as a turn-table. The diameter of the wheel is about 25–30 ft. The goods are placed upon the wheel at A, and are carried by the wheel away from the fires B to C, where they are removed and sorted. This is a very perfect arrangement, and works continuously. Its disadvantage is the large amount of space in the centre of the wheel, which is practically useless.

Yet another arrangement for annealing glass has been devised by Dr. C. W. Siemens. According to this invention, glass to be annealed is placed on a travelling furnace-bed mounted on wheels, and heated in a permanent furnace. When this truck is filled, it is wheeled out of the furnace, and over it is immediately placed a cover, the edges of which are so immersed in sand as to prevent all access of air. The truck is then wheeled away and allowed to cool, whilst another is put in its place in the furnace. Fig. 748 shows a section on the line 1 1 of Fig. 749, which is a section on line 2 2 of Fig. 748. The kiln or stove is composed of a fixed brickwork heating-chamber A, and a movable bed or truck B, in which are placed the articles to be annealed. The truck is constructed of sheet metal, the sides being provided with internal ribs B^1, to prevent the glass articles from coming into direct contact with them, while the bottom has a layer or lining B^2 of sand or other suitable non-conducting material; it is mounted on wheels C, which travel upon rails, as shown, so that it can be readily run into and out of the kiln. The truck is open at the top and inner end, so that, when in position in the kiln, the flames or hot gases issuing from the ports A^1 on either side can play freely into and over the whole surface of the floor, before escaping through the openings A^2 to the chimney D. When the truck is in position in the kiln, a close joint is formed between the two, by means of sand-troughs E on the sides of the truck, into which clip flanges F, fixed to the brickwork of the kiln. When in this position, the interior of the truck is first heated to the required temperature, and the articles to be annealed are introduced into it through the openings G, which are then closed by covers. When a truck has been filled, and the articles have been subjected to the heat of the stove for a sufficient length of time, the former is withdrawn, and its open end and top are immediately closed by the hood or cover H, suspended close in front of the kiln, the flanges of which hood dip into the sand-troughs E E^1, so as to form a close joint; the truck, thus forming a closed chamber, is then run to any convenient locality, where it and its contents are allowed to cool. The hood is then removed; and, after the glass has been taken out, the truck is again ready for use. The combustible gas for heating the kilns passes from the main channel I, leading from a gas-generator, up through the flues J, to the openings A^1, where it meets the air entering through passages K. Slides L and L^1 are provided for regulating the supply of gas and air to the kiln, or cutting it off

746.



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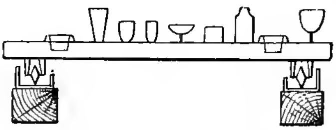
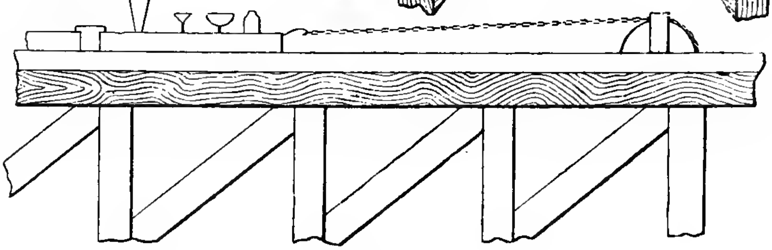
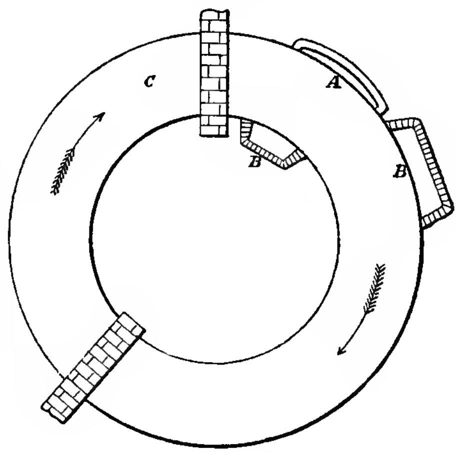




744.

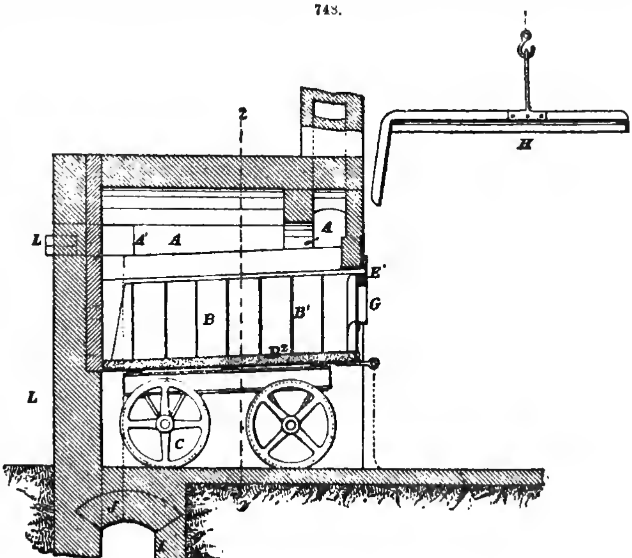
747.

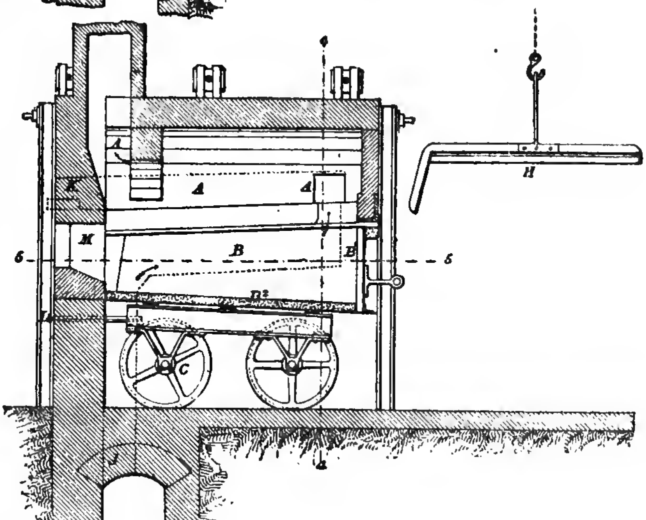


when a truck is moved. The space beneath the truck B being quite open to the atmosphere, the under-framing and wheels are kept sufficiently cool to prevent injury.

Figs. 750, 751, and 752 show respectively a section on the line 2 2 of Fig. 748; a section on the line 4 4 of Fig. 749, and a sectional plan on the line 5 5 of Fig. 749, of another form of truck-kiln. In this last, the truck B has no charging-openings at its front end, but is charged through the openings M in the end wall of the stove. It is provided with double sides B^1 (of which the inner may be perforated), with an intervening air-space, by which the glass articles are prevented from becoming unequally cooled by direct contact with the outer skin, which is cooled by the atmosphere. The gas- and air-ports A^1 in this arrangement are at the front end of the kiln, J and K being respectively the gas- and air-flues leading to them, and the chimney-flue A^2 is at the back end. The other parts are similar to those previously described, and are indicated by similar letters of reference. The results of Dr. Siemens' arrangement may be rendered still more satisfactory, especially for heavy solid goods, by completely covering the glass, when placed in the annealing-oven, with heated sand. The strength of glass thus treated surpasses that of "toughened" or "hardened" glass.

748.





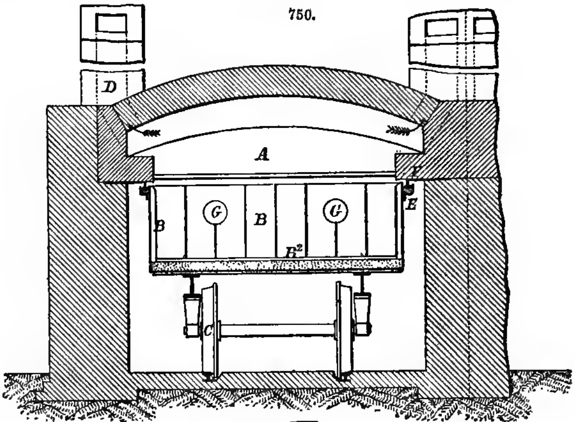
749.

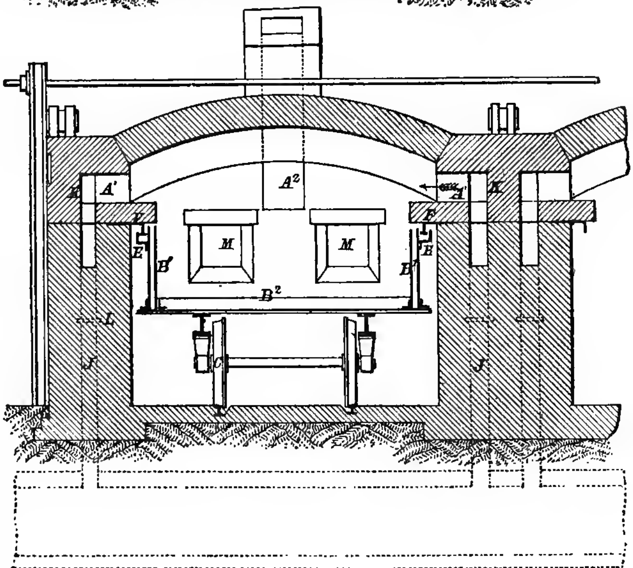
Plate-Glass, Crown-Glass, Sheet-Glass.

	SiO_2.	K_2O.	Na_2O.	CaO.	MgO.	Al_2O_3. Fe_2O_3.
PLATE-GLASS.						
St. Gobain plate-glass	73·00	..	11·50	15·50	..	..
English "	77·90	1·72	12·53	4·85	..	3·59
German "	78·75	13·00	6·50	..	..	1·75
Venetian "	68·60	6·90	8·10	11·00	2·1	1·50
CROWN-GLASS.						
English crown-glass	71·40	..	15·00	12·40	..	0·60
German "	73·11	..	13·00	13·24	..	0·83
SHEET-GLASS.						
French sheet-glass	71·90	..	13·10	13·60	..	1·40
English "	70·71	..	13·25	13·38	..	1·92
German "	71·56	..	12·97	13·27	..	1·29

The glasses whose percentage compositions have been given, may be regarded as mixtures of the sodio and calcic silicates, and may be generally represented by the formula Na_2O, CaO, $6SiO_2$. It is true that the English, German, and Venetian plate-glass contain, as shown above, considerable proportions of potash; but the French plate-glass, which, until quite recently, has surpassed every other kind of plate-glass in quality, is strictly a mixture of the sodic and calcic silicates, and it will be more convenient to consider plate-glass with crown- and sheet-glass, than with Bohemian glass, with which, except for the presence of potash, it has little in common.

750.





751.

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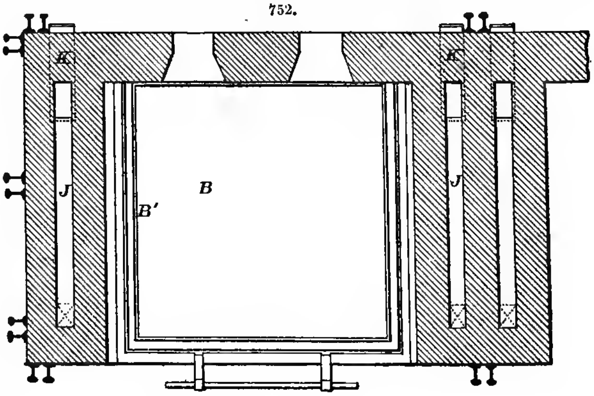


The materials used in the composition of these glasses are:—(1) white sand, as free as possible from oxide of iron; (2) sodic carbonate, or sodic sulphate. If the latter be used, it must be mixed with one-tenth of its weight of carbon, in the form of charcoal or coal-dust; the carbonate is supposed to produce a better coloured glass than the sulphate, and for this reason, its use has, until quite recently, been retained in the manufacture of plate-glass; (3) slaked lime, or chalk; (4) arsenic trioxide, the use of which is preferred to manganese dioxide. The ingredients, having been thoroughly incorporated, are, without further preparation, introduced into the crucibles in which they are to be melted. When barilla, kelp, and other forms of crude alkali were in use, it was the custom to subject the materials to preliminary fusion in a reverberatory furnace, thereby effecting partial decomposition, and the burning off of carbonaceous impurities. The introduction of the use of the carbonate or sulphate of soda has rendered this treatment superfluous.

The crucibles are open reservoirs, and vary in form and size according to the purposes for which they are intended. Plate-glass crucibles have either grooves or projections on their outer surface, to afford a firm grip to the iron "claspers," or forceps, by which they are raised for the purpose of casting their contents. Fig. 753 is a sectional view of a gas-furnace, arranged for melting sheet- or crown-glass: C are crucibles; G, G[1], gas-ports; R, R[1], regenerators; A, air-ports. The furnace is oblong. The crucibles stand on the furnace-bed, and immediately within arches, which are temporarily closed. Through these arches, new crucibles are introduced, and injured ones withdrawn, and, in plate-glass works, the crucibles are removed and restored respectively before and after each casting. In crown- and sheet-glass manufactories, when the crucible is in position, the opening of the arch is closed up to a point level with the upper edge of the crucible. Above this point, one or more spaces are left for the convenience of working, and are so arranged as to be readily closed by movable fire-clay slabs or stoppers. Plate-glass crucibles are enclosed by movable doors, by the removal or replacement of which, the entire arches can be quickly laid open or closed. With the exception of the manner in which the arches are closed, and of the absence of grooves on the outside of the crucibles, Fig. 753 represents also one of the best forms of plate-glass furnace.

753.

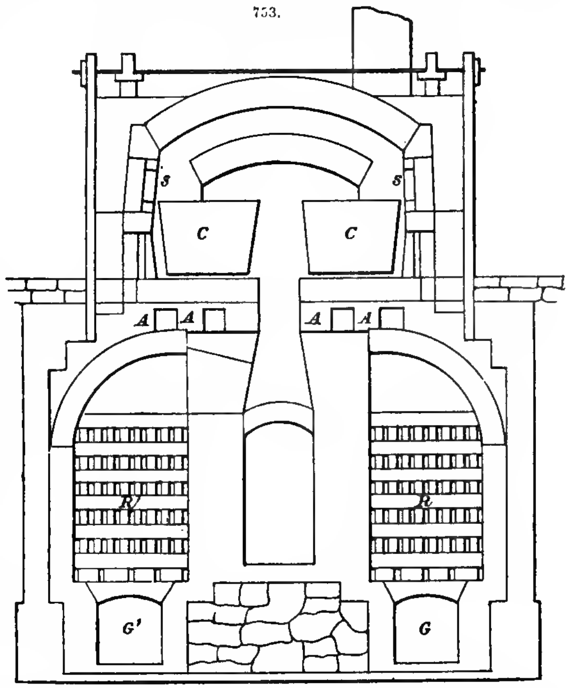


Plate-Glass.—The great thickness of plate-glass, and the uses to which it is applied, viz. the regular transmission and reflection of light, necessitate the utmost care in the selection and manipulation of the raw materials. The manufacture of plate-glass depends upon the fluidity of molten glass, and the readiness with which, in the viscous condition, glass acquires the form of any resisting surface, and, at the same time, yields both to the superimposed pressure of an advancing roller, and to any resisting boundaries which may be set to regulate its extent and thickness. After the complete fusion of the glass, there are seven processes:—(1) the pouring of the molten glass upon a flat iron table; (2) the passage of the roller over the molten glass; (3) the annealing of the glass; and (4, 5, 6, 7) the trimming, grinding, smoothing, and polishing of the glass.

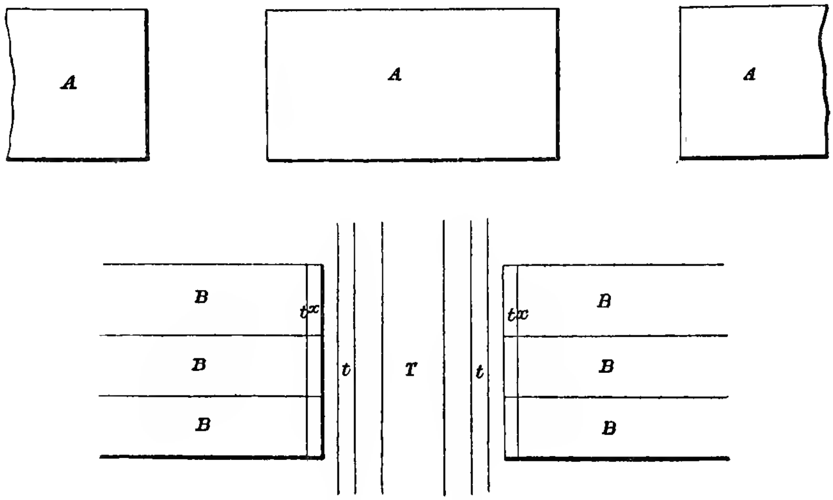
In each plate-glass manufactory, there are different arrangements and different processes. The following description does not refer to any one in particular, but is a selection from various manufactories. The aim of every arrangement and process is the production, with the greatest economy of labour, fuel, material, and time, of the largest number of plates, of great size, strength, and purity of composition, with surfaces parallel to each other, and perfectly reflecting.

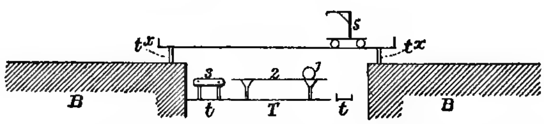
In the accompanying plan and section of a casting-house (Figs. 754 and 755), A represent oblong furnaces; B, annealing-kilns; T t t^x, tramways for various purposes; (1) is the roller; (2) the casting-table; (3) a small movable table, on a level with, and interposed between, the casting-table and the bed of the annealing-kilns. This last works on the tramways t, and can be brought opposite to the mouth of any of the six annealing-kilns B. It is intended to facilitate the removal of the hot plate from the casting-table to the bed of the kiln. To avoid the necessity of pushing the glass, it may be furnished with an endless band of copper gauze, revolving upon two rollers.

A wide carriage or truck (4) runs upon a tramway, the rails t^x of which are respectively placed on the summits of the two sets of kilns, at right angles to the direction of the kilns; (5) is a crane on wheels, movable from one end to the other of the large truck (4). The crane supports the crucible from which the molten glass is poured, and moves with the crucible in advance of the roller. The large truck (4), with the travelling crane, can be moved so as to impend over the casting-table, placed at the mouth of any of the kilns B.

The casting-table (2) is of cast-iron, with a highly polished surface. It must exceed in size the largest plate of glass it may be desired to prȯduce. The average size is 20 ft. by 8–10 ft. The table rests upon a carriage, the wheels of which move upon a tramway. The roller (1) is usually of cast-iron, hollow, well-polished, and slightly concave. Its length corresponds with the width of the casting-table. It can be moved over the table either by handles at each end, or by spur-wheels working into gearing at one side of the table. It is placed at the extremity of the

754.





755.

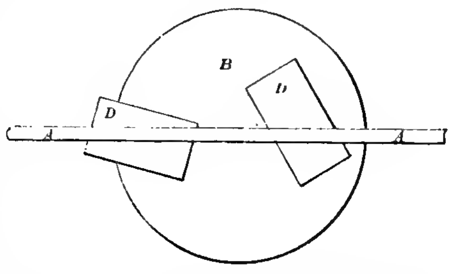
casting-table furthest from the mouth of the annealing-kiln. The thickness and width of the plates of glass are regulated by two plates of cast-iron, bolted together at their ends, and so adjusted to the curvature of the roller, that the roller and the two plates form three impenetrable resisting sides to the molten glass. The thickness of these plates determines the thickness of the glass, and the distance between them determines the width. The windows and doors of the casting-house must be so fitted as tȯ exclude the possibility of sudden currents of cold air, which might interfere with the process of casting. The time required for the complete fusion of the raw materials, and for the refining of the glass, varies, with the construction of the furnace, from 12 to 24 hours.

The size and number of the annealing-kilns are determined by the quantity of glass produced by the furnaces. When very large plates are cast, it is necessary to anneal each plate in a separate kiln, the plate resting on the bed of the kiln. Smaller plates may be placed on movable trucks, running on a tramway in the kiln; in this case, the number of plates in each kiln is regulated by the number of trucks the kiln can contain. Small plates may also be stacked on their edges, so soon as they have cooled sufficiently not to bend. The time required for annealing plate-glass depends upon the size and thickness of the plates; 5 days may be considered as the average time. The process of cooling may be hastened by gradually admitting cold air, to circulate in channels running under the bed of the kiln. The doors of the kiln also are so arranged as to open piece by piece, with a view to the gradual admission of the outer air. The doors, however, should not be opened at all, until the glass has been in the kilns for 2-3 days. Before casting commences, the kiln or kilns are heated to dull-redness, and a layer of sand is spread over the bed of the kilns, or the bottom of the trucks. The casting-table and roller are cleaned, polished, heated, and placed opposite the kiln, and the "carrying"-table is interposed between the mouth of the kiln and the casting-table. The large truck, carrying the movable crane, is wheeled up, so as to be over the side of the casting-table farthest from the furnaces. The end of the crane projects over and beyond the end of the casting-table farthest from the mouth of the kiln. In the meantime, the screen or door protecting one of the crucibles has been removed, the glass has been skimmed, and the base of the crucible has been loosened from the bed of the furnace. The crucible is raised, and moved from the furnace by a large iron projecting fork, supported on wheels. The opening into the furnace is closed. The crucible, having been scraped free from incrustations, is carried to the end of the casting-table, and immediately under the crane. The "claspers," attached to the crane by chains, are fixed firmly in the grooves, or under the projections on the outside of the crucible. The crucible is raised by the crane from off the forked chariot, carried over the casting-table, and immediately in front of the roller. It is tilted sufficiently to allow the glass to pour, and is moved by the forward motion of the travelling crane, so as to supply a continuous flow of molten glass immediately before the advancing roller. The crucible, so soon as the best of the glass has been poured out, is replaced on its chariot, and, if still uninjured, carried back to the furnace, re-set, and re-charged. By the time the pouring is finished, and the roller and regulating-plates are removed, the end of the plate farthest from the kiln is sufficiently solid to resist pressure. Pressure in the direction of the mouth of the kiln is applied by means of chains attached to the two ends of an iron bar, placed against the solid end of the plate, and passing through pulleys fastened to the front wall of the kiln. It is thus gradually moved forward upon the intermediate table, and thence, by means of an endless revolving sheet of wire gauze, into the mouth of the kiln. Here it is conveniently placed either on the bed of the kiln, or on a movable truck, or on its edge. When a sufficient number of plates have been inserted in the kiln, the doors must be securely closed, and sealed with fire-clay. At the same time, the fire is allowed gradually to die out. That side of the plate which was in contact with the casting-table is always rough, while that over which the roller passed is slightly undulating and polished. The undulations are probably due to the action of the air upon the glass, while still liquid. Plate-glass, exactly in the condition in which it was placed in the annealing-kiln, having undergone no mechanical processes of grinding or polishing, is sold at a comparatively low rate, as "rough cast plate," and is largely used for roofing, and pavements, and for all purposes where translucency, strength, and cheapness are essential.

Hartley's Rolled Plate.—Hartley's rolled plate is made in the same way as plate-glass, only on a diminished scale. The molten glass, instead of being poured from the crucible, is ladled out of the crucible by means of large iron ladles. Although the plates produced are necessarily very much smaller and thinner than cast plates, nevertheless great economy is attained through the continuity of the process. The glass produced has an undulating surface, and is suitable for glazing roofs or windows, where translucency, rather than transparency, is required. The glass is made in a considerable variety of tints, as well as with impressed flutes, ribs, and ornamental patterns. The impressions are given by projections on the casting-plate, which acts as a mould, while the advancing roller performs the office of a "plunger." The rolled plate is exceedingly cheap. Tank-furnaces are well adapted for use in the manufacture of rolled plate. (See Bottle-glass.)

Mechanical Processes applied to Plate-Glass.—So soon as the kiln is sufficiently cool, a workman enters to examine the plates, and, if any are cracked, to lead the cracks by means of a heated iron, in whatever direction may be least injurious to the value of the plates. The plates of glass are now carefully drawn forward to the mouth of the kiln, and carried thence to another part of the manufactory, to undergo the processes of grinding and polishing. A plate is first cut with a diamond, to any required dimensions, or so as to get rid of imperfections in the glass, and is then cemented upon an iron horizontal table, in such a manner as to expose one surface to be ground. The processes of grinding, smoothing, and polishing are almost identical in action, and differ only in the media employed. In the first, the plate is ground by an iron rubber, and a medium of sand and water; in the second, it is smoothed by a glass rubber, and a medium of emery-powder and water; and in the third, it is polished by a wooden rubber, covered with felt, leather, or some soft material, and with a medium of rouge of increasing degrees of fineness. Fig. 756 represents an apparatus for grinding: A is a fixed frame; B, an iron horizontal table, revolving, and carrying the plate with it; D, rubbers shod with iron, to which a partial rotary motion is conveyed by friction with the glass carried round upon the revolving table B. Sand and water are fed through a hopper. In another arrangement, the lower table has a backward and forward motion; and the superimposed rubber, a similar motion in a direction at right angles to that of the lower table.

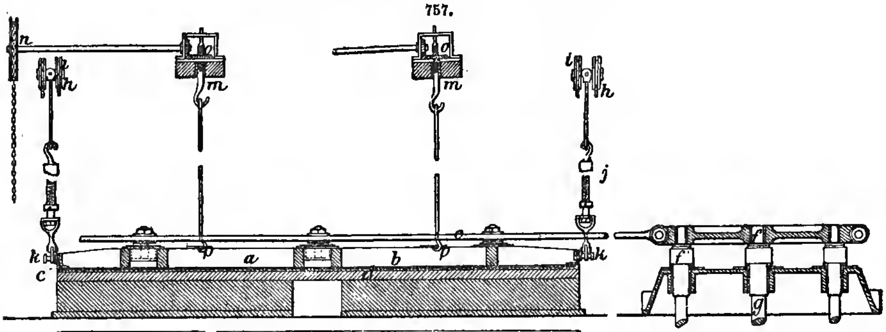
756.

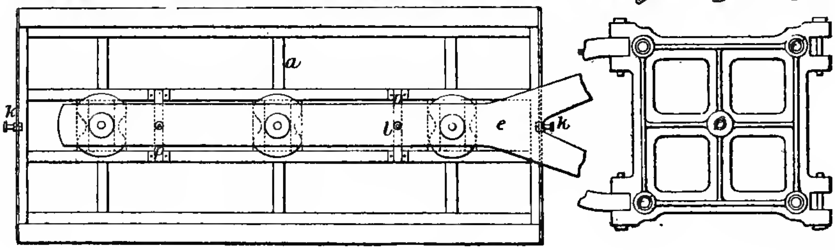


Figs. 757 and 758 show respectively a side elevation partly in section, and a plan of another arrangement, invented by Pilkington, for grinding glass:—*a* is the grinding-runner, with a continuous iron-shod surface *b*, sufficiently large to cover the whole of the plates *c* to be ground; *d*, the bed or table. A circular motion is imparted to the runner *a*, through the arm *e*, which receives motion from the crank-pin *f*, actuated from the shaft *g*, receiving motion from any convenient source of power; f^1 are guide-cranks. Rotary, oscillating, or other motion, may be given to the runner.

The overhead tramway *h* has wheels *i* running on it, and carrying screw-jacks *j*, coupled to the ends of the runner by means of pins *k*. When it is desired to remove the runner from the grinding-bed or table, it is raised by means of screw-jacks *j*, until it is freely suspended from the overhead tramway. The runner is then run along the tramway, until it is clear of the bed or table, when it may be turned on the pins *k*, into any required position, for examination and repairs. The operation is reversed, when it is desired to replace the runner on the bed or table.

757.





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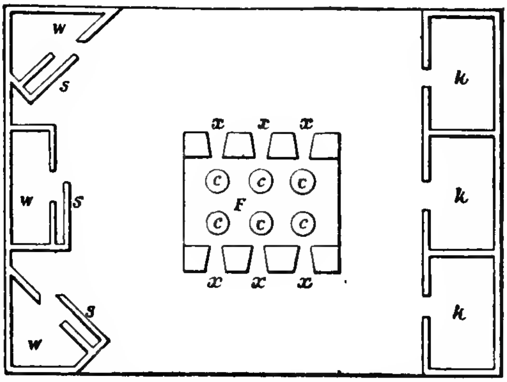
Rods *l* are attached to the back of the runner, and to adjustable hooks *m*, which are raised and lowered by means of the chain-wheel *n*, through which motion is given to the screw-wheel *o*. By adjusting the height of the hooks *m*, the strain on the rods *l* and cross-bars *p* is made greater or less, as desired, and the pressure of the runner on the plates to be ground is increased or diminished at will. If the rods and cross-bars have not sufficient elasticity to produce the desired effect, springs may be interposed. In every instance, after one surface has been ground or smoothed, the plate has to be reversed, so as to expose the second surface.

A fourth plan is to bed one plate of glass in plaster of Paris, upon a flat receptacle, and to attach a second plate by the same means, exactly parallel with the first, to an overhanging movable arm. To this arm, an elbow motion is communicated, and it is caused to press the upper plate upon the lower, and to grind them together, sand and water being thrown upon the lower plate. Thus the opposed surfaces grind each other, and, so soon as one surface of each plate is ground, both plates are reversed, so as to expose the other surfaces to the same action. The same apparatus serves for the smoothing process, fine emery-powder being supplied as a grinding medium, in place of sand. The polishing process generally employed is as follows. The glass plate is cemented to a table, possessing a backward and forward motion, and lying immediately beneath a beam, moving in a direction at right angles to the motion of the table, through which pass rods, having at their ends wooden rubbers coated with felt or leather. These rubbers are pressed upon the surface of the glass by strong springs. The grinding or polishing medium is rouge (peroxide of iron) and water. The loss in weight of each plate, by the three processes of grinding, smoothing, and polishing, amounts to almost 40 per cent. It has been suggested to use, for the purpose of grinding, only the best sand, or calcined flints, with a view to remelting the waste from the glass and the grinding medium with new raw materials. It has also been suggested to perform the levelling process by means of the abrading chemical action of hydrofluoric acid.

In the processes of smoothing and polishing, great care is required in the preparation of the grinding media, i.e. the emery-powder and rouge; neither of these materials is soluble in water, and it is by water that they are respectively sifted into lots of varying degrees of fineness. The sifting is based upon the principle that the largest particles will sink first, and the finest powder will remain longest in suspension. If emery-powder or rouge be agitated with water, and the water, in an uniform stream, be suffered to pass through a succession of troughs or cylinders of increasing size, the powder will be deposited in each succeeding trough in a condition of increased fineness, owing to the fact that the larger the trough the longer will the water be in traversing it.

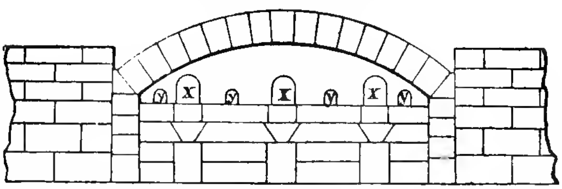
Crown- and Sheet-Glass Manufacture.—The following details of this branch of glass-making have been most obligingly communicated by Chance Bros. & Co., who are by far the largest manufacturers of crown- and sheet-glass in this country. Fig. 759 is a plan of a crown-glass manufactory:—F is the oblong furnace, containing six crucibles *c*; *x*, openings in the walls of the furnace, through which the molten glass is gathered; *w*, auxiliary furnaces, or "nose-holes"; *s*, brickwork screens, to protect the workmen from the intense heat of the furnaces; *k*, annealing-kilns. Fig. 760 is a side elevation of a crown-glass furnace:—X, the openings already referred to; *y*, small recesses, in which the ends of the blow-pipes are heated, preparatory to gathering glass from the crucibles. Fig. 761—A, section of a blow-pipe, measuring about 6 ft. in length; B, a solid iron working-rod or "ponty." Fig. 762 shows the stages of manufacture from the solid mass to the flattened disc.

759.



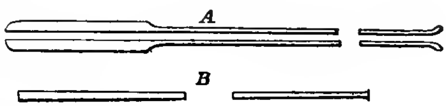
Upon the surface of the melted glass, is a ring of fire-clay, which, when the materials were thrown in, lay at the bottom of the pot, and after the completion of the melting, found its way upwards. This ring, floating in the centre of the pot, prevents the exterior surface of the melted glass, which becomes stiff and stringy during the long period of working, from mingling with the interior or hotter surface, which thus remains throughout of a suitable consistency. The labour of the skimmer, whose duty it is to clear the surface from any scum or dirt that may collect upon it, is considerably diminished by the ring, which, limiting the space from which the glass is drawn, limits also the space to be cleansed, and any bubbles or impurities in the glass have a tendency to attach themselves to the ring.

760.



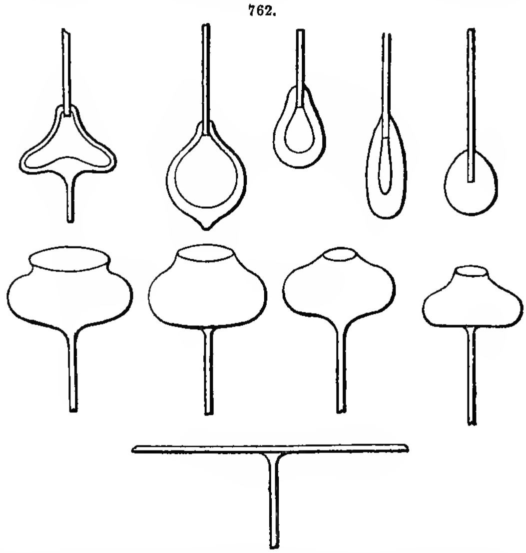
The melted glass having been brought, by the gradual cooling of the furnace, from a state of complete fluidity to a workable consistence, the gatherer dips the end of his pipe, or hollow rod of iron, into the pot within the ring, and, twirling it round its axis to equalize the thickness of the gathering, he collects upon the end, or "nose," as it is technically called, a pear-shaped lump of glass. Resting his pipe upon a stand or horse, he turns it gently round, and allows the surface of the lump to cool, to fit it for a second gathering. The lump completed, the gatherer cools his pipe under a trough of water, that he may handle it at any point, and proceeds to roll the glass upon a "marver," or metallic bed, until it assumes a conical form, the apex of the cone forming the "bullion-point." A boy now blows down the pipe while it is still being turned by the gatherer on the marver, and expands the glass into a small globe. Having been heated, it is blown again, and assumes the shape of a Florence flask, and the future rim of the developed plate is prepared by rolling the piece, near the pipe-nose, upon the edge of a marver. Again heated, it is expanded by the blower into a large globe. During this expansion, it is important to keep the bullion-point exactly in the position which it previously occupied, in a line with the axis of the pipe. To effect this, the blower rests his pipe upon the iron support, and while he blows down the pipe and turns it round at the same time, a boy holds against the bullion-point a piece of iron terminating in a small cup. Again presented to the fire, by the peculiar manipulation of the workman, and the peculiar direction of the flame upon it, the front of the globe is flattened, the possibility of the globe collapsing during this operation being prevented by its rapid revolution round its axis. The piece now resembles in shape an enormous decanter, with a flat bottom and a very short neck. The bullion-

761.



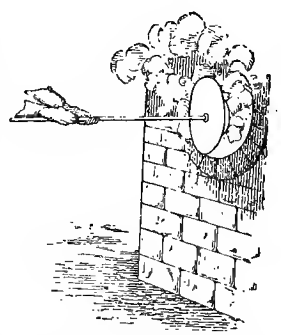
point is still to be seen in the centre of the flat bottom, and its use now becomes manifest. The pipe is laid horizontally upon an iron rest, and a man approaches, having in his hand a ponty, tipped with a lump of molten glass. Pressing this lump upon an iron point, so as to give it the form of a little cup, he fits it, when thus shaped, on to the bullion-point, to which it soon becomes firmly attached. The lump thus formed is called the "bull's-eye" or "bullion" of the developed plate. The incision of a piece of cold iron in the glass round the nose of the pipe, and a smart blow, soon detaches the pipe, which, after having lain a few minutes, till the glass adhering to it has cracked off, is warmed, and carried back to the pot to repeat its course.

762.



The end of the piece, which was next the now detached pipe, is called the nose, and gives it name to the furnace or nose-hole, Fig. 763, where this nose is, on account of its thickness, heated almost to melting, with a view to the coming operation. A man, with a veil before his face, stands in front of a circle of flame, into which he thrusts his piece of glass, meanwhile rapidly revolving his ponty. The action of heat and centrifugal force combined makes the nose of the piece expand, the parts around cannot resist the tendency, the opening grows larger and larger, and finally there appears a thin transparent circular plate of glass. Still whirling, the "table," as it is now called, is carried off, laid flat upon a support called a "whimsey," detached by shears from the ponty, lifted upon a fork into the annealing-kiln, and placed upon its edge against the preceding table. The weight of so many tables pressing one against another would cause the hindermost to bend, were this not prevented by the intervention of iron frames or "drossers," which divide the tables into sets, the first drosser leaning against the wall of the kiln, the second against the first, and so on. As the bull's-eye or centre lump, which the ponty has left, keeps each table from close contact with its neighbours, the air passes freely between them, and the annealing is accomplished with tolerable rapidity, varying from 24 to 48 hours, according to the number of tables in the kiln. From the kiln, the tables are conveyed to the warehouse, having passed, since their first exit from the pot, through the hands of ten distinct workmen.

763.



The process may be regarded as twofold—first, the development of the lump into a sphere; and secondly, the resolution of a sphere into a circular table. Constant rotation of the glass, while in a yielding state, is an essential element of success, as, if allowed to remain motionless, its symmetry would be immediately destroyed.

Sheet-Glass.—As before, a lump of glass is collected upon the end of the gatherer's pipe. For the metallic table or marver, is now substituted a block of wood, so hollowed out as to allow the lump, when placed upon it, to be expanded by the blower to the diameter ultimately required. The block, during this operation, is sprinkled with water, to prevent the wood from being burnt, and from scratching the glass. From the block, the glass is carried to the blowing-furnace, which is accessible through a number of holes or openings, each hole being allotted to a single blower. In front of the furnace corresponding to each opening, is a stage or frame of wood, erected over a large pit or well, about 10 ft. deep, and these parallel stages are sufficiently apart to enable each blower to swing his pipe to and fro in a vertical plane, that the glass may run freely out, as the phrase is, to the required length. When the glass has been sufficiently heated in the blowing-furnace, it is brought out, and swung round in a vertical plane, and also backwards and forwards, and the blower, at the same time, by blowing down the pipe, constantly keeps the lengthening cylinder full of air.

Uniformity of substance and diameter is chiefly secured by the skill of the workman, who, when he finds the metal running out too freely, holds the cylinder vertically above his head, still keeping it well filled with air. These operations are continued until the cylinder has reached the required length. The diameter of the cylinder was determined by the wooden block, and remains the same throughout. The next stage of the process is opening the end of the cylinder. The thinner kinds of glass are all opened by submitting the end of the cylinder to the fire, at the same time forcing in air through the pipe, and stopping up its aperture. The air is expanded by the heat of the fire, and bursts open the cylinder at the end, this being the hottest and most yielding part. The aperture thus made is widened out to the diameter of the cylinder, by subsequently turning the cylinder to and fro with the opening downwards. The thicker kinds are opened by attaching a lump of hot glass to the end of the cylinder, which thus becomes the hottest and weakest part; the air forced in by the blower as before bursts it open. The opening is then enlarged by cutting round it with scissors. If opened in the furnace, as in the first case, the ends of the thicker cylinders would be so thinned out that a considerable portion would be wasted.

The cylinder is now laid on a wooden rest, or "chevalet," and is easily detached from the pipe, by the application of a piece of cold iron or steel to the neck of the glass near the pipe-nose; the neck, being hot, suddenly contracts externally, and breaks away from the cylinder. There still remains the cap or end of the cylinder, which is easily taken off, by wrapping round the end of the cylinder a thread of hot glass, removing the thread, and applying a piece of cold iron to any point which the thread covered. The cylinder, as it lies upon the chevalet, is in weight little more than two-thirds of the lump of glass which the gatherer collected on his pipe. The quantity left upon the pipe-nose, with that which formed the cap of the cylinder, are nearly equivalent in weight to one-half the cylinder.

The finished cylinder is now split open by a diamond, which, attached to a long handle, and guided by a wooden rule, is drawn along the inside length of the cylinder, and should pass through, or in the neighbourhood of, some notable defect, if such be present, for defects thus brought to the edges of the subsequent plate of glass are of less injury to its value. An object to be avoided is the black mark, which the cylinder sometimes receives from the charring of the wooden "chevalet," on which, while hot, it rested in the glass-house. If the diamond passes inside the cylinder, over the space occupied by this mark upon the outside, the cylinder will fly to pieces. The reason of this is not difficult to understand. The chevalet prevented, by its non-conducting tendency, that portion of the glass with which it was in contact, from cooling equably with the rest, and the particles at that point remained in a state of tension. A careful blower will never place any large defect in his cylinder in contact with the chevalet, being aware of the probable result.

The cylinder is now ready for the flattener, who, having prepared it by a preliminary warming in the flue, by which it is introduced into his furnace, passes it, by means of a "croppie," or iron instrument, on to the flattening-stone, from the slight irregularities of whose surface it is protected by a "lagre," or sheet of glass, laid upon the stone. Upon this lagre, the cylinder, lying with the split uppermost, is soon opened by the flame passing over it, and falls back into a wavy sheet. The flattener now applies another instrument, a "polissoir," or rod of iron, furnished at the end with a block of wood, and rubs down the waviness into a flat surface, often, upon a refractory piece, using considerable force. Some cylinders are so distorted in the blowing that no rubbing can flatten them, but all, good, bad, and indifferent, pass through the same treatment. The flattening-stone is now moved on wheels to a cooler portion of the furnace, and, by the aid of the flattening-fork, delivers its sheet to another stone, called the cooling-stone. From this, when sufficiently stiff, it is again lifted, and then piled, generally on its edge, in order to be annealed.

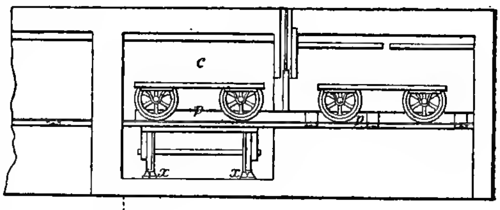
When this manufacture was new in England, the size usually blown was 36 in. long, and 20 wide; the usual size now is 47 in. long by 32 wide, and cylinders are occasionally blown 77 in. long; but large sizes and heavy weights are accomplished only by first-class workmen. A sheet of the last size, containing 21 oz. to the foot, would require for its formation a lump of glass upon the gatherer's pipe, of no less than 38 lb. weight. The size which sheet-glass can thus reach, is obviously a great advantage, and adapts it to many purposes from which the limited dimensions of crown are excluded. But sheet-glass has its faults—it is devoid of that brilliancy of surface for which crown is so remarkable; and is subject to undulations on the surface, the precise origin of which it is difficult to explain, but it is probable that this undulation is produced in the operation of blowing, and is due to the double movement of the particles of glass which accompanies the formation of every cylinder, the one movement being parallel to the axis of the cylinder, and the other in planes at right angles to that axis.

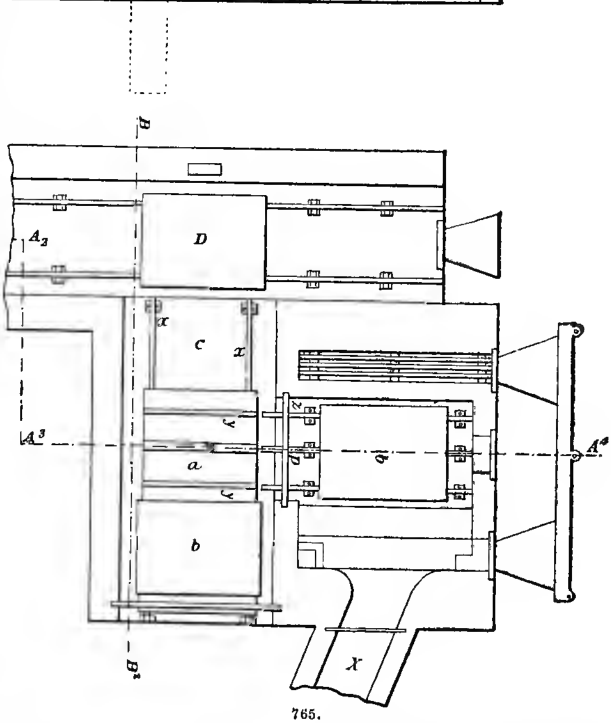
Sheet-glass, by the mode of its production, has the polish of its surface spoiled in some degree; but its greatest defect is that the inside and outside surfaces of the cylinder, not being of the same length after being developed by the flattening operation, cannot be in juxtaposition on two parallel planes, without one being forced to contract or the other to expand; but, as the glass remains too hard during the flattening process to change its molecular arrangement, one surface contracts the other, and the result is a kind of undulating or wavy appearance, called "cockles." These cockles reflect and refract light in various and contrary directions, and the objects seen through the glass are thereby distorted. Several attempts have been made to grind and polish this glass, in order to destroy these inequalities and imperfections. James Chance conceived the idea of laying every sheet to be ground and polished upon a flat surface, covered with a damp piece of soft leather. The sheet adheres completely to the leather, after having been pressed against it, producing, in truth, a vacuum, maintaining the whole sheet in a flat position. Two sheets having been placed in this manner, each on the retaining or sucking surface, they are turned one against the other in a horizontal position, sand and water being constantly supplied between them, and by means of machinery, the two surfaces are rapidly rubbed one against the other in all directions, and are ground at the same time by the sand. When the grinding has been performed on one surface, the sheets are turned, to have the other surface ground in the same manner. The sheets are smoothed and polished in the same way as plate-glass.

The sheet being ground while it is kept perfectly flat, it is not necessary to wear out more than a thin layer of the whole surface. Of course, after the operation, the sheet, by its own elasticity, resumes its former more or less curved shape; but the whole surface of both sides has a polish as perfect as plate-glass, and this is the desired condition for glazing purposes.

Spreading- and Annealing-Kiln.—Figs. 764, 765, 766, and 767 show the various arrangements of the spreading- and annealing-kiln. The split cylinder is introduced through the tube x upon the movable flattening-carriage b^1, which, when the cylinder is flattened, can be moved from the tramway $z p z$ to the tramway $y p y$, placed upon the "traversing-carriage" a. This moves upon the tramway x, and conveys the spreading-carriage b^1 to position C, at the same time bringing the second spreading-carriage b^2 into such a position that it can be moved upon the tramway $z p z$, just vacated by b^1. The sheet can now be removed from b^1 to the carriage D, upon which it is gradually carried down the annealing-kiln, and away from the fire. The carriage b^1 is moved back to the position b^2.

764.





765.

In place of the spreading- and annealing-kiln just described, it has been proposed to use two contiguous circular kilns with revolving beds. The split cylinder is introduced at one side of the revolving bed, and carried round to the heated side, where it is spread. It is then passed through a narrow opening on to the bed of the contiguous kiln, and carried by it gradually away from the fire.

Blowing Sheet-glass.—Mechanical appliances, called "iron men," are used to assist the blowers in making pieces of unusual size and thickness. The iron man merely carries the weight of the cylinder, during the operation of blowing, and has no blowing-apparatus in connection with it. It is believed that some arrangement with bellows has been used.

Moulding Cylinders.—The cylinders used to be moulded in wooden blocks, and are so still to some extent; but metal blocks of various kinds are now largely substituted.

Size of Cylinders.—Cylinders are made in a great variety of sizes, from 40 in. to 80 in. long, and from 20 in. to 50 in. wide. In Fig. 768, *a*, *b*, *c*, *d*, *e* represent the stages of the manufacture of a cylinder.

Glass Shades.—The manufacture of glass shades is almost identical with that of sheet-glass, except that the process is not carried so far. The materials and manipulation are identical. In *c*, Fig. 768, if the elongated globe be cut from the blow-pipe at a point represented by the dotted line, a shade would be formed. The dimensions and forms of shades are regulated by the size and forms of the moulds into which the glass is blown.

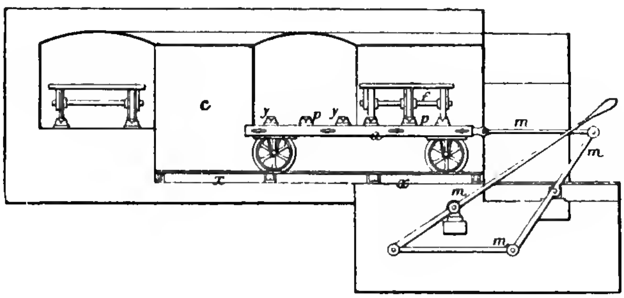
Steam-gauge tube.—This is made from the same material as plate- and sheet-glass; for process of manufacture, compare Flint-glass.

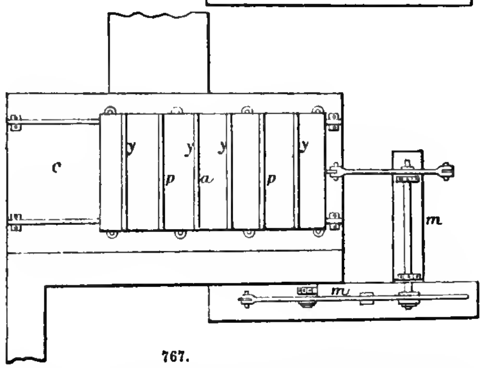
Bohemian Glass.—The percentage composition of Bohemian glass is :—

	SiO_2.	K_2O.	Na_2O.	CaO.	MgO.	Al_2O_3. Fe_2O_3.
Drinking-glass	71·70	12·70	2·50	10·30	..	0·70
Mirror-glass	76·00	15·60	..	8·00	..	1·00
Combustion-tube	73·13	11·49	3·07	10·43	0·26	0·89

Bohemian glass is properly a mixture of the silicates of potash and lime; it is, however, in this condition so difficult to work, from its high melting-point, that, for ordinary purposes, it has been found advisable to replace half the potash in this mixture by an equivalent of soda. Bohemian glass is, as has already been noticed, but little affected by chemical reagents. For this reason, and on account of its high melting-point, it is chiefly valuable for the production of apparatus used in chemical research. Bohemian combustion-tube, which is the form in which Bohemian glass is probably best known, may be represented by the formula K_2O, CaO, $6SiO_2$. Owing to the absence of oxide of lead from its composition, Bohemian glass can be melted in open crucibles, and thus the greater part of the heat of the furnace is available for the fusion of the glass. The methods of working the glass, whether for chemical or ornamental purposes, are similar to those employed in the manipulation of flint-glass.

768.





767.

The production of a ruby colour, commonly met with in Bohemian vases, is referred to under Coloured Glass.

Flint- or Lead-glass, and Ornamental Glass.—There are various kinds of lead-glass (compare Optical Glass), but that generally used in the manufacture of domestic and ornamental articles may be represented by the formula K_2O, PbO, $6SiO_2$. A glass, answering approximately to this formula, but varying slightly in every manufactory, is used in the production of tube and cane for lamp-workers, and of chemical and physical apparatus, as well as of tumblers, jugs, bottles, wine-glasses, ornaments, and vases. The essential qualities of a glass intended for these purposes, are ductility, long-continued viscosity, absolute purity of colour and substance, together with brilliancy and perfect transparency. The raw materials of lead-glass are sand, carbonate of potash, red-lead, nitrate of potash, trioxide of arsenic, and binoxide of manganese. Transparency, and purity of colour and substance, depend upon the purity of the raw materials, upon their right combination, and upon the regularity of the heat. Brilliancy is due to the powerful refraction and dispersion of light, caused by the presence of silicate of lead. Although lead-glass offers many advantages, it has the following drawbacks:—(1) it is so soft as to be easily scratched; (2) it is liable to tarnish when exposed to the action of sulphides; (3) it is costly, on account of the high price of lead; (4) also on account of the difficulty of obtaining it free from blemishes.

The raw materials, after having been weighed, are placed in a large bin, and are passed three or more times through a brass-wire sieve, so that they may be thoroughly mixed. To this mixture, is added broken or ladled lead-glass, in a proportion varying with the quantity available. The broken glass must first be carefully sorted, in order to remove even the smallest fragments of coloured or chemically different glass. The raw material is now ready to be introduced into the crucibles. In order to avoid the reduction of the oxide of lead, a lead-glass crucible is domed over, and only one small opening is left, which is turned away from the fire, for the introduction and withdrawal of the glass, and for the convenience of the glass-blower. The manipulation of lead-glass in large manufactories ceases, as a rule, on Friday, to be resumed on the following Monday morning. The raw materials are, therefore, generally placed in the crucibles on Friday evening, so that the glass may be ready for use when the workmen return. The length of time required for the complete fusion and purification of lead-glass may be greatly modified by the nature of the furnace. After the raw materials have been placed in the crucible, the opening or mouth is closed by means of a fire-clay slab, and the joint is cemented with moist fire-clay. An average-sized crucible holds 10–12 cwt. of glass. It is usually filled by 3–4 distinct charges, one being allowed to become partially melted before another is added. The crucibles stand around the grate of the furnace, and under a common dome; the mouth of each protrudes through an arch in the side of the dome, and the crucibles are separated by pillars, through which, flues pass upwards into the main cone. Gas-furnaces are now being used in lead-glass manufactories, but the old-fashioned circular coal- or coke-furnace, with certain economical modifications, and sometimes fed by Frisbie's apparatus, is still most common.

768.

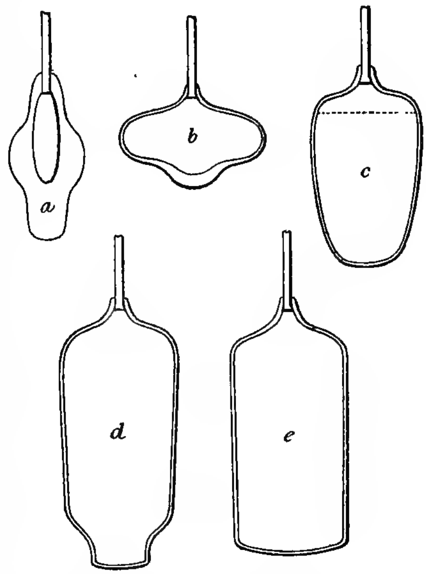


Fig. 769 shows the details of the space between two pillars or flues of an old-fashioned circular furnace: F are the pillars containing flues leading into the cone; D, iron doors for cleaning and mending the flues; B, iron buck-staves, carrying the iron ring R, and supporting the weight of the cone. There are usually 20 of these staves. The mouth A of the crucible, is partially closed by a fire-clay collar; H is the bed of the furnace, upon which the crucible rests; C, the arch in the side of the common dome; E, a door of ironwork and bricks, to protect the workman from the heat of the furnace; X, an iron-grooved rest, which supports the working-irons of the glass-blower; S, a fire-clay box or "shoe," in which the ends of the irons are heated; P, a small round opening, closed with a movable fire-clay plug, and through which the interior of the furnace can be viewed.

Where small crucibles are used, it is customary to continue work throughout the week, alternately melting and working out the glass. By this means, great economy is effected, but it is impossible to produce glass of first-rate quality. As soon as the glass is completely fused and purified, and the workmen have returned to work, the mouths of the crucibles are opened, and the surface of the molten glass is skimmed, in order to remove any infusible impurities, which may have fallen into the crucible, or may have been introduced together with the raw materials. The glass may now be considered ready for work; but before describing the processes of manipulation, the workmen themselves and the tools employed, demand notice. Work is continued night and day, and the workmen are divided into two sets, or "turns," relieving each other at the end of every 6 hours. Each turn is made up of groups, or "chairs," of workmen, the number varying with the number of crucibles in the furnace. The usual complement is one "chair" in each turn to every two crucibles; but it varies with the size of the crucibles, and the style of work. If the crucibles hold sufficient glass to supply a larger number of "chairs," a larger number may be accommodated by providing additional auxiliary working-furnaces. It must be remembered that, for manipulation, every workman requires a supply of heat, which is usually provided by the mouth of the crucible from which the glass is gathered. Each chair is made up of a "workman," a first assistant or "servitor," a second assistant or "footmaker," and one or more boys.

The tools used in the manipulation of blown-glass are represented in Fig. 770 :—*a*, hollow iron blow-pipe, usually 5 ft. long, and used for gathering glass from the crucible, as represented in

769.

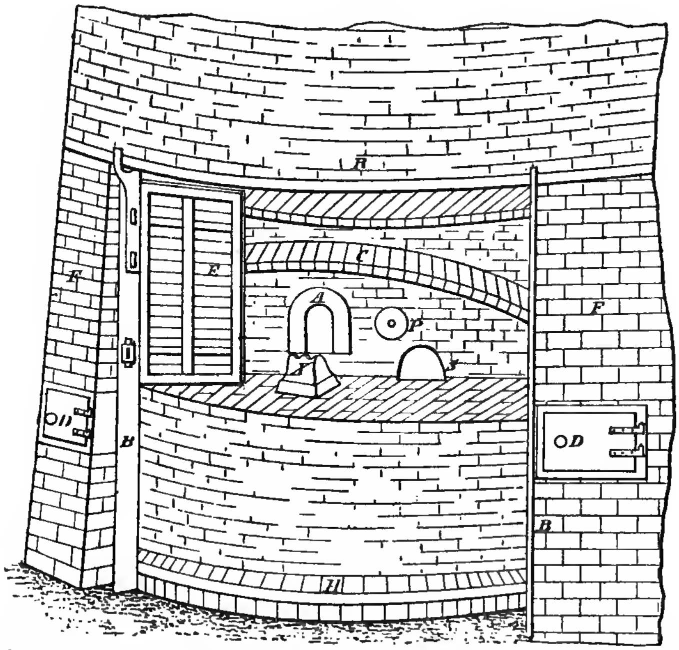
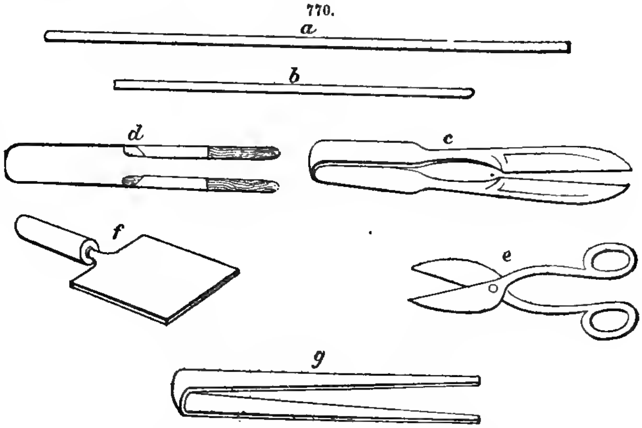


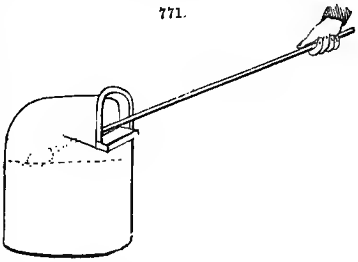
Fig. 771, and for the first or blowing process; *b*, solid iron working-rod, lighter and slighter than the blow-pipe, tapering from the handle to the point, and used for holding vessels by means of a seal of glass during the later manipulatory processes; *c*, sugar-tong spring tool with knife-blades; *d*, a similar tool with wooden legs, valuable for opening wine-glass bowls, &c., and for fashioning other objects in which it is important that the glass shall not be scratched or marked; *e*, shears, for removing any surplus; *f*, a flat plate of iron, with handle, for flattening the bottoms of tumblers; *g*, pincers, for taking hold of and fixing the ends of handles, and other purposes. At H, Fig. 772, is shown a flat slab of polished iron, called a "marver," resting upon a firmly constructed stool, on which the glass is rolled, immediately after gathering, with a view to its consolidation. Very important is the seat in which the glass-blower works. Fig. 773 represents a glass-blower at work in his chair. The arms A B project 18 in. in front of the seat, are exactly parallel, and slope gently downwards from B to A. The innumerable forms of blown-glass are mainly due to the power possessed by the workman of imparting to the viscid glass a continuous rotatory motion, whilst he simultaneously fashions it. The blow-pipe, with the glass attached, is rolled backwards and forwards upon the arms A B with the left hand, whilst the right hand remains free to shape the glass.

770.



Moulds are used (1) for giving the exact form to dishes which are required to fit into metal-work, or are of an oval or irregular form. In Fig. 774, *a b* represent two methods of blowing dishes into moulds: in *a*, after a bulb has been blown, and has been forced by the breath to take the form of the mould, the surplus glass is blown out so thin as to be easily broken away; in *b*, the surplus remains thick, and has to be removed by the glass-cutter. Moulds, especially wooden ones, are used (2) for shaping the bowls of wine-glasses and the bodies of decanters, though not often for this purpose in England; and (3) for imparting patterns to the surface of blown-glass; *c* shows a mould; and the remaining figures, the section of a mould, and the glass before and after it has been moulded.

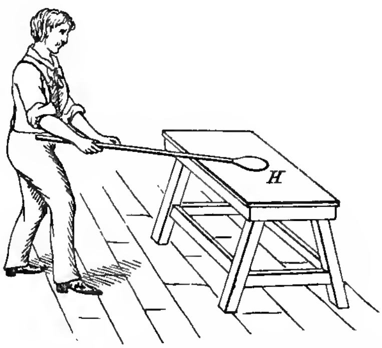
771.



The general principles of glass-blowing are:—(1) a hollow bulb at the end of a blow-pipe will collapse under the pressure of the atmosphere, unless it be continually blown into; (2) a bulb blown while the blow-pipe is raised will have a flattened form; (3) one blown whilst the blow-pipe points downwards will be elongated; (4) a hollow bulb or a solid mass, allowed to hang downwards, and swung from side to side, will be greatly elongated; (5) if a bulb be not continuously rotated, it will become distorted; (6) hollow or solid masses of viscid glass may be almost indefinitely elongated by traction.

The course of manufacture is:—(1) The blowing-iron is heated at the end, and a sufficient weight of molten glass is collected upon it; (2) the glass is blown and fashioned with the tools, and may be decorated with knobs or threads, with coloured casings, with gold, platinum, or

772.



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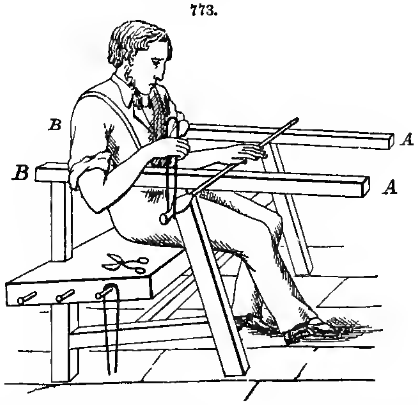
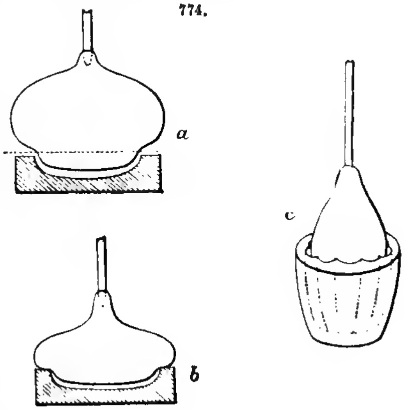


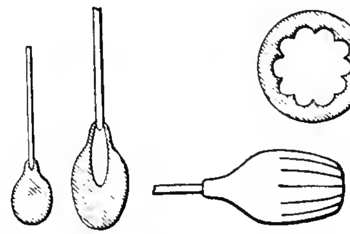
powdered glass, with iridescence or with frosting; (3) the fashioned vessel is placed in the annealing-oven; (4) the vessel is removed from the annealing-oven, and probably requires to be flattened at its base by means of the cutters' wheel. If it be a bottle, it may require to be stoppered. The other processes to which the annealed vessel may be subjected, and which will be briefly described, are—cutting, engraving, carving, engraving by acid, and roughening by the sand-blast process.

In Fig. 775, *a b c*, &c., represent the different stages in the manufacture of a light wine-glass: (*a*) the molten glass has been gathered upon the end of the blow-pipe, and has been consolidated by rolling upon the iron slab or marver; (*b*) the solid mass has been slightly marked by the compression of the knife-blades of the spring tool; the knob thus formed is pulled out by the same tool to form the leg; (*c*) the upper part of the mass is expanded by the breath to form the bowl; (*d*) the leg is gradually formed; the small button remaining at the end is removed by a sharp blow; (*e f*) a small quantity of glass has in the meanwhile been gathered, blown into, and compressed, as shown at *f*, to form the foot; the bowl and leg are pressed against the doubly indented hollow bulb *f*, and made to adhere to it; the bulb *f* is severed from the blow-pipe, upon which it was gathered, by the application of a moistened tool; (*g*) the bulb, which is now attached to the leg of the wine-glass, is divided by the spring tool at the point of indentation; (*h*) the open cup which remains is flattened, partly by the insertion of the points of the spring tool, partly by centrifugal force generated by rapid rotation; to the bottom of the flattened foot, a light solid working-rod (*k*) is affixed by a seal of glass, and the bowl (*i*) is severed from the blow-pipe by the application of a moistened tool; (*l*) the rough edge is sheared and smoothed by melting at the mouth of the crucible. The finished wine-glass is separated from the working-iron by a sharp blow, and is carried by a boy to the annealing-oven.

The seal of glass, by which the working-iron was fixed to the bottom of the foot, leaves a rough mark, which has to be polished away by the glass-cutter, after the wine-glass has been annealed. To avoid the necessity of this extra process, a tool has been lately used to a considerable extent, which clips and holds the foot of the wine-glass by means of a spring. This tool, represented in section in Fig. 776, takes the place of the solid working-iron. By depressing the outer coating *a* of the tool upon the spring *s*, space is left between *c d* for the admission of the foot of the wine-glass. The spring *s*, as soon as pressure is removed, presses the foot of the wine-glass, which rests upon *a*, against the stationary plate *c*. In Fig. 775, *a b c d e* represent the work of the "servitor" or first assistant; *f g h k*, the work of the footmaker or second assistant; and *l*, the work of the workman. In making heavier wine-glasses, the bowl is blown first, and a piece of molten glass is dropped on to its base to form the leg. The stages of manufacture are shown in Fig. 777.

774.





A patent has lately been secured by Richardson, of Hodgetts and Richardson, for a tool for fashioning the feet of wine-glasses. This consists of two plates of wood or carbon hinged together, with straps for regulating the extent of the opening, and for opening the two plates. The workman's right hand compresses the soft metal of the foot between the plates, whilst his left hand rotates the wine-glass attached to the end of the blow-pipe. By means of this tool, a foot is formed from a solid mass of glass, and the operation requires but little skill. The feet thus formed are even and smooth, but inferior to blown feet in lightness. The same inventor has produced a machine for shaping the bottom and sides of heavy tumblers. The tumbler is blown, roughly fashioned in the ordinary way, and, while still attached to the blow-pipe, is pressed against a flat disc of iron (the size of the bottom of the tumbler), from which, iron fingers project upwards, and surround the body of the tumbler. The weight of the blowing-iron is supported upon a rest, and a rotary motion is given to the fingers and disc, by means of a fly-wheel attached to its base. The disc forms the bottom, and the fingers shape the outside of the tumbler by friction.

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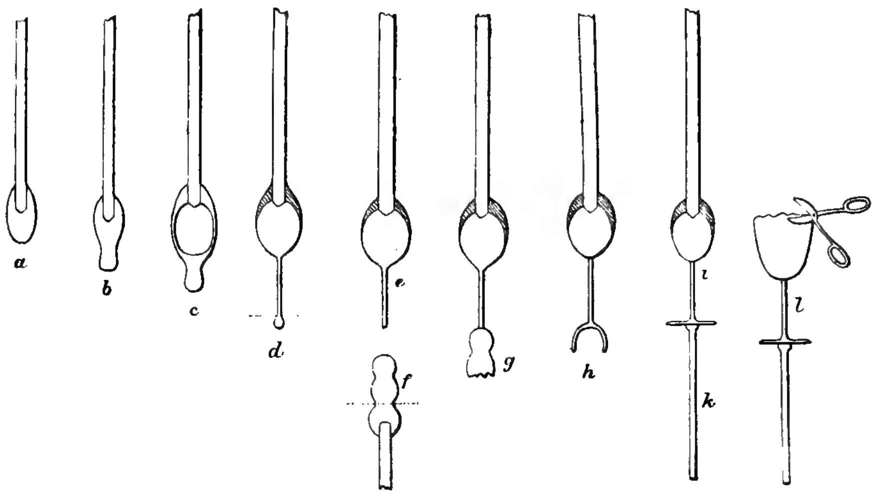

In Fig. 778, *a b c* illustrate the process of affixing a handle to a jug. A small quantity of glass is gathered at the end of a working-rod, and is rolled to an even thickness upon the marver. It is now lengthened by holding the rod with the glass downwards, and by pulling the free end with a pair of pincers. When the mass is sufficiently long, the free end is made to adhere to the side of the jug, and the other end is severed from the iron by the shears. The end which now remains free is seized by the pincers, bent round, and made to adhere to another point on the side of the jug,

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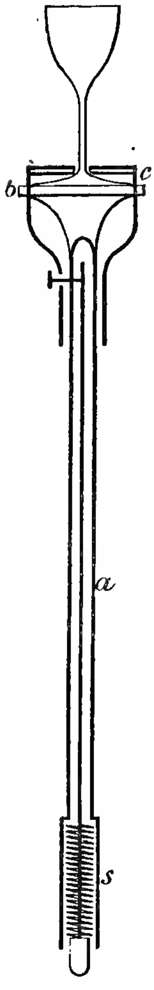

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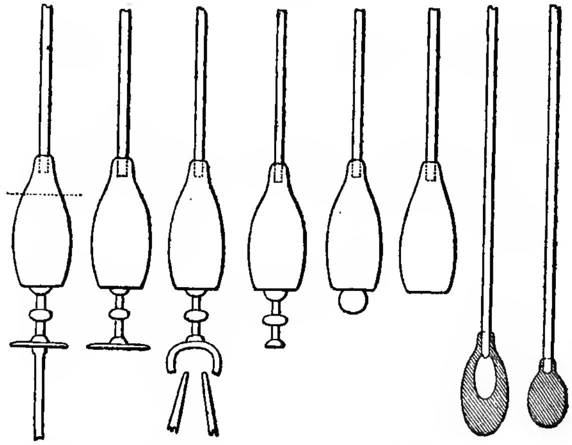

below, but in the same line with, the first junction. If it be wished to form a compartment for ice, in the inside of the body of a jug or decanter, the body must be blown in the usual way, and, whilst it is still attached to the blow-pipe, a mass of molten glass must be dropped upon one side of it, and suction be applied to the mouth of the blow-pipe; by this means, the hot glass is drawn inwards, through the wall of the body of the decanter or jug, and the pressure of the external air forms the hot mass into an open bulb.

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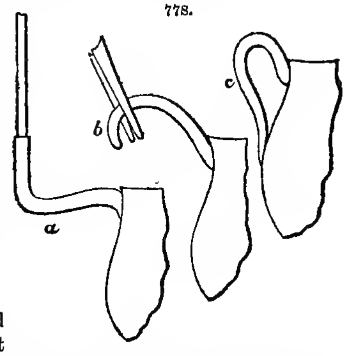

Fig. 779, *a b c d e f*, illustrates the formation of long flower-vases. A sufficient weight of glass is gathered and rolled. An indentation is made in order to form a knob, and the mass is expanded as shown at *c*. By swinging the bulb with the knob downwards, the bulb becomes greatly elongated. A working-rod is attached to the knob, and the other end is severed from the blow-pipe. The rough edge is sheared, and the open mouth is formed by rotation.

The manufacture of tubes and solid canes of glass depends upon the almost unlimited ductility of glass in the intermediate condition between liquidity and solidity. In making cane, a mass of glass is gathered, and rolled upon the marver. A flat disc of glass, adhering to a working-rod, is fixed to the end of the mass opposite to the attachment of the blow-pipe. The workman retains his blow-pipe in his hands, and an assistant holds the working-rod. The workman and assistant now separate, and recede from each other; the greater the distance is by which they are separated, the smaller will be the diameter, and the greater the length, of the glass which unites them. Tube is made in the same way as solid cane, with the difference that the mass of glass is blown into and expanded before it is extended. The stages of tube-drawing are illustrated in Figs. 780, 781: *a* is the solid mass of marvered glass; *b c*, the same expanded; *d*, the working-rod with disc of glass attached; *f g*, the process of drawing. The shape given to the mass of the glass, or to the hollow within the mass before extension, will be retained by the tube after extension. If the mass be flattened, a flat or oval tube will be formed; if moulded into a triangular form, the tube will be triangular; if the hollow mass be flattened, and then dipped into the crucible, and fresh glass gathered upon it, a round tube with a flattened bore will be produced. These facts are taken advantage of in making tubes for thermometers. A flattened bore makes the mercury more visible, and an angle in front of the bore magnifies it. Thermometer-tube backed with enamel is thus formed:—A mass of glass is gathered, blown hollow, and flattened by pressure; upon one side of the flattened mass, a thin cake of hot enamel is carefully spread and fixed; the mass with the enamel attached is dipped into the crucible, and coated with glass; it is then marvered, moulded into any form, and finally drawn out in the same manner as ordinary tube.

Fig. 782 represents the process of making variegated cane or tube. A mass of molten glass attached to the blow-pipe is pressed into a circular open mould, around the inside of which, short

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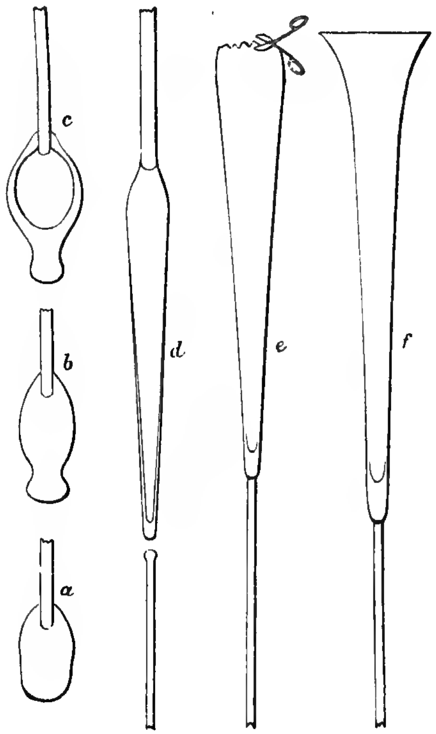

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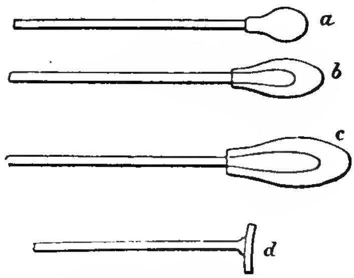

lengths of coloured cane have been arranged. The mass is withdrawn with the canes adhering to its surface, and, after being rolled upon the marver to effect amalgamation, is drawn out in the usual manner. If short lengths of variegated cane be used in the above process, in the place of plain coloured cane, the section of the cane produced will bear some resemblance to a flower. Pretty effects may be obtained by incorporating minute sections of the "flower" cane in the bodies of decanters, or in the bowls of wine-glasses, and by surrounding them with engraved foliage.

The tube drawn for thermometers and barometers is cut into suitable lengths, and passed on to the lamp-worker, who inserts the mercury and seals the ends. The "lamp" is a combination of a gas-jet, an air-jet, and a foot-bellows, or of a gas-jet and a mouth blow-

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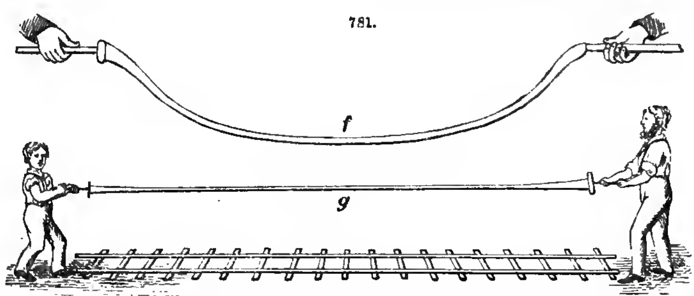

pipe. Tube or cane is speedily rendered ductile by the intense heat of the blow-pipe flame, and can be readily manipulated. The lamp-worker prepares from tube some of the most delicate apparatus used in scientific research. A variety of goods for domestic and medical purposes, e. g. syringes, globule-bottles, vaccine-tubes, breast-glasses, &c., are made at the lamp from the same source. Cane is used in conjunction with tube in the manufacture of many useful and ornamental objects. Coloured canes are used to a considerable extent for imitating the decoration so common in Venetian vases. From cane, or in fact any solid glass, rendered ductile by the heat of the blow-pipe flame, a thread may be drawn out, which, if attached to a rapidly revolving wheel, may be indefinitely extended. In this way, spun glass is made. In order to render the thread more durable, it is annealed by heating the wheel upon which it is being wound. In Austria, spun glass has been pressed into the service both of science and of decorative art; it is used in the laboratory for filtering acids, and appears in the drawing-room as a permanent substitute for silk and feathers. Some ornamental processes during manufacture are:—(1) Upon the surface of a vessel in course of manufacture, small drops or seals of molten coloured glass may be fixed, and may be pressed by moulds into the form of stars, gems, &c. (2) A small quantity of molten glass is gathered upon the end of a working-rod, and allowed to lengthen by the force of gravity; the free end is attached to some point on the body of a vessel in course of manufacture, and the vessel is rapidly rotated, thus a thread is evenly coiled around the vessel. A machine is now being used for causing the vessel attached to the blow-pipe to revolve more evenly and rapidly than can be effected by the unaided skill of the workman. (3) If, after the first gathering, the bulb of white glass be dipped into a crucible containing coloured glass, a vessel may be formed with a coloured casing. In preparing coloured glasses for casing, great care must be taken that they shall neither be harder nor softer than the white metal, or the vessel formed is sure to crack. (4) If a bulb of molten glass be rolled upon variously coloured powdered glasses, flakes of mica, or leaves of gold, silver, or platinum, it will adhere to them, and, by continuous rolling, will amalgamate with them. Very beautiful effects of colour may be obtained in vessels made from glass prepared as described. (5) Iridescence, which is due to inequality of surface, may be produced by the action of an acid, or of the fumes of chloride of tin, upon the surface of glass. The glass, whilst hot, is subjected to the fumes of chloride of tin, during manufacture. Any acid process must take place after the glass is annealed and cold. To effect iridescence, weak solutions of hydrofluoric or hydrochloric acids may be used. In the latter case, the process takes place in heated air-tight vessels. (6) Glass vessels may be frosted by plunging them, whilst still red-hot, into cold water, and afterwards reheating them. (7) Etchings in gold-leaf may be introduced into the substance of a vessel in the following manner. The gold-leaf is floated on to a thin plate of glass, and etched. The plate of glass is heated, and a mass of molten glass is dropped upon the surface of the gold-leaf, and adheres to the thin plate of glass through the pores in the gold. The molten mass may be fashioned in the glass-house, or by the cutter.

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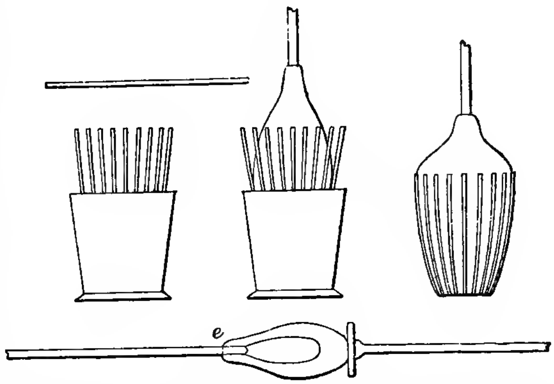

Cutting.—Annealed glass vessels may be subjected to a variety of processes after they have become cold. The mark of fracture left at the base of a blown-glass vessel by the working-iron, is removed by pressing it upon the edge of a swiftly-revolving stone wheel. After the inequality is removed, the roughness is polished away by substituting a wooden wheel for the stone one. Cutting and engraving are modified forms of the same process. The difference of effect lies in the greater depth of incision produced in cutting. In either process, lathes are used, in which the glass is pressed against the cutting-tools, instead of the cutting-tools being pressed against the glass. The cutting-tools are wheels revolving rapidly in a perpendicular plane. In cutting, the lathes are driven by steam, and the cutting-wheels are of considerable dimensions. The actual cutting is performed by iron wheels supplied from hoppers with sand and water. The incisions produced by iron wheels are smoothed by stone wheels supplied with water, and are polished by wooden wheels supplied with water and emery-powder, putty-powder, pumice, or rouge. For engraving, the lathes are usually worked by foot-treadles, and the wheels are of copper, and in some cases do not measure more than $\frac{1}{8}$ in. in diameter. In engraving, it is customary to leave the pattern rough, and the ground clear; this arrangement, however, may be reversed, by polishing the pattern with leaden wheels supplied with oil and rouge, and by previously roughening the ground. Specimens have lately appeared with polished patterns upon a clear ground, and the effect is decidedly pleasing.

Stoppering.—In stoppering a bottle, there are two processes: (1) The mouth of the bottle is opened to the required size by a steel cone revolving in a lathe; (2) the stopper is fixed in a wooden chuck, reduced to proper dimensions, and finally ground into the mouth of the bottle.

Roughening.—This may be produced by the recently invented sand-blast process, based upon the principle that if a stream of sand be made to fall through a vertical tube open to the air at the top, and the falling sand and air be received in a suitable closed vessel below, a jet or current of compressed air can be obtained. The entire surface of a vessel may thus be roughened, or, if parts are protected by a suitable medium, only the exposed portions will be abraded. By this means, very delicate patterns may be produced. Glass may be etched by the action of hydrofluoric acid, either in solution or in the form of gas. The parts of the vessel which are required to remain clear must be coated with wax, and the vessel be exposed to the fumes of the gas, or dipped into the solution. The variety in depth of incision, which gives the chief beauty to engraved glass, cannot be gained by either of these processes.

In the British Section at the Paris Exhibition, 1878, were exhibited some specimens of carved glass composed of two layers of glass, namely, a white upon a darker base. The carver had removed with his chisel parts of the upper white crust, and discovered, or partially discovered, the dark ground below; in this manner, were produced designs of the greatest beauty.

Imitation Jewels.—The property of glass to display a variety of tints by the addition of metallic oxides, is made use of for the production of artificial gems (see Gems—Artificial). The percentage composition of the base used is SiO_2, 38·10; K_2O, 7·90; PbO, 53·00; Al_2O_3 . Fe_2O_3, 1·00. For the colouring agents used in imitation of precious stones, compare Coloured Glass.

Bottle-Glass.—The manufacture of moulded bottles depends upon the principle that a mass of moulded glass, expanded by the breath, will take the shape, externally as well as internally, of a resisting environment. It is essential that a moulded bottle shall be cheap, strong, and capable of resisting the corrosive action of any liquid which may be placed in it for preservation. These essentials may be gained by great economy in manufacture, great care in manipulation, and by a scientific combination of the raw materials. Economy of manufacture depends on the position of the manufactory, on the power of obtaining the greatest result from the consumption of the smallest quantity of fuel, and on the utilization of waste products in the composition of the glass. Bottle-manufactories are, as a rule, placed within a short distance of coal-bearing strata, and have easy access to water-carriage. It is also a considerable advantage if sand, suitable for glass-making, can be obtained in the vicinity of the works. The consumption of fuel is mainly regulated by the construction of the furnace. The ordinary furnace for bottle-making is oblong, with openings at the angles, to allow the flame to pass from the main structure into four subsidiary ovens, containing the mixture of the raw materials. By this arrangement, the mixture will have already undergone partial fusion, before it is placed in the working-crucibles. The absence of oxide of lead from the composition of common bottle-glass permits the use of open crucibles, in which fusion is effected more quickly than would be the case if the crucibles were even only partially covered. The form of the crucibles, except in this particular, varies in different manufactories. Large reservoirs or tanks seem, however, to be best suited. The combination of gas-furnace and tanks, introduced by Dr. C. W. Siemens, is in every respect admirably adapted for the production of bottle-glass. On the old system, a crucible, when emptied and recharged, is useless for all working purposes, until the fusion of the fresh charge is completed, i. e. for some 18 hours.

The object of Dr. Siemens' system is to render the process of glass-making continuous and more uniform. Fig. 783 is a longitudinal section of his arrangement of tanks A B C. The raw materials are received and partially fused in A, whence the liquid glass flows into the clarifying-compartment B; on leaving this, it passes into the working-compartment C, from which it can be withdrawn in the ordinary way through the openings D D. The compartment A is charged through the aperture E, at the back of the furnace, and is separated from B by a party-wall F, in which are formed a series of passages, one of which is shown at *a*. Through these passages, the melted glass flows, and from B, it passes to the tank C, through the passages *c* in the division-wall G. The sides and bottom of the tank are perforated with air-passages *d*, through which cold air is made to circulate by the draught produced in the chimney H; thus the tank walls are kept cool, and enabled to withstand the action of the melted glass. The gas-ports are shown at K; the heated air issues from corresponding openings, passing in diverse directions over the upper edges of the tank. By this means, is produced an effectual intermixture of the combustible gas and the heated air, and the air is prevented from coming into immediate contact with the surface of the melted glass.

Fig. 784 shows a vertical cross-section, and Fig. 785 a horizontal section of this combined arrangement of furnace and tanks. The principal advantages to be derived from the use of the continuous melting-furnace are:—(1) Increased power of production, as the full melting-heat may be employed, without interruption in one part; whilst in another part, through the perfect control of the gas and air supplied to the furnace, the glass may be allowed to settle and cool: with the old method, these results could be attained only by the heating and cooling of the entire furnace; (2) economy of labour in the melting operations; (3) durability of tank and furnace, owing to uniformity of temperature; (4) economy of fuel, by the consumption of gas and air on the regenerative system, already explained.

The composition of bottle-glass is very varied. It is, speaking generally, a silicate of soda or potash, and lime, together with alumina and oxide of iron; it is to this latter oxide, present as an impurity in the cheap materials employed, that the glass owes its green colour. An analysis of a sample of French bottle-glass gives the following result:—Silica, 53·55; potash, 5·48; lime, 29·22; alumina, 6·01; oxide of iron, 5·74; total, 100·00. It may be represented by the formula—$3(K_2O)$, $27(CaO)$, $3(Al_2O_3)$, $2(Fe_2O_3)$, $45(SiO_2)$.

The materials employed for the preparation of bottle-glass are common coloured sand; the residual alkaline and lime salts from gas-works, soap-works, and alkali-works; common salt, salt-cake, and ashes from fires of wood or charcoal; clay, basalt, and other rocks containing felspar; and lastly the slag from blast-furnaces. This slag accumulates as refuse at the rate of nearly 8000 tons per annum, and great credit is due to Bashley Britten for having worked out a practical method of utilizing it in the manufacture of glass. Both the heat and the material of the slag is made use of, and it is upon the possibility of utilizing the former that the economy of the process depends. The manufactory, at Finedon, in Northamptonshire, is in close contiguity to the blast-furnaces of the iron-works; and as the molten slag is run from the furnaces, it is conveyed on "carriers" to its destination. The ingredients of the glass, of which the larger portion is molten slag, the remainder being sand and alkalies, are fed into the tank of a Siemens' continuous melting-furnace.

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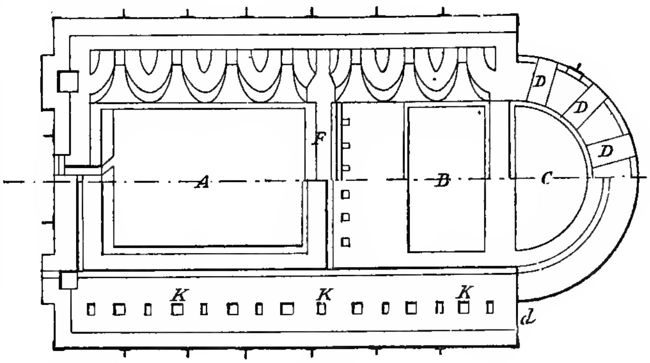

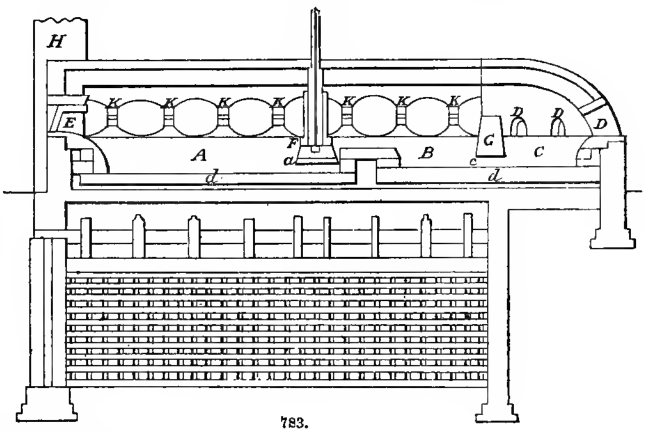

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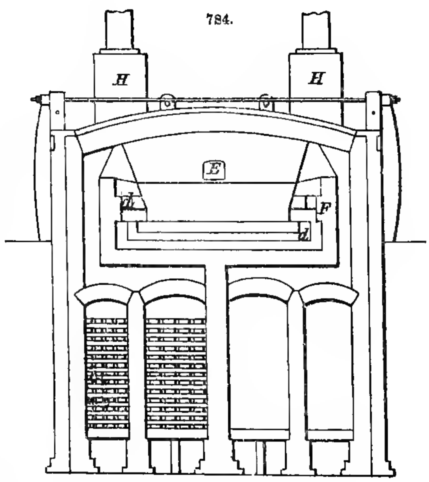

Bottles are made by a "set" of "hands," which usually consists of five persons, respectively known as the "gatherer," the "blower," the "wetter-off," the "workman," and the "boy." "Medicals" require four, and other bottles five manipulations. The glass being ready melted in tanks or crucibles, the "gatherer" inserts the end of a long hollow iron tube through the opening D into the working-tank C, Fig. 785, or, if an ordinary furnace is in use, through an opening in the furnace, opposite the mouth of a crucible, and into the crucible. The melted glass adheres to the heated end of the tube, and the gatherer, by revolving the tube, is able to collect as much glass as he judges will be sufficient to form the bottle required. The blower now takes the tube, with the glass attached, blows through it, and trundles it on a smooth iron slab. The mass of glass is slightly hollow, and conical in shape. It is placed in a mould, and distended by the blower's breath, until it acquires the internal form of the mould, both externally and internally. The blower now has a shaped bottle at the end of his tube. If it is a small one, such as a "medical," he taps his tube on the edge of a tray, and the bottle drops off, ready to be carried to the annealing-oven. If it is large, it is handed to the "wetter-off," who runs a wetted iron round the neck, and, in this manner, severs the bottle from the blowing-tube. The bottle is still without a lip, which it is the "workman's" business to make. The "workman" holds the bottle, either by an iron rod attached to the bottom by a seal of melted glass, or by a support with four prongs which surround and clip the body (Fig. 786). He heats the neck of the bottle, at an opening in the main furnace, or at a separate small furnace, which is especially arranged for his work, coils a small piece of molten glass round the neck, and then fashions it, when in a plastic condition, with a tool, which is best understood by reference to Fig. 787: A represents a rounded projection, which regulates the shape and size of the inside of the neck; C is a bottle in position; B B can be compressed upon the hot glass by means of H, which acts as a spring, and thus form the rim of the lip. The bottle is turned by means of the rod attached to its base, the tool is compressed, and the rim is finished. Fig. 788 is a modification of Fig. 787, and provides for the formation of an indented ring in the inside of the neck, in which, indiarubber can be fixed as an adjunct to the stopper. One side of this tool is shown open, and the

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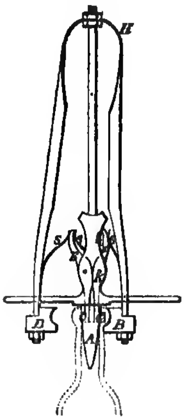

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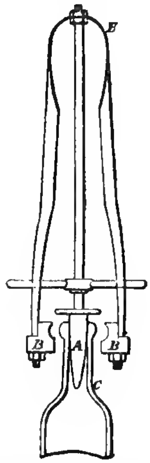

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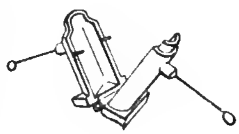

other shut. By compressing the arms of the tool, the spring S forces in one end E of a curved implement, which turns on the screw K, and drives the other end C into the plastic glass. Before the tool is compressed, the end C is contained in the body of the rounded projection A, which is thus enabled to enter the neck of the bottle. When A is inserted, the tool compressed, and the bottle turned, an external rim and an internal indentation are produced simultaneously. When indiarubber is attached to the stopper itself, as in Lamont's patent, the stopper is dropped into the bottle, a tube is thrust after it, and firmly seizes one end, and the indiarubber ring is forced over the tube and stopper, by a second tube sliding over the first. When the rim or lip is finished, the "workman" either takes the bottle out of the holder with a pair of wooden tongs, or separates it from the iron rod by sharply striking the latter. The "boy," finally, carries the finished bottle on a fork to the annealing-kiln, which is kept at a temperature rather below the melting-point of glass, until stacked full, when it is allowed to cool gradually. The process of making bottles is exceedingly rapid. In a day of ten hours, one "set" of workmen will turn out 130 dozen of finished bottles.

Bottle-Moulds.—Moulds are made of various substances, in various forms, and are the subject of a considerable number of patents. The material of a mould must be durable, and must impart a good surface to the heated glass. Brass, cast-iron, and wet wood, are the materials most commonly employed. Metallic moulds, while being worked, require to be kept nearly at a red-heat. Without this precaution, the surface of the glass is "ruffled." Care, on the other hand, must be taken, that the moulds are not so hot as to cause the glass to adhere. A small aperture must be left in the lower part of every mould, to allow the imprisoned air to escape while the hot glass is being introduced.

In order to form the neck of a bottle, moulds must be made in at least two, and usually in three pieces. Fig. 789 shows the simplest form of bottle-mould in use, in which the two sides are hinged together at the base. The chief objection to this mould is the fact that, where the two sides of the mould join, a seam in the glass is always formed. This seam is not noticeable when the bottles are square, and the join of the mould is at two angles of the bottle. Moulds in three pieces are made up of one piece for the body, and two for the neck, which are hinged above the shoulder. The seam down the body is thus avoided, although two slight seams are observable in the neck. Bottles made in these moulds can never be perfectly cylindrical, as the upper part of the body of the mould must always be slightly larger than the lower, to allow of the delivery of the bottle. The mould is closed by a treadle, acting upon two levers with inside springs, which re-open the mould when the foot is removed. A patent has lately been secured for giving a rotatory motion to the body of a mould, whilst being worked, in order to remove the seam in the glass at the point of junction of the two sides. Fig. 790 is a vertical section, and Fig. 791 a side elevation, of a bottle-mould hinged at the bottom; Fig. 792 is a vertical section, and Fig. 793 a side elevation, of a bottle-mould hinged at the shoulder, with apparatus for giving the mould a partial rotation whilst the bottle is being blown. For this purpose, the folding sides A, which are opened and closed by the treadle B, instead of being hinged to the stationary bars of the mould, are hinged to a casing C. A second treadle D, pressed upwards by a spring *d*, is connected with the casing C. The "blower," closing the mould by pressure of his heel on B, can, by an up-and-down movement of his foot on D, cause a partial rotation of the whole mould around its base, or can cause the upper and lower parts to turn a little to and fro in opposite directions.

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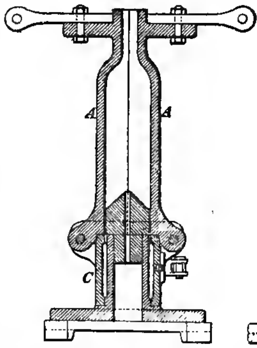

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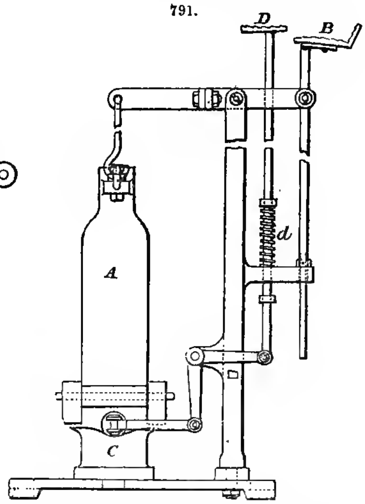

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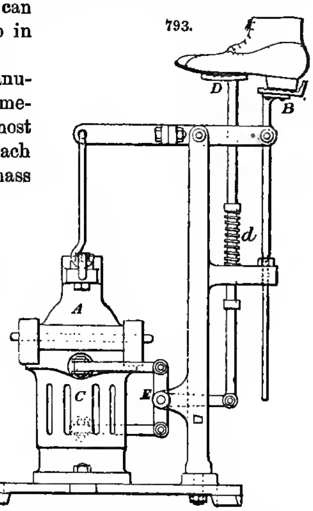

Pressed-Glass.—The application of machinery to the manufacture of glass, and the consequent partial substitution of mechanical for manual labour, has produced a ware suitable for almost every domestic purpose, and so cheap as to be within the reach of all classes. In the process of moulding glass, the molten mass is forced to take the form of the mould, both on its inner and outer surface, by the pressure of the glass-blower's breath; in pressing glass, the molten glass takes the form of the mould, upon its outer surface, under the pressure of a metallic plunger, driven by mechanical means, whilst the form of the inner surface is fashioned according to the shape of the plunger. Pressed-glass always requires to be polished by the remelting of an outer film, roughened by contact with the metallic surface of the mould. The roughness is probably caused by the comparative coldness of the mould, which produces shrinkage and irregularity upon the surface of the hot glass. It is found that the hotter the mould can be kept, the smoother and brighter is the surface of the glass. Hand pressure can be applied to the production of small articles, by attaching a rubber or plunger by hinges to the mould, so that the hinges may form the fulcrum, and the resultant pressure may be obtained between the fulcrum and the handle attached to the plunger.

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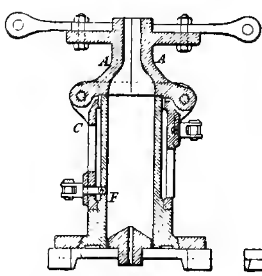

For work on a large scale, pressure is usually applied by a weighted lever, or a screw and fly-wheel. In the former, Fig. 794, the mould is placed at M; a sufficiency of molten glass is gathered from the crucible by means of an iron rod, and dropped into the mould, being severed from the rod by aid of a pair of large shears. By depressing the handle H, which turns upon a fixed axis F, motion is communicated to the rod P, through the elbow. By this means, the frame B, sliding over the uprights I, together with the plunger P, is lowered. The lever H is restored to its original position by the counterpoise W. Fig. 795 represents a screw-press. By turning the fly-wheel W, which is rigidly connected with the screw S (working in the fixed cross-bar O), the plunger P is lowered, together with the rods R, and the bar V, sliding over the fixed uprights I.

The moulds are usually made of iron or gun-metal. When the shape of an article to be pressed necessitates the division of the mould, the several pieces are so hinged together, that the article

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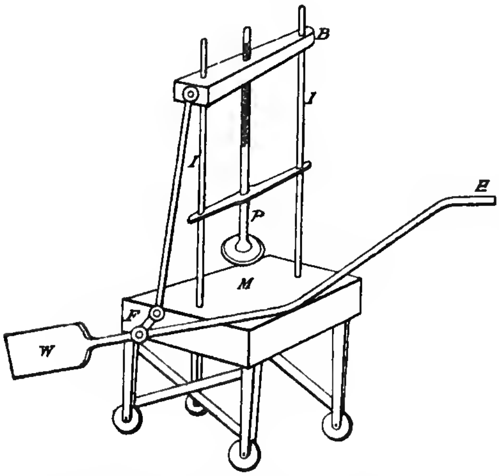

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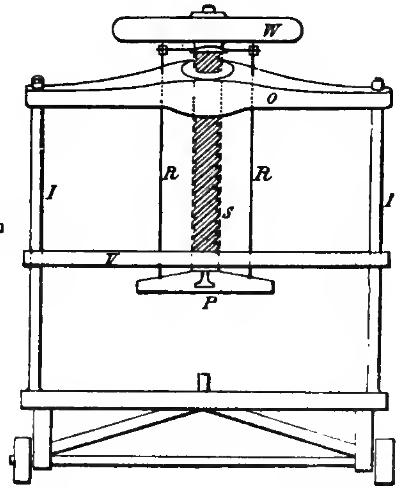

can be liberated with the greatest ease, and the joints are so fitted, that the glass may be as little marked by them as possible.

In addition to the saving effected by the use of the press, and by the substitution of unskilled for highly trained labour, a considerable reduction in cost has been brought about by the introduction of cheap substitutes for the raw materials originally used. The manufacturer of pressed-glass aims at the production of a glass rivalling flint-glass in clearness and whiteness, and surpassing it in softness, and in the power of retaining heat. Originally the same ingredients were used for pressed-glass as for flint-glass, the flint-glass for pressing being softened by the addition of borax in considerable quantity.

Flint-glass is expensive, owing to the large proportion of red-lead used in its composition. A substitute for red-lead has been found in certain of the salts of barium. The following recipe is the subject of a patent, and the resultant glass is said to be one-half less expensive than flint-glass, but to be equal in transparency, clearness, and brilliancy:—Sand, 17; carbonate of soda, 4; carbonate of barium, 6; borax, 2. Another raw material used for pressed-glass is cryolite, a compound of fluoric acid, water, soda, and alumina. If 4 parts of cryolite be added to 1 of oxide of zinc, and 10 of sand, a milk-white opal will be produced, transparent for light rays, but cutting off the red rays. If a smaller quantity of cryolite be added, a white transparent glass will be the result, of great brilliancy, strength, and refractive power. If, on the other hand, more than 4 parts of cryolite be used, an opaque white mass will be obtained, which, in appearance, closely resembles china or glazed earthenware. This opaque substance is now pressed into a great variety of useful and ornamental articles. It can be coloured by various metallic oxides.

Toughened Glass.—The discovery of a process by which either flat or shaped glass may be rendered less liable to breakage is due to M. de la Bastie. His process is to heat glass to the point of plasticity, and immediately to plunge it into a heated bath of molten fat. The temperature of the bath must be adjusted to the chemical nature of the glass. The temperature for a soft glass is 68°–75° (154°–167° F.). For the bath, mutton-fat is preferred; before being fit for use, it requires to be melted for at least 12 hours. The simplest form of the process is that used in the treatment of open-shaped vessels, such as tumblers and finger-basins. These are treated in the course of manufacture, being dropped into the bath, instead of being sent to an annealing-oven. For this purpose, a bath, Fig. 796, heated to the necessary temperature, either by a small gas-stove or by the insertion of hot metal, and containing a lining of wire net, is placed as near to the workman as possible. The heat of the bath, once acquired, is maintained by the heat of the vessels immersed in it. When the wire net is full, the bath is allowed to cool down to about 45° (113° F.); the glasses are taken out in the net, and arranged on sieves in an iron closet, which can be heated. The temperature is raised to about 70° (158° F.), causing the fat, which still adheres to the glasses, to drip through the sieves into a tank beneath, where it is collected for future use. From the heated closet, the glasses are removed to a tank containing caustic soda in solution, which is also slightly heated; and thence to a bath of warm water.

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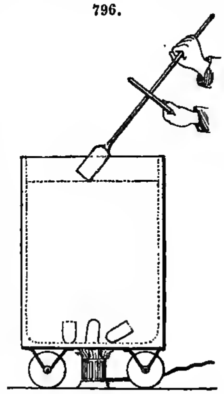

One of the first and most serious obstacles encountered in the application of the discovery to vessels of general utility was the difficulty of expelling air, contained in bottles and other utensils with narrow apertures, sufficiently quickly to allow the interior and exterior surfaces of the glass to be simultaneously affected by the liquid. The manner in which this difficulty has been overcome, in the case both of large and of small vessels, will be understood by reference to Figs. 797 and 798. In Fig. 797, A represents the bath, B a bent tube, supported on guides at P, and having a pocket M to receive any of the liquid which may enter the end of the shorter arm; E is the surface of the liquid. The bottle H is depressed to D, by the rod adhering to its base, and guided by supports P′. The air escapes by B, and the liquid takes the place of the air. The rod is detached, and B D is canted over, so as to allow the bottle to slip off and into the net. If necessary, suction may be applied at the end of B. Fig. 798 shows an arrangement for forcing the liquid into a vessel:—H is an air-compressing pump; A, a bent tube, with an enlargement at B, and a valve C opening inwards. The short arm is perforated. The handle of the pump is depressed, the air presses on the liquid in B, C is closed, and the liquid is forced through perforations against the inner surface of the vessel.

Figs. 799, 800, and 801 show different views of the apparatus used for the treatment of flat sheets of glass. The cold sheets are introduced into A (Fig. 799), where they are gradually warmed; are then transferred to a movable slab B, where they are heated more strongly; and pass thence to a canting shelf C, the motion of which is made apparent in Fig. 801. At this point, the sheet passes from the furnace into the bath, suitable arrangements being provided for preventing the flame of the furnace igniting the inflammable liquid in the bath X. When the shelf C is sufficiently tilted, the sheet of glass slips on to the support D, by the motion of which, after its immersion, it is raised in such a manner that it can be easily moved on to one of the shelves F. The support D is such an arrangement of wire netting and open bars as will allow free access of the liquid to the under surface of the sheet.

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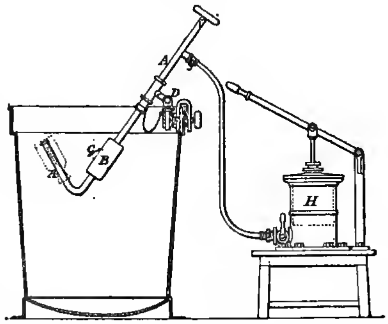

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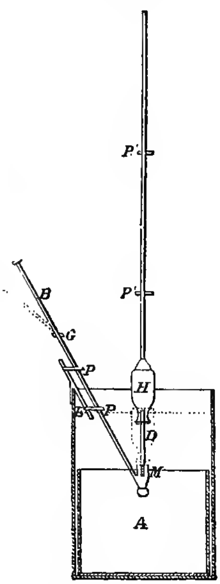

Pieper's Process.—Pieper's process for hardening or toughening glass differs from that of De la Bastie, although the results are similar. Glass vessels are heated almost to the point of plasticity, and are then subjected to the action of injected superheated steam.

The insignificant demand for toughened glass at the present time proves that the quality of the material has not fulfilled the sanguine expectations aroused in the first instance. The reason is to be found in the physical nature of the glass. The characteristics of unannealed glass, and especially of glass which has passed very suddenly from the liquid to the solid condition, have already been discussed. Toughened glass presents all these characteristics in a modified form. The outside case is exceedingly hard, and capable of resisting the diamond, and shocks of very considerable violence. Directly, however, the case is pierced, either by external action—whether that of a blow, of hydrofluoric acid, of a file, or of the cutter's wheel—or by the internal disturbance of molecules in a state of extreme tension,

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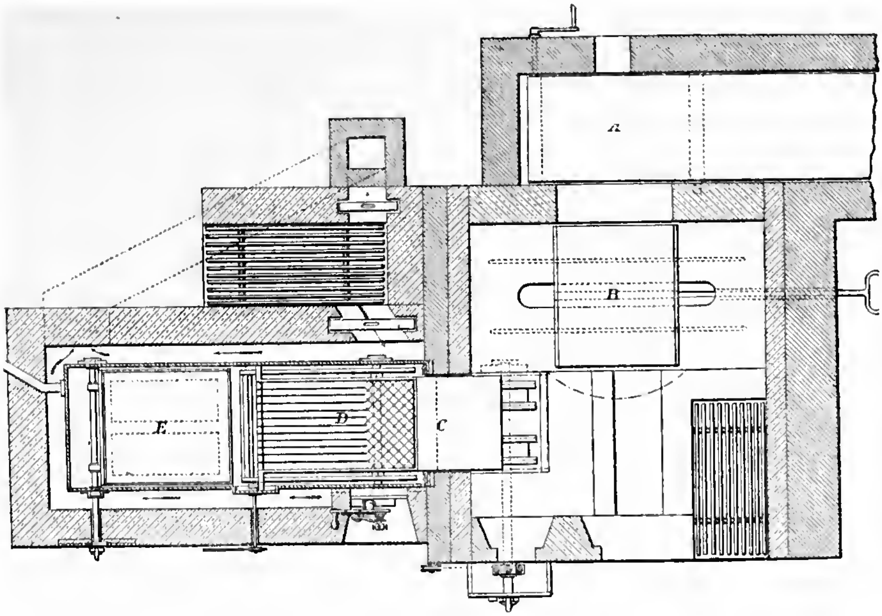

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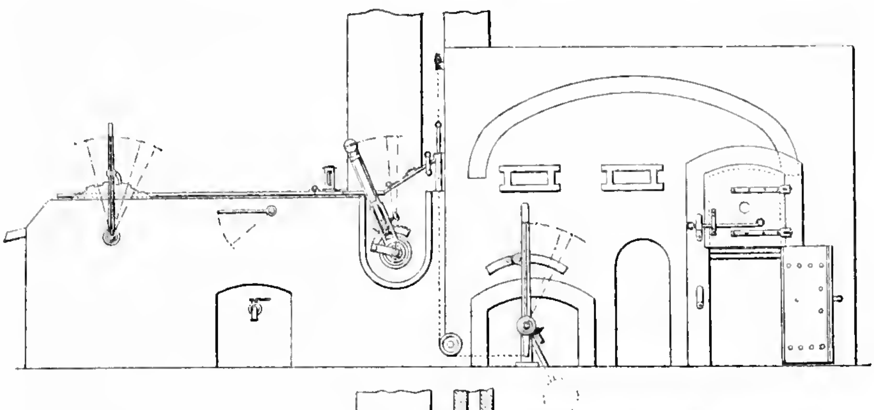
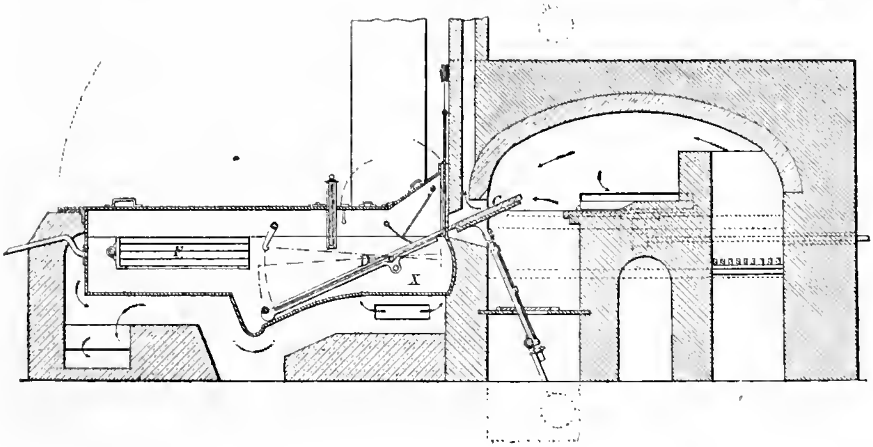




801.

the mass is entirely disintegrated. The similarity of toughened glass to Prince Rupert's drops is displayed in its fracture, in its resistance to the diamond, in its power of returning to the normal condition of annealed glass by the action of heat, and in the porous condition of its internal substance. The names by which this glass is generally known—"toughened" and "unbreakable"—are unfortunate; it is certainly not unbreakable, and is not toughened, but case-hardened.

Optical Glass.—The relations of light to glass are modified by the form, and the physical and chemical conditions of the glass. Transient effects of colour may be due to the form, to the physical condition, and, to a certain extent, to the chemical nature of a glass. Permanent effects are entirely due to the presence in the glass, whether in suspension, solution, or chemical combination, of certain metals and metallic oxides. A glass prism produces effects of colour principally by its form. Glass under certain circumstances will produce them by acquiring the physical property of double refraction. If the elasticity of glass becomes more modified in one direction than in another, whether by curvature, pressure, or sudden cooling, and if the glass is then traversed by a beam of polarized light, effects of colour are obtained. These effects vary, according as the glass has a circular, square, rectangular, or triangular shape, and according to the degree of tension of its particles. A transient effect of colour is also produced by the physical action of uranic sesquioxide contained in the substance of a glass. This effect of colour is due to the power possessed by glass holding uranic sesquioxide in solution, of diminishing the refrangibility of the invisible ultra-violet rays of light, and of rendering them visible, and is known as fluorescence.

The chief points to be considered in the selection of glass for optical purposes are transparency, density, and homogeneity. In order to obtain perfect transparency, the raw material of the glass must be chosen and purified with immense care. The presence of iron in the sand must be especially guarded against, as a very small quantity will tinge the glass, and diminish its transparency. The chief troubles, however, arise from the presence of bubbles and striæ in the substance of the glass; the latter may be removed by agitation, produced either by stirring, or by the application of heat beneath the crucible; the former, by rest. Faraday suggests the removal of bubbles by mixing spongy platinum with the raw materials. Striæ are probably caused by the tendency of molten glass to become stratified according to the density of its constituents. Solid specks are due to the corrosion of the crucible.

The value of a lens depends upon the power of refraction possessed by the material of which the lens is made. The most highly refracting medium is that in which the velocity of the propagation of light is least. The velocity of propagation is diminished by an increase in the density of the material through which the light is passing. The density of a glass varies according to its composition. The higher the atomic weight of the metals it contains, the greater is its density, and the higher its refractive index. Many experiments have been made to produce a glass of the greatest density without diminishing its transparency and durability. Faraday has suggested the use for optical purposes of silicated borate of lead, and of silicated triborate of lead. To both of these compounds, want of durability may be urged as an objection, although they possess density in a marked degree. Maez and Clemandot have introduced boro-silicate of zinc. This glass has a very pleasing white appearance. It possesses a greater relative density than lead-glass, and can be produced in a condition suited for optical purposes, without being subjected to constant agitation. Lamy's thallium-glass, made from a mixture of silica, red-lead, and carbonate or sulphate of thallium, excels zinc-glass in density, and is homogeneous. Increased density is practically obtained by augmenting the proportion of lead in flint-glass.

Manufacture.—It will be readily understood that, if the density of a lens is not equal throughout, an effect of aberration is produced, and the lens is useless for optical purposes. Molten glass, especially if it contains lead, has a tendency to arrange itself in the crucible according to its density; the top layers have been found to vary in density between 3·28 and 3·81; the bottom layers, between 3·85 and 4·75. In order to ensure uniform density and homogeneity, it is essential that the molten mass should be constantly agitated. The materials are melted in covered crucibles, and agitated by means of a hollow fire-clay cylinder, into which an iron bar can be inserted. The cylinder is raised to a white heat in an auxiliary furnace, and introduced into the liquid glass, supported by suitable tackle. The iron bar is inserted, and stirring commences. The iron bar is removed after each stirring, but the fire-clay cylinder is allowed to remain in the crucible. Stirring commences directly the raw materials are thoroughly melted, and is repeated at regular intervals until the glass is ready to be worked. When large lenses are required, and the whole contents of the crucible are to be devoted to the production of one or two lenses, the stirring is continued whilst the furnace is gradually cooled, and so long as the glass is sufficiently mobile to allow of the motion of the stirring-rod, and of the removal of the fire-clay cylinder. For the production of large lenses, small furnaces, containing only one crucible each, are used, and, so soon as fusion is completed, the fire is allowed slowly to die out, so that the glass contained in the crucible cools with the furnace, and becomes annealed.

When the glass is considered to be sufficiently annealed, the crucible is drawn out of the furnace, and is broken away from the mass of glass contained in it. The glass is now cut, by means of sand, wire, and water, into horizontal slices, which are carefully examined, and re-cut, so as to eliminate defects. Slices thus obtained are placed upon iron moulds, and inserted in a suitable furnace. As the heat of the furnace is increased, the glass adapts itself to the shape of the mould, and obtains from it the rough outline of its future form. After it has been cooled and annealed, the glass is ground, smoothed, and polished. For the manufacture of smaller lenses, the glass in the crucible is stirred and cooled until it has attained a viscous condition. It is now removed, by means of large ladles, into suitable moulds, re-heated, and annealed. It has been suggested for the manufacture of large lenses to pour glass directly from the crucible into moulds or collars, so as to avoid the necessity of putting out the furnace and breaking the crucible. The glass would be immediately moved with the collar or mould into an annealing-kiln. A mass of optical glass may also be ladled from the crucible, and, having been attached to the end of a blow-pipe, be manipulated in the same manner as sheet-glass. The result is a cylinder, usually thicker in substance than ordinary sheet-glass, which is annealed, split longitudinally, flattened, and re-annealed. The plate of optical glass thus formed may be cut, ground, and polished, as required.

Coloured Glass.—When light falls upon a transparent body, the body appears colourless, if all the vibrations are transmitted in the proportion in which they exist in the spectrum. If some of the vibrations are checked or extinguished, the emergent light will be of the colour produced by the coexistence of the unchecked vibrations. Certain metals, when in combination with glass, have the power of checking certain vibrations; some exert a more powerful action than others, and only transmit the least refrangible vibrations. An increased proportion of the metal in the glass, or an increased thickness of the glass, produces the same effect as is gained in the process of sifting by diminishing the mesh of the sieve, or by repeating the operation. If two slips of a glass containing iron and cobalt in proper proportions be examined, they will be found separately to transmit a green effect, but when placed together, so as to double the thickness, they will transmit a red colour.

It is very generally supposed that any one of certain metals, if its condition of oxidation, or its proportion be varied, will, in combination with glass, produce the several effects of colour into which white light can be decomposed. Thus copper, when suitably treated, will produce the effects of blue, green, and red. Metals enter into combination with glass in various ways. The effect of avanturine-glass is due to the suspension in the body of the glass of minute particles of metallic copper. When oxide of gold is used as a colouring agent, it often happens that some oxide is reduced to the metallic state, and the result is a glass, which, when viewed by reflected light, appears to be of a dull, opaque, red colour, but, by transmitted light, yields a beautiful opaline blue. Opacity is probably due to an insoluble excess of metallic oxide held in suspension in the glass. White opacity is obtained by the use of arsenic trioxide, tin dioxide, lime phosphate, powdered talc or cryolite. The effect of blackness is obtained by the oxides of iridium, manganese, cobalt, copper, or iron in excess.

Gold to be used in colouring glass is first dissolved in aqua-regia; the solution, together with oxides of antimony and tin, is added to the ordinary ingredients of flint-glass. The ruby colour is in a great measure due to the reducing action exercised upon the gold salt by the stannous oxide. Ruby-glass is usually gathered from the crucible in the form of lumps, weighing ½–1 lb. As it is gathered from the crucible, it is perfectly colourless, and only acquires its colour after it has been chilled and reheated in the annealing-kiln. The ruby lumps, after having been annealed, are reheated, as they are required, and used for casing the flint-glass. Articles are never made of solid ruby-glass, partly on account of its cost, but chiefly because the colour is so powerful that an almost invisible film imparts a rich colour to the article upon which it is spread.

The red colour of copper ruby-glass is due to cuprous oxide, and all substances liable to part with oxygen, and to convert the cuprous into cupric oxide, must be avoided in its preparation. In addition to avoiding oxidizing agents, such as red-lead, and oxide of manganese, it is necessary to add reducing agents, to counteract such effects of oxidation as are unavoidable. Stannous oxide and iron scales or filings, are for this purpose mixed with the raw materials. The ruby colour produced is intense, and can only be used as a casing for colourless glass. The ruby-glass, when gathered from the crucible, is of a pale greenish-blue colour, and, like the gold ruby, requires to be partially cooled and again heated before the red colour appears. If reheating is carried too far, the red is replaced by a dull-brown tint. If copper and iron scales be added in great excess, an opaque red mass is obtained.

Cupric and cuprous oxides, when used without reducing agents, produce peacock-blue or green; the result apparently depends rather on the quantity than on the state of oxidation of the copper. A very minute proportion of cupric oxide will give a distinctly blue tint. Ferric oxide (Fe_2O_3), in the presence of manganese dioxide, which parts with its oxygen, and thereby tends to maintain the oxidation of the iron, produces a rich yellow. Ferrous oxide (FeO) gives a dull-green; it is obtained either by the oxidation of metallic iron in the crucible, or by the reduction of ferric oxide.

Manganese dioxide by itself and in large quantity gives violet. If the mixture be heated too long, the oxygen is driven off, and the glass is rendered colourless. A red is obtained by a mixture of manganese dioxide and ferric oxide. A minute trace of cobalt oxide imparts a deep purple-blue. Nickel oxide produces a deep red-brown. The oxides of chromium are very slightly soluble in glass; a minute quantity gives an emerald-green or yellow colour; any excess will remain in the form of glistening crystals in the body of the glass, and tends to its disintegration. Antimony trioxide imparts a faint-yellow tint; excess tends to produce opacity. Oxide of cadmium gives a pale-yellow. Uranic sesquioxide produces a bright-yellow, but its peculiar property of fluorescence, already referred to, gives to the glass, when viewed by transmitted light, a bluish-green effect. Oxide of silver, in common with cuprous oxide, possesses the power of staining glass, when applied as a pigment to its surface, and heated. This is a more convenient way of obtaining the yellow colour which silver oxide gives to glass, as, when mixed with the raw materials of glass, and placed in a crucible, it is only with the greatest difficulty that the oxide can be prevented from becoming reduced. If reduced, metallic silver sinks to the bottom of the crucible, and the glass remains colourless.

Glass Mosaic for Windows.—The heading of this section is used advisedly. The common expressions "stained" and "painted" glass are misleading, because, in the production of decorative windows, stain, enamel, or paint ought to play a very subordinate part, and because excellent effects can be obtained without them. It is true that there are coloured windows in which the effect of colour is obtained solely by the use of ordinary pigments, cemented to the surface of white transparent glass by means of gum or varnish, or by the employment of enamel colours fused to the surface of white glass by means of heat. These methods do not produce the essential conditions of a good ornamental window, namely, transparency or translucency combined with durability. It is unnecessary to point out the instability of colour depending for its existence upon the strength of a gum or varnish. It has been proved by long experience that enamel colours cannot resist lengthened exposure to air and moisture, however effective they may be for internal domestic decoration. It is obvious that opaque powders fastened upon glass must destroy its transparency and translucency. Permanent and transparent effects of colour can alone be obtained by the mosaic treatment of fragments of coloured glasses. For this reason, the mosaic method will alone be considered. By mosaic treatment, is meant the representation of the different colours of a design by separate pieces of coloured glass. The general effect may be heightened by the appropriate application of the transparent yellow silver stain, and by the sparing use of an enamel brown or black for outlines and shading, both the stain and enamel being fixed by heat.

Glass for coloured windows is made either as crown- or as sheet-glass. The circles and sheets, however, are thicker in substance and smaller in dimensions than those used for ordinary glazing. The manipulation of coloured circles is the same as that of crown-glass. In the manipulation of the coloured sheet-glass, so soon as one end of the cylinder is opened, a flattened circular mass of glass, attached to the solid working-rod, and larger in diameter than the cylinder, is made to adhere to the opened end of the cylinder, the closed end being at the same time detached by a sharp blow from the end of the blow-pipe. The cylinder is now manipulated by the working-rod. The small broken end is heated and gradually opened, and the finished cylinder is detached from the circular mass of glass, and sent to the annealing-kiln. The size of the cylinder is usually only about 14 in. × 7 in.; the size of the sheet, 14 in. × 21 in. The attempted process of ripping up the cylinder as soon as made, by means of a large pair of shears, in order that the cylinder may be flattened without being previously annealed, is too dilatory to be practically useful; the coloured cylinders are annealed, cut by a diamond, and flattened, in the same way as the thick cylinders of ordinary sheet-glass.

The metallic oxides, necessary for the production of colours, are introduced into the crucibles with the raw materials. Sheets or circles may be entirely gathered from one crucible, or from more than one, so as to produce a glass composed of two differently coloured layers. Copper-ruby and gold-ruby glasses are always treated in this manner, on account of the great strength of the colours. Ruby is often cased upon blue, green, and yellow, as well as upon white; and blue upon white and green. These cased glasses are particularly useful for representing heraldry, as the casing can be removed by abrasion, or by hydrofluoric acid, and the subjacent ground discovered. Splashed or sprinkled glass is produced by rolling the gathered mass of molten glass in small fragments of differently-coloured glasses; the fragments become incorporated in the molten glass, and expand together with it. Sheets of glass marked with irregular squares or oblongs are often used for domestic glazing, in which translucency without transparency is desired. This effect is produced by inserting the partially expanded bulb, which is formed in making sheet-glass, into a mould marked by deeply indented ribs, and by forcing the glass by the pressure of the breath to adapt itself to the form of the ribs. By twisting the hollow ribbed mass, the lines are made to cross, and the cylinder is finished in the ordinary way. The bulls'-eyes so largely used now for domestic glazing, in imitation of the centres of old crown-glass, are formed like crown-glass on a very minute scale.

Hartley's rolled coloured plate is used in considerable quantities for domestic glazing. Glass stamped with patterns, and shaped into quarries, is produced in the same manner as pressed-glass. These quarries, when part of the stamped pattern is picked out with yellow stain, are very effective and cheap.

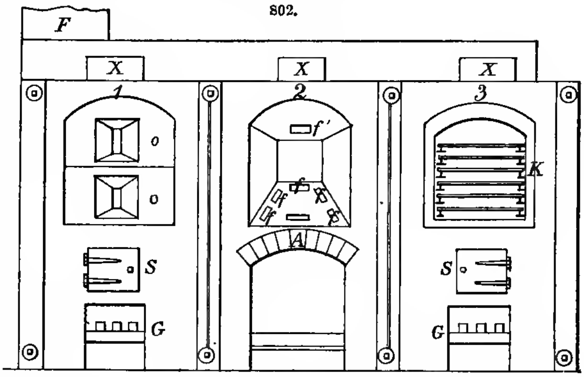
The first step in the manufacture of a mosaic window is the drawing of a small sketch to scale. According to the general features of the sketch, a full-sized drawing or cartoon is formed; a tracing on transparent cloth is then taken from the cartoon. Upon this cloth, are marked the shapes in which the pieces of glass must be cut, also numbers, indicating which colours are to be used. The cutter selects the glasses, and places them over the working drawing, which is raised upon a transparent desk, and marks the shapes with a diamond. The glass is severed by a sharp blow, and minute alterations of curvature or size are effected by means of clippers. If the window is merely to be filled with glass ornamentally arranged, it is only necessary to unite the different pieces in a panel; this is usually accomplished by surrounding and binding together the pieces with doubly-grooved strips of lead. These are first roughly cast in lengths of about 1 ft. These lengths are separately placed in a mill, and compressed between two wheels, revolving in a perpendicular plane and an inward direction. On either side of the space between the edges of the two wheels, is a cheek, which forms the double leaf of the leaden strip. When the end of a length of lead is introduced between the wheels, and these are caused to revolve, the lead is drawn inwards, and at the same time compressed and elongated. The lead issuing from between the wheels is usually more than six times longer than when it was inserted. When the pieces of glass have been united, and a panel has been formed, and bound round with a leaden grooved strip similar to, but stronger than, that used for uniting the small pieces of glass, the joints of the different pieces of lead are made good by solder; and finally, the union of glass and lead is rendered impervious to moisture, by temporarily raising the leaf of the lead, and rubbing in a cement made of boiled oil and white-lead.

Stains.—There are only two transparent glass-stains at present known: a yellow stain, produced by oxide of silver; and a ruby, by cuprous oxide. The latter is very rarely used. A stain may be roughly described as a transparent effect of colour obtained by applying certain metallic oxides to the surface of glass, in the same manner as pigments are applied to canvas or paper, and by subjecting the glass to heat. The stain should be incorporated in the glass, and should be as durable as the glass itself. For yellow, either oxide or nitrate of silver is used; the latter is preferable by reason of its solubility and easy manipulation. In either case, it is necessary to employ some finely divided infusible medium, moistened with water or tar-oil. The media generally used are peroxide of iron, and kaolin.

Enamels.—An enamel paint may be either an exceedingly fusible glass, coloured by some metallic oxide, and rendered opaque by the presence of arsenic trioxide, or an equally fusible transparent glass, mixed with some opaque infusible powder. It is always applied as a pigment, and is fixed to the glass background by heat. It is essentially a glass, and, by heat, should become partially incorporated with the glass upon which it is painted. There is little doubt that, in former times, artists ground up for their paint some of the self-same glass as that with which they were glazing their windows. Paints formed in this manner require for proper fusion the actual melting-heat of the glass to which they have been applied. The pieces of glass background are, therefore, usually found to be injured and distorted when removed from the kiln. To obviate this defect, it has become customary to fix the paint by means of a glass very much more fusible than the glass used for glazing. Such a glass may be produced by the addition of a considerable proportion of borax to the raw material of fluid glass, or by the diminution of the proportion of silica in the same glass. One of the first requirements in a window is that it shall keep out the weather. Any decoration, therefore, that happens to be on the outside of the glass, must be able to resist the action of the atmosphere. Internal decoration is at the same time exposed to the continued action of the products of human respiration, viz. moisture and carbonic acid, as well as to the moisture always present in the air. The borax contained in an enamel paint is rendered anhydrous by fusion, but after lengthened exposure, it reabsorbs moisture, and becomes hydrated and efflorescent. The efflorescence of the borax means the decay of the glass used to fix the pigment to the background. After efflorescence has continued for some time, the pigment begins to flake off, and finally the background is denuded of ornament. Very few of the pigments sold at the present time for the decoration of glass do not contain borax. The use of such pigments upon work intended to be permanent should be carefully guarded against. Flint-glass, rendered more fusible by the reduction of the proportion of silica, is not liable to efflorescence when used as a fixative; care, however, must be taken in preparing the fixative, that the raw materials are mixed in combining proportions. If there be an excess of any ingredient, decay must necessarily follow. A glass formed according to the formula $PbO . K_2O . 4SiO_2$, which is the same as that of flint optical glass, will be found sufficiently fusible for use as a fixative, and will resist the action of the atmosphere. The legitimate use of enamel paint for the permanent decoration of glass is in the form of a dark-brown or red-opaque colour, for outlines and shading. This is prepared by carefully grinding and mixing with the powdered fusible glass a proportion of ferric oxide, cupric oxide, or black oxide of cobalt. The oxide of iridium is also occasionally employed. The colour is applied to the surface of glass in the same manner as an ordinary pigment. Shadows may be represented by one of three methods, or by a combination of the same: (1) by colour applied in a mass, known as "smear shadow"; (2) by thin lines of colour interlaced, known as "cross-hatching"; (3) by a mass of colour allowed partially to dry, and then disturbed by the action of a soft-haired brush, known as "stipple" shadow. By the last method, the colour is scattered in separate particles, and a certain amount of light is allowed to pass, which gives an effect of transparency. The effect of high light is obtained by removing, with a sharp point, parts of a smear shadow.

The kilns used for burning-in stain and enamel are represented in Fig. 802. 1, 2, 3 may be regarded as the same kiln in different conditions; S is the firing door; G, the grate; *o*, cast-iron screens, placed one upon the other, with protruding openings to allow the stoker to watch the progress of the glass within; K, cast-iron casing or muffle, with iron shelves resting upon ridges projecting from the sides of the muffle, upon which the pieces of glass rest; the inside of the muffle is always carefully coated with whiting, and the shelves are covered with a layer of plaster of Paris, in which the glass is imbedded; *f*, openings, allowing the fire to pass from the grate, and through the arch A, in such a manner as to surround the muffle, and to pass off through *f′* into the main flue F; X, soot doors.

802.



Mosaic windows may be divided into two classes, namely, pattern and picture windows; in the former, the pattern may be entirely represented by the shapes and colours of the glass of which it is composed, or may to a certain extent depend upon the use of enamel colour; in the latter, the use of enamel colour is absolutely necessary. In the manufacture of a picture window, or of a pattern window, whose effect partly depends upon painted outlines or shadows, the pieces of glass must pass from the cutter's hands into those of the artist. The artist places the pieces of glass over the cartoon, and traces the outlines with enamel colour. The process of tracing upon dark-coloured glass is facilitated by the use of a transparent desk. After the outline has been traced, the pieces of glass are fastened to a glass easel, by means of wax, in such a way that the artist can obtain an idea, as the work proceeds, of the ultimate effect of the pattern or picture. Whilst the glass remains upon the easel, the artist introduces shadows and high lights, and applies stain wherever it may be required. The pieces of glass pass from the artist to the kilns; and from the kilns, to the glazier and cementer.

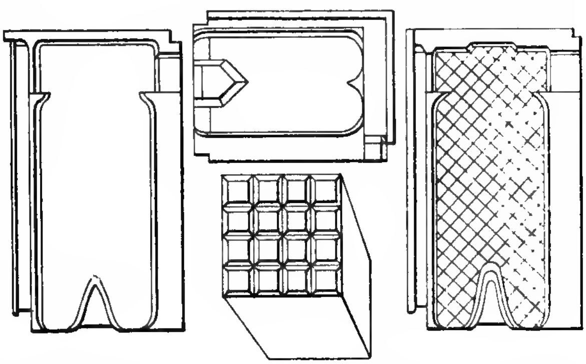
Economies in Glass-Manufacture.—In every glass-manufactory, there must be considerable waste: prosperity much depends upon its reduction to the smallest limits. The production of highest-quality goods necessitates an accumulation of disqualified glass, for which profitable uses must be found. Before discussing the subject, it is necessary to briefly review the course of the manufacture. The raw materials are mixed, and introduced into crucibles standing around the grate of a furnace; the heat is raised, and the fusion of the raw materials, and the purification of the molten glass, take place. Purification consists in the escape of gases generated by the decomposition of the materials, and in the rising of infusible impurities to the surface of the glass. The latter are removed by a process of skimming, and may be regarded as the first instalment of waste or inferior glass. The glass at the bottom of a crucible is generally impure, and, though fit for remelting with the raw materials, is unfit to be worked into goods, and is therefore ladled out. Whenever a crucible breaks, the glass which runs into the furnace is utterly lost, and the remainder can only be saved by ladling.

Glass is liable to various blemishes, even though it be prepared with the greatest care. Discoloration arises, not only from impurity in the raw materials, but is often caused by a variation of temperature in the furnace: if too low, the manganese dioxide will remain unreduced, and the glass will be pink; if too high, the reduction will be carried too far, and the glass will be green or brown. A cold furnace will account for the presence of bubbles in the substance of glass; white solid specks are caused by decay of the crucible; cords or striæ are due to variations of temperature, or to imperfect combination. The waste caused by these blemishes may be exemplified by the fact, that a shade of either pink or brown, or a single bubble, speck, or cord, is sufficient to condemn a first-class wine-glass. Considering the extent to which the temperature of the furnace influences the purity of glass, it is astonishing that manufacturers are still in want of a reliable and handy pyrometer. Those at present in use depend either upon the contraction of unburnt clay, or upon the expansion of burnt clay, and are cumbrous and untrustworthy.

When glass is gathered, scales from the gathering-rod adhere to the portion immediately in contact with it. If glass, soiled with scales of iron, be remelted without the addition of a considerable quantity of the manganese dioxide, the resultant glass will be discoloured. To avoid the scaling of the iron, it has been proposed either to plate the ends of the gathering-rod with platinum or some other difficultly fusible metal, or to subject them to the process of oxidation by superheated steam, invented by Prof. Barff. For the manufacture of a wine-glass, at least two distinct gatherings of molten glass are necessary. At each gathering, the weight taken from the crucible is at least double that actually used. Considering also the large number of wine-glasses rejected in course of manufacture, at least half the contents of the crucible is wasted. In annealing, in moving from the annealing-kiln, in smoothing and grinding, in cutting, and in carriage, there is necessarily a very large amount of breakage and of waste. All broken glass is carefully collected and sorted. The best, together with that ladled from the crucibles, is mixed with the raw material, and remelted. To the second best, i.e. that to which iron scales adhere, a proportion of manganese dioxide is added, together with the raw material. The third quality must be used for the production of coloured glass, or be worked up into some inferior ware.

At the St. Gobain Works, inferior glass is worked into tiles and transparent paving-blocks, as represented in Fig. 803. In manufactories where mosaic windows are made, the discoloured glass may profitably be mixed with metallic oxides, and worked into coloured sheets or circles. It may also be slightly tinted, and pressed into glazing-quarries. In addition to glass of inferior quality, there is always a large quantity which has become so mixed with clay and dirt as to be unfit for use as transparent glass. If this final waste be carefully collected and sifted, and if, after it has been ground into an almost impalpable powder, it be spread upon clay tiles, and partially melted in a kiln, it forms an opaque substance, which is exceedingly hard, and suitable for pavements or wall decorations. By the intermixture of metallic oxides, almost any colour can be produced. The substance possesses a granular surface, and its colour is usually beautifully irregular; in these respects, it compares favourably with clay tiles. Another use proposed for powdered glass waste is as a partial substitute for emery in emery-wheels.

803.



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GRAPHITE (Fr., *Graphite*; Ger., *Graphit*).

Graphite is also called "plumbago" and "blacklead," misnomers associated with the erroneous idea that lead enters into its composition. This valuable mineral is now recognized as a native form of carbon; its chemical properties, however, have yet to be fully discovered, and geologists are still at variance concerning its probable origin; on these points, therefore, only so much will be said as has a practical bearing upon the applications of the substance. Two distinct varieties are noticed: the one, fine-grained, or amorphous; the other, foliated, or compounded of numerous little scales; sometimes also it appears as an impregnation of other rocks, rather than as a distinct rock in itself. Geologically, it is confined to the oldest formations, and is usually, if not universally, associated with metamorphic action.

Its geographical distribution includes all five quarters of the globe. Among European localities, the first place must be assigned to the historically renowned mines of Borrowdale and Keswick, in

Cumberland. These were revealed by an accidental occurrence, and were worked as early as 1644. The value and scarcity of the mineral severely provoked the thieving propensities of the neighbouring population, so much so that special legislation was needed in 1752 to protect the owners. In 1788, the output was 417 casks (each containing 70 lb.) of the best quality, whose value was estimated at 45,000*l.* In 1804, when the price was 35*s.* a lb., the nett profits reached 118,875*l.* The entrance to the mine was enclosed by a stout building, and the workmen were searched on leaving. The graphite found here is of the fine-grained or amorphous variety, containing from 95 to nearly 100 per cent. of carbon, the impurities being usually small quantities of silicates. The mineral, which is locally known as "wadd," occurs in nests, "sops," "bunches," or "cells," in a partially decomposed trap-rock, running through clay-slate; it is worked by means of "stages," "veins," and "pipes." These mines were for many years the sole known source of graphite, and their productive capabilities were so great that it was only necessary to work them for a few months in order to supply the markets for several years. During the intervals of idleness, means were adopted for flooding the workings with water, as the surest preventive of stealing.

Late in 1875, the mines were reopened, after having been closed for an unusually long time, on account of private and legal difficulties. The protracted inactivity had given rise to rumours that the deposits were exhausted, but nests have recently been discovered of as large dimensions and as good quality as hitherto. For the purpose of pencil-making, it remains unequalled by that from any other source. The minor occurrences of the mineral in the United Kingdom are:—in gneiss, at Glenstrathfarrar, in Inverness; in coal-beds which have been formed in contact with trap, at Craigman, in Ayrshire; and in small lumps, in the elvan courses of Cornwall.

Germany possesses several graphite deposits. A variety about equal in purity to that of Cumberland, but somewhat more amorphous and friable, occurs in considerable quantities at Griesbach, near Passau, in Bavaria. It is not refractory, and is therefore valueless for crucible-making, and is of little use as a lubricator; but for pencils, it is largely employed, and is imported into this country for making domestic blacklead (stove-polish). In the Adelheids-Glück coal-mine, at Rybnik, Prussian Silesia, an important layer of graphite earth has been found, in thickness exceeding 40 ft. Trials are said to have proved it well fitted for luting, muffles, hearths, &c. A specimen of graphite from Styria exhibited coarsely foliated structure, strong metallic lustre, and sp. gr. 2·1443. Its composition was:—Carbon, 82·4; silica (belonging to the ash), 12·38; alumina, 3·9; peroxide iron, 0·53; protosesquioxide manganese, 0·62; lime, 0·02; alkalies, traces. The production of graphite in the Austro-Hungarian Empire was 203,166 metrical centners (of 110¼ lb.) in 1875, and 127,171 in 1876. Spain has lately sent some graphite of fair quality to this country. An analysis of Portuguese graphite gave:—Water (including hygroscopic), 10·21; carbon, 38·47; ash, 50·81. A sample from Upernavik, Greenland, hard and of pale colour, useless for pencils, showed:—Carbon, 96·6; ash, 3·4 per cent. An occurrence of graphite with quartz is reported from Arendal, Norway. The mineral has also been found in Finland.

The distribution of graphite in Asia is by no means inconsiderable. A deposit, said to be very abundant, has been discovered in the Bagoutal mountains of S. Siberia, near the Chinese frontier, of which great things are predicted. Seebohm, in 1879, brought about 20 tons of almost pure graphite from the banks of the Kúreijka. The deposit is leased by a Russian from his government, and has not yet been the scene of anything like scientific working. Two samples of Siberian graphite from Stephanovsky respectively revealed on analysis the following composition:—Carbon, 36·06 33·20; silica, 37·72, 43·20; ferric oxide, 4·02, 3·05; alumina, 17·80, 15·42; lime and magnesia, 1·20, 1·06; volatile matters, 3·20, 4·03; sulphur, traces, 0·04. English graphite is said to be imported into Russia, for admixture with the low-grade native produce. Deposits of lamellar graphite have been found in several parts of India. In 1862, a new mine was discovered at Sonah, near Goorgaon. The mineral is found in masses of variable size, and generally quite detached. In some cases, the surrounding rock is impregnated with graphite, mixed with small micaceous particles. It yields on analysis:—Carbon, 78·45; silica and alumina, 12·98; peroxide iron, 3·30; carbonate lime, 0·84; water, 4·35; alkaline sulphates and chlorides, 0·08. The soil and rocks of Ceylon are almost everywhere impregnated with graphite, so that it may even be seen covering the surface in the drains after a recent shower. That found at Ratnapoora and at Belligam is in large detached kidney-shaped masses, at 4 to 24 ft. below the surface. The cost of digging and transport are the chief expenses attending it; the supply is practically inexhaustible. The mineral exists in such quantities in the gneiss rocks that, upon their decomposition, it is seen in bright silver-like specks throughout. Graphite-diggings are scattered throughout every part of the island, and are numbered by hundreds, and fresh discoveries are constantly being made. Ceylon graphite is particularly remarkable for its purity, containing as it does very small proportions of siliceous ash. Three samples revealed the following features:—

1. Amorphous,	sp. gr., 2·2671;	volatile matters, 0·158 %;	carbon, 99·792 %;	ash, 0·050 %.
2. ,,	,, 2·2546;	,, 0·900 ,,;	,, 98·817 ,,;	,, 0·283 ,,
3. Foliated	,, 2·2664;	,, 0·108 ,,;	,, 99·679 ,,;	,, 0·213 ,,

Graphite mining on private lands was subjected to a Royalty by the local government as early as 1851. The amount was then fixed at 4*s.* per ton of mineral raised, which was increased to 5*s.* in 1852, 7*s.* 6*d.* in 1859, 14*s.* in 1862, 16*s.* in 1864, and 30*s.* in 1869. In consequence of the difficulty experienced in collecting this Royalty, it was abolished in 1873, and was replaced by an export duty of 1*l.* per ton, levied by the Custom House on all graphite exported beyond the seas. This came into force on the 1st April, 1874. The quantity and value of graphite exported from Ceylon for seven years ending 1877 have been as follow:—1871, 125,257 cwt. (62,095*l.*); 1872, 136,051 cwt. (43,837*l.*); 1873, 173,996 cwt. (147,939*l.*); 1874, 149,938 cwt. (135,016*l.*); 1875, 110,023 cwt. (103,146*l.*); 1876, 117,361 cwt. (110,026*l.*); 1877, 96,792 cwt. (90,743*l.*). The mineral has also been recognized in Burmah, and has been contributed in small quantities from Vizagapatam and Malacca. The general Indian product is not sufficiently fine for pencils, but is available for crucibles.

Little as we know of the African continent, graphite has already been found in many parts of it. A very good quality is found to the south of Springvale, in Natal, in gneiss. As the working is not very expensive, a ton of pure mineral costing only about 30*l.*, hopes are entertained that it will pay to ship. Traces of graphite are met with at several points in the "old colony." A considerable deposit occurs not far from the mission station of Inyatin, about 20° S. lat. In Bamba Hill, Southern Usambara, Keith Johnston found it disseminated through the mass of the rock, a garnetiferous gneiss.

Graphitiferous rocks of the Laurentian system are widely spread throughout Canada and some parts of the United States. The graphite of these rocks usually occurs in beds and seams, varying in thickness from a few inches to 2–3 ft. They are often interrupted, giving rise to lenticular masses, which sometimes are nearly pure. The deposits generally occur in the limestones, or in their immediate vicinity, and granular varieties of this rock often contain large crystalline plates of graphite. At other times, the mineral is so finely disseminated through the limestone as to give it a bluish-grey colour, and the distribution of the stained bands serves to mark the stratification of the rock. The graphite of the Laurentian series is not, however, confined to the limestone.

Perhaps the most important and extensive of the Canadian deposits is that near the township of Buckingham. Here the graphite occurs both in beds or veins, and disseminated. The veins are fourteen in number, some 6–10 ft. wide, and 3–14 in. thick, besides more or less disconnected lenticular masses, yielding 30–35 per cent. of mineral. The vein graphite is of two varieties: (*a*) foliated: of dense, massive structure; made up of broad and thick laminæ; colour, dark steel-grey; lustre, metallic; sp. gr., 2·2689; carbon, 99·7, ash, 0·147, volatile matters, 0·178 per cent.; (*b*) columnar: carbon, 98·0, ash, 1·78, volatile matters, 0·594 per cent.; sp. gr., 2·2679. Second samples of each gave: (*a*) sp. gr., 2·2714; volatile matters, 0·109, carbon, 99·815, ash, 0·076 per cent.; (*b*) sp. gr., 2·2659, volatile matters, 0·108, carbon, 99·757, ash, 0·135 per cent. Besides this vein graphite, there is a quarry of the disseminated mineral, more than a ½ mile long, and 70 ft. high, giving 10–60 per cent., the average being about 25 per cent.

The graphite is here prepared or "dressed" for the market in the following way:—The crude ore is stamped fine in water, and then put through buddles, by which the graphite and the rock matter associated with it are separated according to their specific gravities. The graphite is subsequently charged into reverberatory furnaces, and ultimately passed through bolters, whose gauze is of various degrees of fineness, according to the size required. According to Hofmann, the Canadian graphites equal those from Ceylon in point of incombustibility, and on that score are as well fitted for crucible making. On the other hand, all the samples examined contained more or less carbonate of lime and oxide of iron, both exceedingly objectionable in graphite intended for refractory purposes. By a process of treatment to be discussed further on, it is possible, however, to remove these and other foreign matters, so that "dressed" mineral showing 13–15 per cent. of impurities, may contain only 6·69 per cent. after treatment 5·35 of this amount being silica. In this way, the Canadian graphite can be rendered quite fit for crucibles, &c. Its cost price after dressing is about 3*l.*–5*l.* per ton. Workable deposits of graphite also occur in the Dominion, near the townships of Burgess, Lochaber, and Grenville.

There are two important graphite mines in the United States, the principal being the Eureka mine, near Sonora, California. The lode from which the mineral is obtained runs about 4000 ft. in a N.-E. and S.-W. direction, and ranges from 29 to 40 ft. in width. It is much broken up and mixed with the surrounding rock and earth to a depth of about 30 ft., but below this it is well defined between walls of sandstone and clay-slate. The lode is frequently divided by lenticular masses of clay-slate, from a few inches to several feet in thickness. A shaft sunk on the lode to a depth of 65 ft. showed the mineral to be purer and more solid than at the surface. The lode continues 25 ft. wide, and much of the mineral is so pure that a couple of men can extract and sack about two tons daily of a quality that can be sent to market without any preparation.

The apparatus used for separating the graphite from the impurities, when the mine was first opened, consisted of a wooden barrel, perforated with small holes, an iron rod passing through it lengthwise. The ends of the rod formed journals, which rested on two upright posts, the machine being turned by hand, by means of a crank, precisely like a barrel churn. The dirt to be washed being put into the barrel by means of an opening at the side, a small stream of water was led through a pipe to the top of the machine. After a few minutes' turning, all the graphite, sand, and fine grit were washed through the holes; the stones and lumps remaining in the barrel were thrown out at every charge. The water containing the finer materials was caught in a tank, about 5 ft. deep, placed immediately under the barrel, the only outlet from the tank being a shallow spout a few inches from the top. The graphite in exceedingly fine particles floated off in the water which passed over this spout, while nearly all the sand and other materials remained in the tank. The water holding the graphite in suspension was then passed through a series of shallow tanks made of board. After a "run" of several days, the water was let out of the shallow tanks, and the sediment they contained was left exposed to the sun for a few hours, when it became blackened ready for the market. That obtained from the last of the tanks was finer than that from the first, though all was extremely fine. An analysis made of some from the last tank gave 97·9 per cent. carbon. Nearly 200 tons were prepared in this way, and sold readily in New York, Philadelphia, &c., at 20*l.* per ton.

As operations increased, improvements were made. Iron cylinders worked by water-power were substituted for the barrel, the water and sediment leaving them being conveyed by pipes to a large tank made of planks and stout framing, and capable of holding 1000 tons. When this tank was filled (in about three days), its contents were allowed to settle for 24 hours, after which the dirty water was let off from the surface, and a powerful stream of clean water was let on, which forced the sediment through spouts into 18 shallow tanks, each 20 ft. wide, 25 ft. long, and 1 ft. deep. After remaining in these tanks about 3 days, the water was let off, and the sediment was exposed to the sun. In 24 hours it becomes hard enough to be taken out in blocks, which, after lying for another 24 hours on plank platforms, are ready for market. About 25–30 tons per week were treated by this method; but the demand still growing, arrangements had to be made for turning out 20–25 tons per day.

These consist of a sort of *arrastra*, or puddling-machine, to replace the cylinders, comprised in a circular bed 20 ft. in diameter, with water-tight sides 3 ft. high, in the centre of which is an upright post with 4 arms, to which are attached stirrers instead of grinders, as in an *arrastra*, it being desirable not to grind the mineral, only to separate the particles. It is driven by a water-wheel, and 15 Chinamen are employed to feed in the mineral. A small stream of water passing constantly through it carries all the lighter particles away. The rocks and sand are let out by a sluice-gate every 3–4 hours. The water carrying the graphite is conveyed by a flume to an enormous tank built in the ground, measuring 200 ft. long, 150 ft. wide, and 7 ft. deep, and capable of holding 30 days' collection. This was very expensive to construct, its entire inner surface being coated with a specially prepared cement, sufficiently smooth to prevent the graphite adhering, and so porous as to preclude its retaining moisture after the water had been let off. When the tank contains 3–4 in. of sediment, it is considered full, and, after standing for a few days, the water is run out, and the sediment is exposed to the sun. In two days, with fine warm weather, it is sufficiently dry to be taken out and laid on the drying-platforms, and in 24 hours is ready for market.

The cost per ton of the pure graphite needing no preparation, employing Chinese labour at 8 dol. a week, without board, is thus stated:—Extraction, 4*s.* 2*d.*; sacks, 8*s.* 4*d.*; land carriage to Stockton, 65 miles, 1*l.* 17*s.* 6*d.*; rail to San Francisco, 6*s.* 3*d.*; ship to Liverpool, 2*l.* 18*s.* 4*d.*; commissions, insurances, &c., 2*l.* 12*s.* 1*d.*; total, 8*l.* 6*s.* 8*d.* Its market value in Liverpool is about 20*l.* per ton. The output is about 500 tons per annum, nearly all of which is exported to Europe.

The second considerable American deposit is worked on the eastern slope of the "Black-lead Mountain" of the old maps of Essex County, New York State. The mountain lies just behind the village of Ticonderoga. The ore is mainly of the foliated variety, interspersed in veins among gneiss and quartz, with a dip of about 45°. Two analyses yielded 96·656 and 97·422 per cent. of carbon respectively. Some of the veins are much richer than others; one has been worked to a depth of about 350 ft., and found to be of varying thickness and with occasional pockets. After leaving the mine, the mineral is first crushed in an ordinary stamp battery to a fine powder, and the constituents are separated by Cornish buddles and settling-tanks. The graphite is then washed, dried in an oven, and bolted like flour, after which it is ground in water in a Bogardus mill, and again bolted. The grade thus produced is called "crucible stock"; for finer grades, additional processes are necessary. The miners are paid at the rate of about 25*l.* per ton of prepared graphite. The five grades of manufactured graphite are estimated to be worth about 2½*d.* per lb. for stove polish; 7½*d.* for powder polish; 2*s.* 1*d.* for pencils; and 4*s.* 2*d.* for stereotype powder.

Another important mine is reported at Whitehall, in the same State.

Australia possesses valuable graphite deposits, near Moreton Bay; at Ballarat, a very pure vein has been discovered, 5 in. thick at the top of the drive to 18 in. thick at the bottom. In New Zealand, impure graphite occurs in the Carrick Range, Otago, in considerable quantities, sometimes 13 ft. thick. A seam of graphite runs along the eastern shore of Fairfax Harbour, New Guinea.

Rammelsberg gives the following comparative tables of some graphites:—

a. Loss by ignition.—Ticonderoga (New York), 3·85 per cent.; Ceylon, 2·56; Borrowdale, 3·80–5·08; Upper Jenisei (Siberia), 2·53; Tunguska (Sidorow), 1·77–2·38.

b. Earthy matters.—Ceylon, 1·28 per cent.; Borrowdale, 7·00; Upper Jenisei, 4·50; Tunguska, 6·53.

c. Combustibility in contact with fused saltpetre: completely combustible—Ceylon, sp. gr. 2·257; Borrowdale, 2·286; Upper Jenisei, 2·275; Upernavik, 2·298; Arendal, 2·321. Incompletely combustible—Ticonderoga, sp. gr. 2·17; Ceylon, 2·246; artificial carbon, 2·30.

The application of graphite to the manufacture of pencils (see Pencils), and of stove polish (see Blacklead), are sufficiently familiar, but it is used for other equally important purposes. It is now much employed as a lubricator for the steam cylinders of engines; about 120–180 grains of the fine, dry, pulverized mineral being introduced twice a day through the usual tallow box. It is found to be much superior to oil or grease. Enormous quantities are consumed in crucible making, and another wide application of the substance has been created by the electrotype process, it being used to coat the surfaces of wood, plaster of Paris, guttapercha and other non-conducting materials, so as to make them conductors.

Very erroneous impressions are still generally entertained concerning the commercial value of graphite, so much so that it is a common thing for the discoverer of a new deposit to believe himself possessed of an immensely valuable property, whereas the mineral may be all but worthless. The reasons for this may be sought in the high price of the renowned Borrowdale graphite, and the common error of supposing all graphites to be alike. As a matter of fact they differ most essentially, not only in chemical composition—for crude native graphite is not purely carbon—but also in physical constitution, necessitating the greatest care in purchasing the raw material, that it may be of a character in accordance with its proposed application.

The value of graphite depends largely upon the amount of carbon it contains, which is best ascertained in the following way. The pulverized graphite is dried at about 182° (360° F.), then placed in a test-tube 4–5 in. long and ½ in. wide, of hard glass. To this is added about 20 times as much well dried oxide of lead, and the whole is well mixed. The tube and its contents are carefully weighed, and then heated by the blowpipe flame till the mixture is completely fused and no longer evolves any gases. After this operation, lasting about 10 minutes, the tube is allowed to cool, and the weight is again ascertained. The loss in weight is carbonic acid, the oxygen of which has been taken from the lead oxide, while the carbon is all that there was in the graphite. For every 20 parts of loss there must have been 12 of carbon. In general it is sufficient to take 1 to 2 grammes of graphite, and 20 to 40 of oxide of lead. Touching other chemical peculiarities, it will be useful to observe that argillaceous matters, though they reduce the value of the mineral, are not prejudicial; but the presence of carbonate of lime, or oxide of iron, is very objectionable in graphite intended for refractory applications. Presently it will be seen how far chemical treatment can be made to overcome these drawbacks; but first of the physical differences.

On freeing graphite from its ash constituents, by means of grinding it very fine, and subjecting it to treatment with alkali at the point of fusion, aqua regia, and hydrofluoric acid, the so-called graphitic acids are produced. Graphitic acid thus obtained from amorphous graphite is a fine yellow, amorphous powder, which, when decomposed by heat, yields a black mass of great colouring and covering powers, exceeding those of the finest lamp-black. The same acid prepared in the same way from foliaceous graphite appears under the microscope to consist of foliaceous crystals, whose residue does not colour and has no covering property. The division of graphite into amorphous and foliaceous varieties is, therefore, of the greatest practical importance. When a lubricating or covering body is required, as in antifriction compounds, blackleading, electrotyping, &c., amorphous graphite must be chosen; but for metallurgical and refractory purposes, the foliaceous variety is preferable. Granular or amorphous graphite, which is often the purest, is of little use for crucibles; but, with suitable manipulation, produces the finest grades for electrotyping and fine pencils.

Among the graphites now in the market, it may be said that the supply for refractory purposes, blacklead, and antifriction, comes in a great measure from Bavaria and other parts of Germany, and from Ceylon. The graphite of Passau (Bavaria), so extensively used in apparatus subjected to great heat, contains only 35–42 per cent. of pure graphite, the residue being argillaceous. The better varieties for pencil-making are also principally of Bavarian and Bohemian production, and form the best substitutes for the renowned Cumberland mineral, which owes its value rather to the peculiar state of aggregation of its particles than to chemical purity, as it is much less pure than some of the Ceylon graphite which does not approach it in price. The value of the comparatively pure crystalline graphite of Ceylon and America, containing very small proportions of earthy matters, is placed at about 20*l.* per ton. The former is too fragile for pencils. That found in the neighbourhood of Ronda in Grenada, and near Malaga in Spain, is hard and difficult to grind.

It now remains to describe the process above alluded to by which impure and waste graphites may be rendered available for many uses. The graphite is first reduced to very fine powder, then compacted by moderate pressure, and enclosed in thin paper glued all over and pierced in one place by a small hole, to permit the escape of air when placed under an exhausted receiver. In this way, the air is removed; and the orifice is closed. Within 24 hours, it is subjected to pressure again, and the block formed is capable of treatment as a natural solid body.

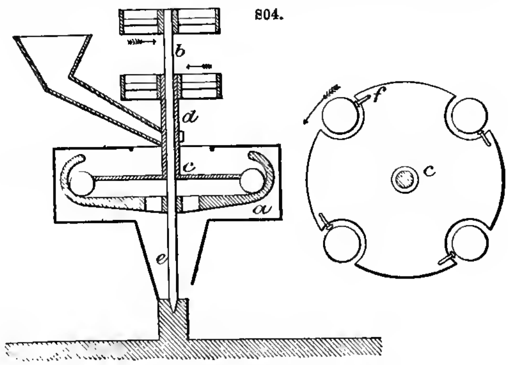
In order to remove the impurities from inferior graphites, the finely pulverized mineral is mixed with a proportion of nitric acid or an alkaline nitrate, chlorate, chromate, or bichromate, preferably chlorate of potash, in weight about $\frac{1}{20}$ to $\frac{1}{16}$ of the quantity of mineral. To this is applied sulphuric acid, sp. gr. 1·8, in quantity about equal to twice the weight of mineral, and the whole is thoroughly blended. The mixture, prepared in an iron vessel, is heated to a moderate degree, by which chlorous gas is copiously evolved. As soon as these fumes subside, the vessel is allowed to cool, and the oxidized and sulphated mass is thrown into water and washed by decantation. It is then dried, and heated to redness in a furnace, which causes it to swell up and disintegrate. The resulting powder has only to be agitated in water in order to separate the graphite, which is porous, and floats on the surface, from the silica, peroxide of iron, and other impurities, which, being heavier, sink to the bottom. The graphite thus prepared is absolutely pure.

The product obtained from amorphous graphite is not so fine as that from lamellar or foliated, and cannot be levigated with the same facility. To complete its purification, a little fluoride of sodium is added to the mixture in the iron vessel, as soon as the chlorous fumes cease to be evolved. The hydrofluoric acid, set free by the combination of the sodium with the sulphuric acid, immediately attacks the silica present, and carries off this impurity as gaseous fluoride of silica.

Ceylon graphite is very difficult to purify. After twice treating as above, there remained 0·42 per cent. of an incombustible residue, which was reduced by a third operation to 0·12 per cent. Bohemian and Styrian graphites purified in this way yielded mere imponderable traces of white incombustible matter.

For making crucibles, the first process which the graphite undergoes is that of grinding in "cannon-ball" mills, shown in plan and section in Fig. 804: *a* is a heavy iron saucer-shaped receptacle, having an aperture in the centre, across which are arms, connecting it with the central shaft *b*. This shaft is rotated by pulleys. Above the saucer, is a disc *c*, in which are four recesses. In these recesses, and resting on the saucer below, are four 32-lb. cannon-balls; and, attached to the middle of the disc, is a sleeve *d*, enclosing shaft *b*, and carrying a pulley, by which it is rotated in a direction relatively opposite to that of shaft *b*. A casing surrounds the mill, through which the graphite enters, emerging below through the funnel *e*, whence it is taken away by an elevator. When the graphite enters, the centrifugal force generated by the swiftly rotating parts throws it outward, so that it may be at once acted upon by the balls. Wear by the latter on the disc is prevented by steel pins *f*.

804.



It will be obvious that, under this condition, the heavier particles of the material will approach nearest the circumference, while the finer ones will arrange themselves in the order of their weights toward the centre. Consequently the finest ground graphite will always be that which is escaping from the mill, while the grinding parts constantly act on the coarser portion. In this way, the grinding operation is greatly facilitated, and, at the same time, the graphite is reduced to a degree of fineness unattainable in ordinary forms of mill.

The graphite thus prepared is mixed with a small proportion of China-clay, varying according to the use for which the crucible is intended. To every 10 parts of graphite, is also added 7 parts of a grey clay which is imported from Klingenberg, in Bavaria, besides a little ground charcoal. These ingredients are mixed dry; water is afterwards added, and the compound passes to a cast-iron cylinder, capable of holding about 3 tons. Here thorough stirring is done by means of arms arranged radially on a central vertical rotating shaft. Each arm, besides having four vertical bevelled blades, is made flat above and bevelled below, so that the mass undergoes a kneading, which secures its rapid and homogeneous mixture. The material emerges in the form of thick mud, and is at once moulded either by hand or machinery, the operation being performed in almost exactly the same way as by potters. The same may be said of the subsequent baking. The above description applies more especially to the Dixon (American) crucibles. The Plumbago Crucible Co., of Battersea, mix Stourbridge clay with their graphite; their crucibles show, on analysis, 52·6 per cent. of carbon, 45·4 of earthy matter, and 2·08 of water.

The imports of graphite into this country, in 1873, were, from Germany, 2009 tons, value 28,964*l*.

(about 14s. 5d. per cwt.); Holland, 662 tons, value 11,390l. (about 17s. 2½d. per cwt.); Ceylon, 2500 tons, value 45,221l. (about 18s. 1d. per cwt.); other countries, 297 tons, value 7043l. (about 23s. 8½d. per cwt.).

(See Blacklead; Carbon; Gems—Diamond; Pencils.)

HAIR (Fr., *Crin, Bourre, Poil, Cheveux*; Ger., *Haar*).

Hair, a projection from the surface of the skin of many animals, consists of multitudes of slender, elastic, flexible, elongated cylinders, formed of fibrous, horny substance, and containing numerous cells, which, in coloured hair, secrete granules of pigment. The composition of hair may be stated approximately as:—Carbon, 50·65 per cent.; nitrogen, 17·71; hydrogen, 7·03; oxygen and sulphur, 24·61. The presence of sulphur is a notable fact, as it has an important effect on the action of dyes, and forms a ready means of distinguishing between animal and vegetable fibres (see p. 911). Hair, like feathers, hoofs, nails, and other modifications of the tegumentary system, when submitted to dry distillation, gives off products highly charged with carbonate of ammonia. The same remarks apply to wool as to hair. The chief distinction between these two products, if there be any save in name, lies in the fact that hair is generally straight, while wool is more or less curly and serrated. The scope of this article will embrace the hair afforded by all animals save the sheep, whose fleece will be described under Wool; while those hairs which have commercial value and use in their natural condition, attached to the animal's skin, are dealt with in the article on Fur. In the manufacture of leather, great quantities of hair have to be removed from the skins (see Leather).

The trade in hair is of no inconsiderable magnitude. Omitting the enumerated varieties, statistics of which will be given under their respective heads—alpaca, cow, goat, horse, and pig—our imports of unclassified hair in 1879 were of the following value:—From Russia, 45,134l.; China, 42,260l.; United States, 33,687l.; Belgium, 12,243l.; Germany, 11,703l.; France, 11,313l.; other countries, 9133l.; total, 165,473l. The exports of hair from Denmark in 1878 were 170,892 lb., value 216,327 *kroner* (of 1s. 1½d.); in 1879, 159,767 lb., 628,710 *kroner*. The exports of cow-, horse-, and pig-hair from Hamburg to Great Britain were 18,232 cwt. in 1876, 29,435 cwt. in 1877, and 28,656 cwt. in 1878. The exports of hair from Austro-Hungary in 1877 were 2344 metrical centners (of 110¼ lb.), value 460,808 florins (of 1s. 11½d.). Riga, in 1877, exported 43,740 *poods* (of 36 lb.), value 262,440 *roubles* (of 3s. 2d.). The exports of all kinds of hair from Canton were, in 1877, 665 *piculs* (of 133⅓ lb.); in 1878, 1076 *piculs*. The exports from Ceará (Brazil) in 1878 were 6827 kilo. to England, 460 kilo. to Havre, and 311 kilo. to Hamburg; and from Rio Grande do Sul, in the same year, 486,469 kilo.

The length, strength, and elasticity of hair render it useful for many purposes, varying according to its nature and origin. These will be alluded to under the head of each kind. The chief varieties of hair will now be separately considered.

Alpaca.—The name "alpaca" is somewhat indiscriminately applied to several allied hair-bearing animals, to the hair they afford, and to the goods manufactured from that hair. The genus includes four species—the alpaca or paco (*Auchenia paco*), the vicuña (*A. vicunna*), the llama (*A. lama*), and the huanaco or guanaco (*A. huanaco*).

The most important of these from our point of view is the alpaca. This animal, in size somewhat exceeding a large goat, ranges in its native condition from the centre of Peru into Bolivia, or between 10° and 20° S. lat. At and above an altitude of 8000–9000 ft., in the table-lands and mountain-ranges of the Andes, it lives in herds in a half-domesticated state, almost every peasant owning a dozen or so head. The animals feed principally on the *ichu*, a coarse, tall grass, frequenting the wild desolate spots below the snow-line, but have often to content themselves with mosses and lichens. They are driven in only at the shearing season. Their economic value lies primarily in their hair, and secondarily in their flesh, which latter resembles mutton, and is 3–4 times more abundant than that of the sheep. This species is not employed as a beast of burden. The fleece is superior to that of the sheep, both in length and softness. It averages a length of 7–9 in., and sometimes greatly exceeds these figures. It is very lustrous and fine, and is coloured mostly white, black, or grey, brown or fawn shades being rare. Each filament is straight, well-formed, and free from crispness, and the quality is uniform throughout, the fibre acquiring strength without coarseness. It dyes with facility, and takes the colours well. Its softness and elasticity are conspicuous, it spins into an even, strong thread, and textiles made from it have almost a silky lustre (see Woollen Manufactures—Worsted). The weight of the fleece reaches 10–12 lb., while 17 lb. is not an unknown figure.

The utility and value of the animal, which first aroused attention in 1836, led to many attempts to naturalize it in various parts of the globe. For some years, repeated efforts were made to raise flocks in this country, but they met with the ill-success that might have been expected from so great a change in the natural conditions surrounding the animals. That better results would attend a similar essay in the Highlands of Scotland seems probable. In the Pyrenees, a small herd did at one time exist, and there seems to be no good reason why the animals should not thrive there, and in other European mountain-chains, as the Alps, Carpathians, &c. In 1859, an attempt was made, on an extensive and costly scale, to introduce alpacas and llamas into New South Wales. For a time, all promised well, and the animals throve and multiplied; but by 1863, nearly all the old animals were dead, and the progeny, numbering some 350, several of which were hybrids between the alpaca and the llama, sickened and drooped, and in a short time numbered less than 200. Several of the survivors were purchased by other Australian colonies, and by New Zealand, but no care seems to have been able to compensate for the change from their mountain climate, and the experiment has ended in total failure. It has been proposed to repeat it in Natal, but the prospect there is not much more encouraging.

The vicuña is a much rarer and more valuable animal. Its geographical range in point of latitude exceeds that of the alpaca, as it extends throughout Peru and into Bolivia and Ecuador; but it seldom descends lower than 13,000 ft., and it is very wild, and sparsely distributed, in the district which it inhabits. It is somewhat smaller than the alpaca, and the weight of its annual fleece is but little over 1 lb.; on the other hand, the hair is exceedingly fine and delicate, varying in tint from a pale reddish-brown to a dirty-white, and usually brings double the price of alpaca for fine felting purposes.

The llama is larger than the alpaca, and is useful chiefly as a beast of burden and for its flesh. It inhabits only the loftier mountains of N. Peru. It affords a valuable fleece, which is, however, never shorn, and is almost entirely consumed locally, to the extent of 5–6 million lb., for sacking, cordage, carpets, and other coarse fabrics.

The guanaco attains almost to the size of our red deer, and is found from the equator to Tierra del Fuego, herds of 500 being met with in Patagonia. Its hair is dark-brown in colour, and shorter and coarser than that of any of the other species. It is worked up by the natives into blankets and ponchos, and rarely comes into this market.

Though the hairs afforded by these several animals are separately packed and marketed, the Board of Trade Returns do not distinguish them, but class them together, under Wool. In the first 4 years of the trade, our imports of all kinds were over 500,000 lb. annually, and the value was 10*d.* a lb.; in 1852, we imported 2,186,480 lb., value 2*s.* 6*d.* a lb.; in 1864, 2,664,027 lb.; in 1872, 3,878,739 lb., value 2*s.* 6*d.*–2*s.* 10*d.* In 1879, our imports were:—From Peru, 3,671,660 lb., value 230,284*l.*; Chili, 633,096 lb., 49,982*l.*; other countries, 21,027 lb., 1045*l.*; total, 4,325,783 lb., 281,311*l.* The exports from Mollendo (Peru) in 1878 were:—Alpaca, 1st class, 25,826 *quintals* (of 101½ lb.), 2nd class, 9691 *quintals*; vicuña, 216 *quintals.* In 1879, they were 29,416, 4631, and 203 *quintals* respectively.

Bison (*Bison americanus*).—The American bison, generally and erroneously called "buffalo," inhabits the prairies of America, from the eastern slopes of the Rocky Mountains to the Appalachian chain, and from 63° N. lat. to New Mexico. The hair afforded by the animal is spun and woven into gloves, stockings, gaiters, and largely into cloth for making overcoats. It is very strong and durable, and the fabrics have as good an appearance as those of sheep's wool. It is probable that much of the hair which figures in the Returns as elk's is really derived from the bison. The pelts of the animal, termed "buffalo-robes," measure 8 ft. × 12 ft., and are of dun-brown colour. The best come from the Saskatchewan. Prime ones are used as sleigh-robes, &c.; inferior are converted into mocassins, and form an excellent buff leather (see Skins). The value varies from 12*s.* to 40*s.*, and the number marketed yearly is about 100,000.

Camel.—The camel is of two species. The Arabian, "single-humped," or "dromedary" (*Camelus dromedarius*), is found in Arabia, India, N. Africa, and Asia Minor; the Bactrian, "two-humped," or common "camel" (*C. bactrianus*), is larger, more robust, and rarer, and occurs throughout the regions eastward and northward of the habitat of the former species, i. e. from the Black Sea to China and Lake Baikal. Both species occur in Central Asia. The under side of the neck, the upper part of the legs, and the humps, of these animals are covered with an abundance of woolly hair, exceeding sheep's wool in length, and varying in colour and quality, according to the species, and the climate under which it lives. The hair of the Arabian camel is thin, whitish, and fine; while that of the Bactrian is thicker, coarser, and darker coloured, and, in Tartary, is divided into three classes, according to its shade, black being the most highly prized, red next, and grey only half as valuable as red. The hair varies in quality from a fineness equal to that of silk, to a considerable degree of coarseness; in quantity, it commonly amounts to 10 lb. annually. In the spring, the animals cast this hair, which is called *koork*, or "down," and is little inferior in fineness to that afforded by some breeds of shawl goats, while it possesses the advantage of being much longer, and more easily separated. In the young animal, it is fine and smooth; but with age, it becomes curly and crisp. The animals are shorn every spring after the second year, and the hair is cleaned and assorted for home use, or exported in the raw state. The Arabs, and other Eastern nations, spin it and weave it into a kind of semi-waterproof cloth for wrapping merchandise, and into tent-coverings, shawls, and carpets. In Persia, very fine stockings are made from it, the white being most valued; and both in Persia and Tartary, a most durable, warm, soft and light cloth is made, patterns being produced by selecting the naturally coloured hair. Some 25 years since, the hair was already finding its way into European commerce. It was shipped from Smyrna, Constantinople, and Alexandria, and used chiefly by the French for making superior hats, and the longer hairs for making artists' pencils. In 1861, however, we received 322,000 lb. For a time, Russia almost monopolized the trade, quantities of the hair being shipped from Russian ports chiefly to London and Liverpool. The exports from Revel to Great Britain in 1878 were 6894 *poods* (of 36 lb.), and in 1879, 6793 *poods*. Much of this was re-shipped, especially to America. As the supplies increased, the coarser qualities began to be converted into carpets, and the better staples to be combined with wool for making winter garments. When the Chinese port of Tien-tsin was opened to foreign trade, camels' hair soon developed itself into a commercial specialty. The authorities levied an export duty of 5 per cent. *ad valorem*. The actual prices paid in 1877 ranged from 2 *taels* (of 6*s*.) a *picul* (of 133⅓ lb.) for the coarsest and dirtiest, to 16 *taels* for "finest recleaned," and 6 *taels* 5 *m*. was the value fixed as a basis for the tax. But in 1878, when the local prices ranged from 2 to 14 *taels*, the authorities increased the taxation standard to 10 *taels*, a step which cannot fail to check the growth of what promised to be a most lucrative trade for one of the poorest and most barren portions of N. China. The shipments from Tien-tsin (in *piculs* of 133⅓ lb.) have been:—in 1874, 3129½; 1875, 4070¾; 1876, 9824; 1877, 13,384¼. Shanghae, in 1878, exported a total of 11,788 *piculs*.

Cattle.—Cow- and ox-hair is afforded generally by the same countries as horse-hair, and the quantities produced in this kingdom are supplemented by large importations from abroad. Here it is principally used by plasterers, to increase the cohesiveness of their mortar, and in the manufacture of felt for roofing, sheathing, and packing purposes. Smaller quantities are employed in admixture with horse-hair for stuffing, and for making coarse friezes, blankets, rugs, and horse-cloths. In Germany, it is applied in carpet manufacture; and in Norway, the peasants convert it into hosiery. Much cattle-hair is obtained from the tanneries, where it is sold in the wet state at about 2*s*. 6*d*. a bush. Our imports (including the hair of the cow, ox, bull, and elk) in 1879 were as follows:—From France, 18,288 cwt., 16,742*l*.; Holland, 13,784 cwt., 10,968*l*.; Russia, 5772 cwt., 10,796*l*.; Germany, 5247 cwt., 5350*l*.; other countries, 8336 cwt., 11,343*l*.; total, 51,427 cwt., 55,199*l*. Riga, in 1878, exported 37,675 *poods* (of 36 lb.) of cow- and horse-hair, the former being valued at 8½ *roubles* (of 2*s*. 8*d*.) a *pood*. Santos (Brazil), in 1879, shipped 150 kilo. of ox-hair, value 8*l*., to Europe. The values in this market are about 13–14*d*. a lb. for cow-hair off the skin, and 11–12*d*. on the skin. White hair is much dearer than coloured. Plasterers' hair is worth about 5–8*l*. a ton; washed, 10–11*l*. Deer-hair is valued for stuffing saddles.

Goat (*Capra hircus*).—Two varieties of the domestic goat are valuable as hair producers—the Angora or Mohair, and the Cashmere. The mistake is commonly made of supposing them to be identical; but though they are only varieties of the same species (which includes at least four other varieties), their differences are such as to entitle them to separate consideration. Collectively, the goat ranks second only to the sheep as a source of hair or wool, and its fleece is the most important of those discussed in the present article.

Angora or Mohair Goat.—This useful animal is a native of the mountains and central plateaux of Asia Minor. The characteristics of the district where it attains greatest perfection are extreme dryness of climate, an elevation averaging 2500 ft. above the sea, and an abundant growth of oak (either trees or scrub), on the leaves of which, green in summer, dried in winter, the animals feed, maintaining themselves in good condition where grass-eating creatures would starve. The mohair-producing district is comprised within the following four towns:—Kastambol, near the Black Sea, in the north; Sivas, in the east; Konieh, in the south; and Eskishehr, in the west. More than twenty distinct and recognizable varieties of mohair are here grown, the differences arising from local peculiarities. The chief localities are as follows:—(1) Kastambol: its proximity to the moisture-laden winds of the Black Sea is prejudicial to the quality of the hair; the fleece, though lustrous, is hard and coarse; hence the error of selecting from this point animals for naturalization at the Cape, an error induced by the facilities for shipment. Passing southwards, the large province of Angora is divided into five separate districts—(2) Yabanova: yields a heavy lustrous fleece; (3) Tchorba: produces a mohair so soft and fine that it falls to pieces as soon as it is shorn; (4) Tchibúkova: its staple is remarkable for length and fineness; (5) Ayash: affords a white but lustreless variety; (6) Jeevar: the hair is bright and showy, but full of "stick," or kempy hair. The district of (7) Beybazar is remarkable for the hardiness and large size of its rams, some of which have been recently exported with good results. North-eastward lie (8) Tcherkes and (9) Geredeh: the animal has only of later years been introduced here, yet it has developed distinct traits from the differences of climate; the rams are very fine, and their fleece is so surcharged with grease as to appear almost black, but when scoured, it is second to none in quality. No animal has yet been exported from these two districts. Towards the east, are (10) Sivrihissar and (11) Eskishehr; here most of the goats perished by drought and famine in 1874–5, necessitating the introduction of fresh stock. Due south is (12) Konieh: the fleeces produced here assume the brick-red colour of the soil, and are of reduced value, though useful for special purposes; they are commonly known as "pelotons." This completes the tale of the chief districts within the quadrilateral before mentioned; but far to the eastward, on the Armenian and Mesopotamian frontiers, lies the province of Van, which has hitherto contributed large quantities of very inferior mohair, but having been devastated by the Russian invasion, will possess little importance in the immediate future. In Asia Minor, these goats are tended in flocks, varying from 200 to 5000 head, generally in company with sheep; this plan is found advantageous to the pastures, as the goats are more enterprising than the sheep, and, by breaking up the flock, prevent the latter cropping the herbage too closely. Turkish folds are of the most primitive kind, generally consisting of a sheltered spot enclosed by a low wall; they are little used except during heavy and continuous rain. When snow lies on the ground, as it does for two or three months, the surface is strewn with chopped straw or dried leaves for the animals to feed on. One goatherd, with a wolf-dog, can look after a thousand head, except in early spring, when the kids are born. The kids are singularly helpless during the first week of their lives, and the ewes show little maternal instinct; kids born in cold, wintry weather require shelter and indoor nourishment after nightfall. A running stream or good well is indispensable to a goat-run, as the animals drink frequently; an equally important precaution is to form a salt-lick, by placing lumps of rock-salt near the watering-place. No ordinary fence suffices to restrain them, and they are very great enemies to neighbouring cultivation.

The breeding of the mohair goat, and its cross-breeding with the common goat, has an important bearing upon future supplies of the hair. The best mode of commencing a flock is to secure a small but perfect selection of thorough-bred rams, to cross with the common ewe-goat. The rams of the second, third, and fourth districts mentioned above are undoubtedly thorough-bred, and, though smaller in size than some other varieties, possess all the points that a stock-breeder desires. In 5–6 years, a pure flock may be raised, limited only by the numbers commenced with. Of course the breed will not be absolutely pure, but practically every trace of under-breeding may be eliminated, and the mohair will be as fine and as long, though scarcely so abundant, as in the pure animal, while the silky lustre is increased. On the other hand, a constant infusion of pure blood is necessary to prevent deterioration. This is best accomplished by maintaining two distinct flocks: (1) a small flock consisting of 10 pure Angora rams, and 90 of the best of the ewes obtained from the cross, to be used as a feeder for (2) 100–200 of the cross-bred rams with as many common ewes as are procurable.

From 1866 to 1873, with a succession of fine seasons, the Asia Minor clip rose steadily from a total of about 30,000 bags (of $1\frac{1}{2}$ cwt.) to nearly 50,000. In the summer of 1873, however, great drought reduced the animals to a miserable condition, and their starving state rendering them unable to resist the very severe winter that followed, nearly one-third perished, thus lowering the clip in the succeeding year to a little over 33,000 bags; of this, 25,000 were Angora qualities, 7000 Vans (which district did not suffer like the others), and 1300 pelotons. The goat-farmers, chiefly Turks, are for the most part both poor and improvident. They might have saved many of their flocks by timely provision, or removal to districts unaffected by the drought and severe winter; but the effects of this disaster, contrary to expectation, were not long felt, for the high prices obtained since 1874 led to extraordinary efforts to increase the number of goats. In 1876, the clip had again risen to about 38,000 bags of all sorts, brought about by extra care of the young, favourable seasons, and judicious crossing with the common goat. In 1877, the total clip was about 42,000 bags. In 1878, it was about 48,000 bags, composed as follows:—Angora qualities, primes, 35,000; inferiors, 3500; Van, 8000; Konieh, or pelotons, 1500. The mildness of the following winter gave promise of a still further increase to 52,000 bags.

The fleeces (*tiftik*) are clipped in April–May, according to the season, and yield an average of $1\frac{1}{2}$–$2\frac{3}{4}$ lb. of hair each. The best fleeces are exported by the Yurúks, who take great care to keep them clean. Van mohair contains on an average 70 per cent. of white hair, which, however, has a slight mixture of black running through it, and 30 per cent. of red and black, the whole much coarser in quality than the Angora sorts. Pelotons consist of 80 per cent. black and red, and 20 per cent. white, all of inferior quality, but containing a small percentage of hair finer than anything to be found in the Angora sorts. The finest hair of all comes from the first clip of the kid at its second year; one-year-old kids are seldom clipped. The second finest is from the she-goat, the next from the wether, the coarsest of all from the entire male. Inferior qualities come from crossing with the common goat, but the second cross brought to the pure male throws pure mohair. Woody and mountainous districts, with fir and oak, produce the best. Animals fed in the plains yield a quality with more kemps, and frothy, light, cottony fleeces. The male and female hair is very commonly united for the market, with the occasional exception of two-year-old she-goats' fleeces, which are kept with the picked hair of other white goats (perhaps 5 lb. being selected from 1000 lb.) for the most delicate native manufactures. The fleeces of surplus he-goats and barren females, killed at the beginning of winter, are 5–6 in. long. The skins are sold to curriers, who remove the hair by a preparation of lime, and employ the skins for slippers (see Skins). The hair thus obtained is harsher than that shorn from the living animal in spring, and is more or less damaged by the lime treatment; it is sold at a lower price as *deri* or "dead" hair. Some few skins are cured with the hair on; these bring 20*s.* each in Angora, and about 30*s.* in Constantinople, and are used in Europe as rugs and saddle-cloths. Formerly, and for a long time, we imported the hair only in a spun state (as "yarn"); but our textile manufacturers at length acquired the art of spinning it, and we now receive the raw hair alone.

The Angora goat is somewhat smaller than the common goat. The principal feature of all varieties of the breed is the length and abundance of its hair, covering the body and a great portion of the legs with closely-gathered ringlets, reaching near to the ground. The coat is composed of two kinds of hair: a short, coarse under-down, lying close to the skin; and a long curly overhair. Both are manufactured, but the latter is by far the more important in point of quantity and value. They are marketed together, and separated by the spinner (see Woollen Manufactures—Worsted). The value of the article depends upon its length, fineness, softness, brilliancy, elasticity, and durability. These qualities enable it to take the place of silk in the manufacture of velvets and laces, and to form the pile of imitation furs, besides being used for more general fabrics.

The export of Turkish mohair takes place chiefly from Smyrna, but Trebizonde also ships large quantities. The latter port in 1877 despatched 694 bales (of 1¾ cwt.), value 8328*l.* to Great Britain; in 1878, 440 bales, value 4400*l.*; and in 1879, 795 bales, value 7950*l.* Aleppo also, in 1878, exported 292 tons, value 46,720*l.*, to Turkey; 82 tons, value 13,120*l.*, to Great Britain; and 2 tons, value 320*l.*, to France. Alexandretta, in 1879, exported 112 tons, value 17,920*l.*, to Turkey; 71 tons, 11,360*l.*, to England; and 2 tons, 320*l.*, to France. The exports from the vilayet of Van, in 1879, were valued at 10,000*l.* Turkish. The productive capacity of Asia Minor is limited to about 60,000 cwt. of good or fair quality, and 15,000 cwt. of inferior. But the climatic and other conditions here prevailing are to be found in many portions of our African and Australian colonies. The goat succeeds admirably on land which will not support any other animal with profit. In the Cape, it is found that where sheep have been grazed, there springs up a *Mimosa*, which the sheep will not touch, but which affords excellent food to the goats. It is estimated that there are already about a million of these goats in the Cape Colonies, where the breeding is making rapid progress. The Transvaal seems to be admirably suited to them. But the Cape mohair is different from the Turkish, inasmuch as it is more kempy, and the kemp runs further to the top, while it is also shorter. On the other hand, it is quite as fine, and may be kept so by repeated infusion of pure blood. Mohair only began to figure in the Cape exports in 1862, the quantity then being 1036 lb.; in 1871, it increased to 536,292 lb., value 43,000*l.*; in 1875, it advanced to 1,147,453 lb., value 133,180*l.*; and in 1877, it amounted to 1,433,774 lb., value 116,382*l.* Great attention has been paid to the naturalization of the Angora goat in the United States, and the flocks there are now estimated to number nearly 2 millions. The first attempts were made in Kentucky and Georgia, more than 30 years ago, while the Pacific States have been selected for more recent experiment. The animal appears to flourish best upon the wild sage, on the desert plains of Nevada, and the fleeces become fine and silky. Yet the breeding of the goat for its fleece must be accounted at least a temporary failure in America, inasmuch as there is no local manufacture of the staple, and it will not pay to export at present prices. The rearing of the goat is attracting stock-growers in many parts of Australia, where the animal thrives well, especially on well-watered undulating prairie. In sandy districts, the hair is inferior, and soon falls off. Shearing is performed twice annually, when the fleece is about 6 in. long. This prevents its being torn and wasted. Each clip from full-grown animals is estimated at 4 lb., value 4*s.* a lb. The Fiji Islands are likely to become producers of mohair of excellent quality. The first considerable sample of Angora hair from Fiji was pronounced to be well grown and of good texture, and sold at a high figure. It was the produce of a small flock of goats bred on the Ra coast, and was declared to be almost equal to the best Turkish mohair. The flock has been raised from a small number of pure Angora goats, by judicious crossing. It now contains several hundred well-grown animals of 2nd–4th cross, the latter producing as much as 4 lb. of hair each, equal to the finest hair from the pure Angora goat. The climate seems admirably suited to the goat, and to the production of a good crop of hair.

Cashmere, Thibet, or Shawl Goat.—This variety of the domestic goat is considerably larger than the Angora kind. Like the latter, its coat is composed of two materials, but it is the undergrowth that here forms the commercial article. It is beautifully soft, silky, and down-like, and of a pretty uniform greyish-white tint. Its removal is effected by clipping and combing, the process occupying 8–10 days. The quantity obtained seldom exceeds ½ lb. It is sold by the *turruk* (of 12 lb.). The overhair is of various colours, lengths, and qualities. There are several modifications of this breed, and they are widely distributed in Asia. The best are produced in Cashmere, Thibet, Mongolia, and the Himálayas. Those of the hilly tracts of Khorassan yield a fine soft hair, generally of a more or less intense brown shade, while the long overhair is usually jet-black. The best are said to be among the Hazaree and Timunee tribes. Two fleeces are afforded annually:

the first grows during winter, and is shorn in spring; the second appears in summer, and is gathered in autumn. The latter is the finer and more esteemed. White fleeces are rare. The winter fleece is shorn off with the overhair, and is cleansed for making shawls, while the overhair is converted into grain-bags, tent-covers, and ropes The autumn fleece is only taken from dead animals. The skins are rubbed with a preparation of lime and potash, and left for 2–3 days; the overhair is then easily pulled out, and the undercoat is subsequently removed separately. This is dearer than the winter fleece.

Turkestan goat-hair is sent in considerable quantities to Amritsur, in the Punjab. The best quality is procured in the immediate vicinity of Bokhara, and in the N.E. districts of that kingdom. It is used in combination with Thibetan hair for making Cashmere shawls. The white is most valuable; light-brown is the predominating hue; black and ashy-grey are packed separately. The hair is shed by the animals in summer; sometimes it is shorn; but most of it is taken from dead animals. Cabul hair is generally darker than that from Turkestan, and is shorter in staple. It is chiefly obtained from the hill country to the W. of Cabul, and between that city and Herat. Its value is only half that of the Bokharan. Considerable supplies are afforded by the Kirghiz Steppes and W. Thibet, whence the hair is taken to Rodokh. Another large portion is carried to Leh. The goats are very common in the provinces of Ladakh, Rodokh, Garoo, and the Chanthan plateaux. It is the produce of these goats which is chiefly converted into shawls in the Punjab towns. The very superior quality grown in Turfan Kechar is taken through Yarkand to Cashmere, and there manufactured. Closely allied breeds of the Cashmere goat are common in the countries west and south of the Caspian. The shawls of Kerman, in Persia, are but little inferior to those of Cashmere; and much of the hair produced in that country is carried to Amritsur, for the manufacture of so-called Cashmere shawls. The Persian and Armenian hair is also largely manufactured into Persian carpets. Attempts to naturalize the animal in France and England have been complete commercial failures. Some French experiments in crossing the Cashmere and Angora goats gave promise of an increased and improved fleece, but the unsuitable climate of France would doubtless soon cause deterioration.

Common Goats.—The common domestic goat is found in most countries of Europe, in Morocco, Algeria, India, the United States, and the Argentine Republic. Recent statistics give:—Spain and Portugal, 6 million; Greece, $2\frac{1}{4}$; France, $1\frac{3}{4}$; Germany, $1\frac{3}{4}$; Italy, $1\frac{3}{4}$; Russia, $1\frac{1}{4}$; Austro-Hungary, $1\frac{1}{4}$; United Kingdom, 1; British India, 6; Morocco, 12; Algeria, $3\frac{1}{2}$; United States, $2\frac{1}{2}$; Argentine Republic, $1\frac{1}{4}$. In all these countries, the hair, which varies much in colour, length, and quality, is industrially employed. In England, it is largely used for low-class carpetings. Mogador, in 1878, exported 22 cwt., value 35*l.*, to France; and Tangier, in the same year, shipped 238 cwt., value 428*l.* (including horse-hair), also to France. Shanghae, in 1878, exported $6273\frac{1}{2}$ *piculs* (of $133\frac{1}{3}$ lb.). The skins of common goats are of more importance than the hair (see Skins).

Imports of Goat-hair.—Our imports of goats' hair, without reference to the description, in 1879, were as follows:—From Turkey, 5,987,276 lb., value 541,812*l.*; British Africa, 2,102,019 lb., 138,178*l.*; France, 1,070,451 lb., 24,048*l.*; China, 343,062 lb., 20,564*l.*; other countries, 569,892 lb., 19,013*l.*; total, 10,072,700 lb., 743,615*l.*

Horse.—Though horse-hair is produced to some extent in almost every part of the world, commercial supplies are obtained chiefly from Russia, Germany, Belgium, several of the S. American States, and Australia. The small quantity obtained from English stables—the combings of manes and tails—is superior to any that is imported. The next in quality comes from Australia and S. America, generally yielded by healthy, vigorous animals. The worst, especially in point of dirtiness, and the presence of contagion, is procured from Russia, and in great part from Siberia. Foreign hairs reach this market packed in bales of strong cloth. The S. American bales are very large, sometimes weighing half a ton, and are bound with hoop iron, after having been subjected to hydraulic pressure. In all but the Russian bales, the mane hair and tail hair is packed in the same bale. The Russian bales are only about one-quarter the size of the S. American, and, being packed by hand, are relatively much lighter; they have also an external covering of the matting which is made in such large quantities by the Russian peasantry, from the bast of the linden tree. The Russian hair is gathered from all available sources by the peasants, who sell it in small parcels at the fairs to dealers, by whom it is made up into larger parcels for sale to the resident merchants. Thus, the "raw" hair which reaches the merchant is the mixed produce of innumerable places. At St. Petersburg, this raw hair is assorted, the long hair being made into "dollies" or bundles, more or less sophisticated with bunches of short hair, to make weight.

Our imports of horse-hair in 1879 were as follows:—From Germany, 6268 cwt., value 42,571*l.*; Argentine Republic, 4839 cwt., 23,165*l.*; Uruguay, 3110 cwt., 18,967*l.*; Belgium, 2869 cwt., 13,341*l.*; Russia, 888 cwt., 8901*l.*; other countries, 1608 cwt., 8019*l.*; total, 19,582 cwt., 114,964*l.* In 1875, the quantities were:—Germany, 7299 cwt.; Uruguay, 4935; Argentine Republic, 3069; Belgium, 1556; Brazil, 996; Australia, 906; Russia, 708; other countries, 762. The exports from

Poti in 1877-8 were 42 *poods* (of 36 lb.). From Riga, in 1878, were shipped 37,675 *poods* (including cow-hair). The shipments from Revel to Great Britain were 3435 *poods* in 1878, and 240 *poods* in 1879, principally tails. Tangier, in 1878, exported 238 cwt., value 428*l.*, to France (including goat-hair); in 1879, the figures were 98 cwt. to Great Britain, and 154 cwt. to France. The average annual shipments from Rio Janeiro are about 10,000 cwt., and from the Argentine Republic, 9000 cwt., much of which goes to the United States. Shanghae, in 1878, exported 292 *piculs* (of 133⅓ lb.). The market values are approximately as follows:—S. American, 4*d.*–1*s.* a lb.; ditto, good to fine, 1*s.*–2*s.* 6*d.*; Russian, 8*d.*–2*s.*; white tail, 11*d.*–4*s.*; black tail, 10*d.*–3*s.*; mixed, 9–14*d.*; short, 4–8*d.* The long hair is employed chiefly in making hair cloth, for covering purposes; also in other textiles, as stiff petticoats, and straining-bags and cloths; and for stockings, gloves, plumes, wigs, fishing-lines, and ropes. The short hair is curled for stuffing seats, mattresses, &c.; while medium coarse hair is sometimes used in brushes.

Human.—Women's tresses have of late years been important articles of merchandise. Scarcely any but "combings" is produced in this country, and supplies come chiefly from Continental Europe, India, and China, while even Iceland is not left unvisited by the itinerant hair-merchant. In S. France, the peasant-girls cultivate their hair with a commercial object. The light-coloured hair comes principally from Germany, Austria, and Scandinavia; the dark, from S. France and Italy. Indian and Chinese tresses are very coarse; yet the shipments of the latter, mostly to France, have risen from 286 *piculs* (of 133⅓ lb.) in 1871, to 11,254 *piculs* in 1875. The value varies according to length and colour. A length of 8 in. commands about 1*s.* an oz., while 36-in. hair may bring 30*s.*; and above 36 in. the prices are fanciful. The standard is 18 in., but 5–6 ft. is occasionally met with. Auburn, grey, light, and pale, are considered extra colours, and fetch much higher prices than the ordinary hues. The best hair is obtained from the living subject; dead hair is very inferior. The weight of a French head of hair (female's back-hair) is about 5 oz.; Italian, 6 oz.; German, 10 oz. The last are seldom marketed in their natural state, but are mixed to hide inferiorities. The tresses from Italy and Brittany require much cleansing. The chief use of human hair is for the manufacture of wigs and false tresses. The latter are the more important, and the fashion which governs them rules the market values. The United States ladies are probably the largest customers for the article. The Chinese hair is in demand among Americans of mixed African descent.

Pig-hair, or Bristles.—The hair which grows on the back of the pig commonly goes by the name of "bristles." The best are the produce of the wild hog, and the quality deteriorates in direct proportion to the degree of cultivation of the animal. Russia supplies the largest quantity and of the best quality. Siberia, and the district of Sarapoul, in the government of Wiatka, are noted for the best. Superior descriptions are obtained from the pigs which are fed on the refuse of the tallow manufactories. The Russian exports of bristles in 1877 were 139,836 *poods* (of 36 lb.), the largest quantity for 12 years, but, on the whole, they are declining. Revel shipped to Great Britain 1057 *poods* in 1878, and 714 in 1879. French bristles have the highest reputation in the market, being white, soft, firm, and elastic. The product is estimated at about 2 million lb. annually. German bristles (which include large quantities of Russian, sent landwise to German ports) are the dirtiest. Servia grows enormous herds of pigs; so also do Hungary and Roumania. These countries probably contribute not a little to the shipments from German, French, Dutch, and Belgian ports. American pig-hair is procured chiefly from the pork-curing establishments of Cincinnati and Chicago. The Chinese port of Shanghae shipped 681 *piculs* (of 133⅓ lb.), in 1878.

Bristles are assorted according to length and colour, and are tied in separate bundles, with the root-ends together, and packed in barrels. At Königsberg, they are classified as 1st and 2nd grey crown, 1st and 2nd white crown, white and grey shoemakers', and white and grey long. The best and dearest are those for cobblers' use; the others are made into brushes of various grades; while a few are employed for stuffing. The price ranges from 1*s.* to 7*s.* a lb., and is always advancing, while the supply decreases. Our imports in 1879 were:—From Russia, 708,694 lb., value 106,998*l.*; Germany, 556,934 lb., 89,145*l.*; China, 98,923 lb., 12,592*l.*; United States, 94,886 lb., 10,110*l.*; France, 75,351 lb., 12,065*l.*; Belgium, 41,525 lb., 4766*l.*; British E. Indies, 33,841 lb., 5314*l.*; other countries, 21,431 lb., 3398*l.*; total, 1,631,585 lb., 244,388*l.* In 1853, we imported 3,237,059 lb.

Yak (*Poephagus grunniens*).—This animal, found in Thibet, China, Mongolia, &c., is covered with a coat of very long hair, and has a long, bushy tail. The prevailing colour is black, but several other tints occur. The hair is much finer than horse-hair, and is locally employed for making strong ropes. It is occasionally exported to Europe.

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(See Brushes; Feathers; Fur; Hair Manufactures; Leather; Skins; Wool; Woollen Manufactures—Worsted.)

HAIR MANUFACTURES.

Since the beginning of the present century, hair, as distinguished from wool, has been largely manufactured. The chief sources of supply of this class of fibre are the group of animals represented by the alpaca, the caprine tribe, the camel, the horse, the ox, and the hog. The chief of these, however, are used so entirely in combination with, or subordinated to, wool and other fibres, or their processes of treatment are so nearly identical with those of the latter, that a description of them will come more naturally under the divisions in which these articles are treated (see Woollen Manufactures—Worsted). Of the above, therefore, it is necessary only to notice the applications of the hair of the horse, the ox, and the hog, and the processes of manufacture through which they pass. The hair from these animals occupies a distinct place in our industries, and is not subordinated in such a degree as to lose its identity.

The bulk of the hair obtained from these sources is used for upholstery purposes, being manufactured into "curled hair" for stuffing, or hair cloth for seating. The raw material (see Hair) is roughly classified into English and foreign, the former being regarded as the best in quality. Each class is divided into several qualities, according to the purpose for which it is destined. The best English hair is that denominated "hard hair," consisting chiefly of hair obtained from ostlers and stablemen, being tail hair procured in combing. That similarly got from the mane is of a different quality, being termed "soft." Knackers' hair, or that obtained from dead animals is much inferior, "dead" hard hair not being more than equal to "live" soft hair. The depreciation which hair undergoes on the death of the animal is such that, when worn-out horses are sent to be slaughtered, the knacker always cuts off the mane and tail previously to the operation.

Horse-hair makes by far the best curled hair, but is not the only sort employed. Cow- and hog-hair constitute a large portion of that which is manufactured into curled hair for upholstery purposes. The former is chiefly procured from home sources, whilst of the latter the greatest proportion is imported from America, the supply from the continent of Europe having been neglected for several years, owing to the superior quality of that obtained from America. The hogs of the United Kingdom, owing to their high feeding, do not yield hair in either quantity or quality which renders its collection worth the cost. That yielded by lean animals is always the strongest and most elastic. Imported pig-hair is exceedingly dirty, and requires to be thoroughly washed and dyed before it can be used.

Both these kinds of hair are mixed with "soft" or mane hair from the horse, in proportions varying according to the quality of the product it is desired to obtain.

Sorting.—The manufacture of hair commences with the process of sorting. This is conducted in a room set apart for the purpose, called the sorting-room. The raw material, having been supplied to the workers, is first separated into long and short hair, the former being carefully reserved for the manufacture of hair seating, fishing-lines, brushes, &c., and the latter for curling. The sorting is next repeated for the purpose of separating the colours. White hair is esteemed the most valuable, being used for special purposes, and the supply being small. A third time this process takes place, this last being for its assortment into qualities. This is very important, and requires nice discrimination and sensitiveness of touch in the sorter, in order to perform the process efficiently.

Washing and Dyeing.—Each quality is next subjected to thorough washing in cold water, to remove dirt, dust, &c. It is then sent to the dye-room, and immersed for several hours in a dye bath chiefly composed of a decoction of logwood. When removed, it is of a dull-black colour. Further washing and cleansing then take place, the hair being put into large vats containing agitators, through which flows a stream of hot water. This treatment removes the superfluous dye, and further purifies the hair. After removal from the vats, it is passed through powerful wringing-machines, to express the moisture, and spread over the floor of an open room until perfectly dry.

Both classes of hair, long and short, undergo the above processes; but at this point, the treatment of the two sorts diverges into separate channels.

Short Hair. *Mixing.*—Following the short hair, the next process is "mixing"—making a blend of certain proportions of horse-, cow-, and pig-hair, according to the quality of the article intended to be produced. Of these there are many, and the prices range proportionately from 6*d.* to 2*s.* a lb. When the blends have been properly laid down, the material is passed through a series of "willows," by which the different sorts are thoroughly incorporated, becoming homogeneous as far as mechanical admixture can produce such a state. After passing through the third of these machines, it is beaten and screened, to clear away the dust created by this treatment, and is then ready for the curling process.

Curling.—"Curling" is carried on in a separate room, called the curling-room. The curlers spin the hair into ropes or strands, by the aid of a machine similar to that employed in rope-spinning. The rope is further twisted in a second operation, by which means it is reduced to half its first length. By a third process, it is twined until it assumes a convolute form, when it is secured as a coil. These processes give to the hair its peculiar curl, which fits it for the purpose to which it is applied—"stuffing" for the seats of chairs, sofas, &c. But were it, at this stage, to be untwisted and used, the curl would soon be lost. It requires to be "fixed" in this condition, which is accomplished by the following treatment. The coils are immersed in cold water, and allowed to stand for several hours. On removal from this, they are placed in specially constructed ovens, which are heated to a very high temperature. After subjection to this heat for a sufficient time, the "curl" is permanently fixed; and the germs of all parasitic life are destroyed.

When the process of "baking" is finished, the hair has become a marketable article, and is sold either in the form of "hard curl," as removed from the ovens; as "soft curl," in which it is partially untwisted; or "towsed," in which the filaments are separated ready for use.

The comparatively high price of hair, whether of the horse, ox, or hog, has led to the search for cheaper substitutes. Of these, two have been utilized to a considerable extent, namely "Mexican fibre," which is very similar in appearance to hair; and "vegetable horse-hair," a product of Algeria, and known as *crin végétal* (see Fibrous Substances — *Chamærops humilis; Nidularium karatas*). The importation of the latter article has become considerable during the past 20 years, as it is extensively used in stuffing the lower qualities of furniture, either alone or in conjunction with hair. It is prepared and dyed in the localities of production, and is imported into this country in the form of hair ropes, to which it bears likeness. Neither of these articles, however, possess a tithe of the durability of real hair, and would not call for notice in this place were it not that they are made to simulate the latter.

Long Hair.—The long hair is applied to the manufacture of brushes and fishing-lines, but chiefly to that of hair cloth for upholstery purposes.

Hackling and Drawing.—After having been thoroughly cleansed, as stated before, it is combed by drawing the bunches through fixed combs, like flax-hackles, which work is done by boys. It is next drawn into different lengths and thicknesses, which is an important and tedious operation, requiring both delicacy of touch and quickness of eye. These lengths range from 14 in. to 35 in. This work is performed by hand, though attempts have recently been made to accomplish the drawing automatically. Black hair is subjected to further treatment, in order to obtain a full glossy blackness. White is bleached, in order to diminish the yellowish tint which is its natural hue; but this is never perfectly removed. English hair affords the best white, that obtained from foreign sources never yielding as clear a colour. It is also variously dyed by makers of coloured damask seating.

The best white hair is generally used for the manufacture of toilet-brushes, and fancy articles of similar classes, in which transparency constitutes an element of quality. Inferior whites are utilized in the production of paint-brushes, fishing-lines, &c., colour being then of minor import.

Hair Cloth.—The most important purpose to which horse-hair has been adapted is the manufacture of hair seating. A century ago, its qualities were highly esteemed in this application; but the invention of the Jacquard machine, and its application to the production of upholstery textiles, such as damasks, brocades, tapestries, &c., has caused hair cloth to be relegated to humbler classes of furniture than of old. Its cleanliness, durability, and coolness will, however, always ensure its retention as an upholstery fabric in warm climates.

By far the largest proportion of hair cloth is black, but it is sometimes made in colours, brocaded and figured, by means of a simple form of Jacquard apparatus, mounted on a hand-loom. This class of goods is a specialty of E. Webb and Sons, Worcester, who have also recently introduced a novelty in horse-hair fabrics, called the "Worcester carpet," made similarly to a "Brussels," but having the pile-warp composed of horse-hair. As may be inferred from the nature of the material, it is very durable.

In hair cloth, the warp is necessarily formed of a different fibre, most generally strong cotton or linen yarns. These are dyed and polished. The length of the hair decides the width of the cloth, as there can only be one hair to a pick. To knot the hair, in order to obtain a greater width, would seriously depreciate the quality, if not render it altogether unmerchantable.

Until within the past 20 years, this fabric was everywhere manufactured on the hand-loom, requiring a "server" to pick out the hairs singly from a lock, and hold one end, whilst the other was drawn across the warp by the hook of the weaver. This loom is still occasionally used, but has been generally superseded by a plan which dispenses with a server, the weaver working both baton and hook by means of a treadle, and supplying the hair for weft from her own hands. The "one-armed" loom, worked by means of a crank handle, or a long foot-lever, has come into extensive use in cottages, and in factories in which steam power has not been introduced.

To the ingenuity of the Americans we are indebted for an invention by which the above primitive process was first superseded. The chief difficulty arose from the nature of the material. The filling or weft employed not forming a continuous thread, an arrangement was required capable of picking up and laying in the warp shed each single hair as required, and to accomplish this with certainty and regularity. The wire motion of the carpet-loom undoubtedly suggested one method of overcoming a part of the difficulty. But this was not all that was needed. The arm or rod analogous to the looping-wire of the carpet-loom was made so as to operate like a finger and thumb, to grasp the hair when presented to it, but it possessed no power of taking up single hairs. Further mechanism was needed to secure this object, and many years passed before it was perfected.

In the Pawtucket loom, the work of picking up and presenting each separate hair to the receiving-rod is performed by a piece of mechanism at the side, containing a pair of nippers, called a "picker," one jaw of which has a groove or slit, almost invisible to the naked eye. This picker dips into a bunch of hair, and seizing one by the end, draws it up out of the bunch, and presents it to the before-mentioned rod, by the fingers of which it is carried transversely between the threads of the open warp. The motion of the picker is arrested until the hair has been laid between the warp, when it is again set free, and descends for another hair. A clever arrangement also provides that should the picker fail to seize a hair at the first dip, it can make a second or third before the receiving-rod comes for the hair.

In the factory of the Pawtucket Hair Cloth Co., where this invention was perfected and applied, a young girl is able to superintend 10 looms, thus performing the work of 20 persons when engaged upon the old hand-looms. The Pawtucket loom has been brought into extensive use, both in this country and on the Continent, for weaving hair cloth.

There are two other forms of power-loom, which are considerably easier to work, being simpler in construction. The least complicated is Henderson's. In this loom, the picker is attached to the end of the rod which draws the hair through the warp, and thus dispenses with the separate picking-apparatus of the Pawtucket loom. The arrangement for raising the warp threads is also much simpler, and less liable to get out of order; and another very important improvement is that the thick and thin ends of the hair are presented to the picker alternately. One end of a hair being very much thicker than the other, it is obvious that, if it were all laid in the warp the same way, one edge of the cloth would appear much stouter than the other; to obviate this, the hair for use is put into two holders, one presenting the thick ends to the picker, and the other the thin ends. An arrangement is made by which these holders oscillate, and so come alternately opposite the picker. In the Pawtucket loom, the hair is mixed, and the picker takes up thick or thin hairs at hazard, which destroys the beauty of the surface by making it appear streaky. In addition, it may be mentioned that a loom for weaving hair has been patented by Samuel Laycock and Sons, Sheffield, in which is incorporated Lyall's positive motion principle. In this loom, the hairs are taken from each side alternately. It seems, however, still to present a few practical difficulties.

The texture of hair cloths, with the exception of the fancy fabrics previously referred to, is chiefly that of a satinette armure or weave, by which the warp is quite hidden from view, only the bright glossy hair being perceptible to the sight or touch.

(See Hair; Woollen Manufactures—Worsted.) R. M.

HATS (Fr., *Chapeaux;* Ger., *Hüte*).

The feature which distinguishes the "hat" from other forms of head-dress is the possession of a brim. Hats are principally of two kinds—felt, and silk; these will receive separate description.

Felt Hats.—The production of felt must have taken place in the earliest times, the combined action of friction and moisture upon wool, and most kinds of fur and hair, being sufficient to form a felt. Such fabrics for clothing purposes long preceded woven goods. Felt hats for both sexes have been known in England for nearly 400 years. At the commencement of the present century, the trade was located in Lancashire, Cheshire, Warwickshire, and London. The stringent rules of the Hat-makers' Association had the effect of keeping the trade in a very few hands, and the exclusive use of manual labour rendered the production so small as not to suffice even for home needs. The more recent application of machinery to almost every branch of the manufacture has permitted a singularly rapid development, and the felt hat trade must now rank among the principal industries of the country.

Manufacture.—The basis of the "common" and "medium" kinds of hat is wool. It is important to select a sound and clean wool, whether washed or unwashed; dirty and broken wools must be avoided at any price, as being certain to produce bad results. Superior effects are produced from a mixture of several kinds of wool. Those preferred are "blue Cape," "Port Philip," and "Sydney" lamb, and such as are of medium staple, and capable of affording a soft and close fabric. These wools, unwashed, are carefully mixed, in proportions varying according to the particular product desired.

Opening.—The mixing having been completed, the wool is passed into the "opener," shown in Fig. 805. This machine performs the office of scavenger, opening the fibre of the wool, ejecting all loose sand and dirt, and preparing it for the "washer." At the bottom of the cylinder B, is a grid, through which the teeth in the cylinder play; within the cover A, shown raised in the illustration, other teeth are firmly fixed, through which the teeth of the cylinder pass, drawing the wool through the fixed teeth at the top, and acting the part of a rude comb. Care should be taken not to choke the machine with too much wool in feeding, and not to put the arms in too far. Having placed the wool in the machine, the workman lowers the lid A, until it covers the aperture down to C, and allows time for the wool to be passed through the teeth of the machine. Then, without stopping it, he gathers the wool in his arms, and places it in a large basket. Such a quantity is passed through as will serve for one operation of the washing-machine, described in detail in the article on Wool.

Washing.—Single and double machines are in use, according to the consumption of the manufacturer. If the single one with three rakes and lift be used, it will require the pan to be charged

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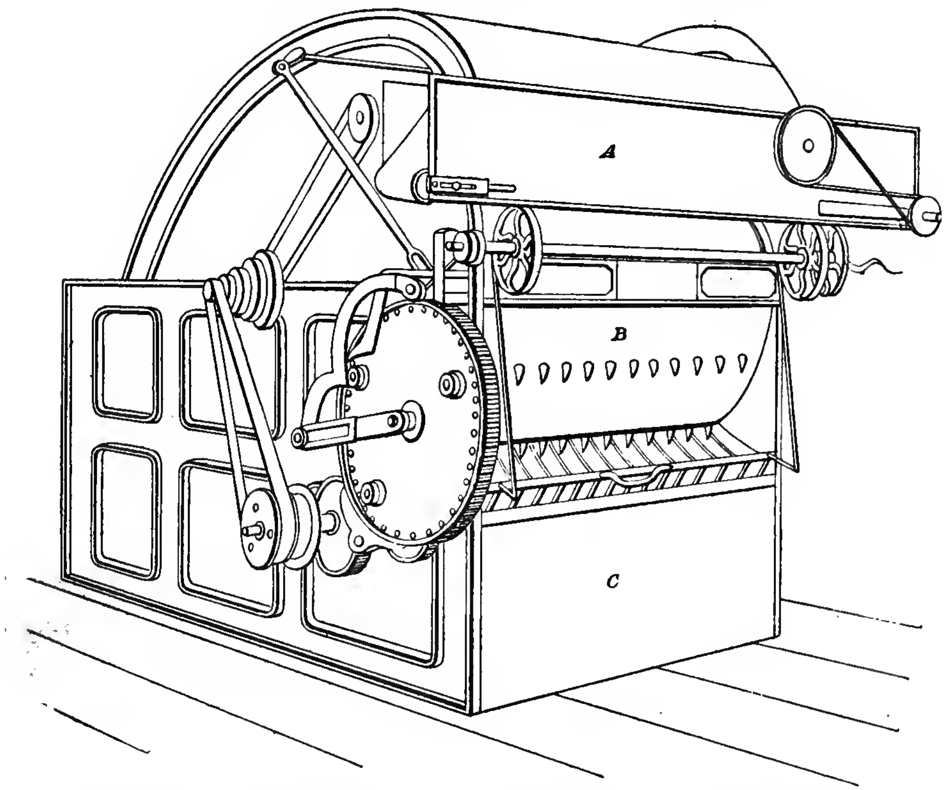

with soap and scour (caustic soda). These articles ought to be in a state of solution in two separate vats, the usual proportions being 1½ lb. of soap, and the same quantity of scour, to every gallon of hot water. Much will depend upon the state of the wool: if very dirty, more soap and caustic soda will be required to effect a thorough cleansing of the fibre. A little experience will soon determine the most effectual method of washing. The water must not be boiling in the machine, or the staple of the wool will be made knotty and harsh, giving much trouble in the after process. A thin layer of wool is placed upon the travelling brat in front of the machine, and introduced in exact proportion to what the squeezing-rollers will take with ease, all the wool having previously passed through the hot water and scour. The bowl of the machine ought to be cleaned out, the wool that is left behind being taken out of the dirt, and sent through the machine with the next mixing. The washed wool is passed again through a warm bath with a little soap, and will then be ready for carding. There is great economy, where the consumption is large, in providing a double machine; the first part will contain the strong scouring-liquor, and the wool, having passed through the first set of squeezers, continues to be washed in the second bowl, and finally passes out ready in one operation to the carding-engines, after having undergone a little drying.

Carding.—The wool brought from the wash, and dried until containing only very little moisture, is taken to a small "opener," like the one used in the first process before washing. This fully prepares it for carding. Small manufacturers use single carding-engines for breaking up the wool first, and then take it through a second engine, before which the hat-former is placed, and where the form is completed. Large manufacturers find it more economical to use double machines, so as to complete the hat-forming in one process, the machine being placed at the end of the double engine. In Fig. 806, A is a travelling "brat," for taking the wool on to the first roller B, called the "lickor-in"; this, on the breaking-engine, carries the wool in across the whole width of the machine. This first roller B, running at a high velocity, is covered with small stout wire teeth, which throw the wool on to the large central cylinder C. As a rule, this is made of iron, cast in one piece, turned very true, and where the casting has been drawn from the moulder's sand, strips of iron are bolted to the thin side, to make up the difference in weight between it and the thick one, thus preserving a perfect balance; otherwise, the high speed at which the cylinder runs is a cause of expansion, and produces such an irregular motion as to endanger the machine. It is therefore most important that all carding-cylinders should be exactly balanced, to run with the greatest smoothness.

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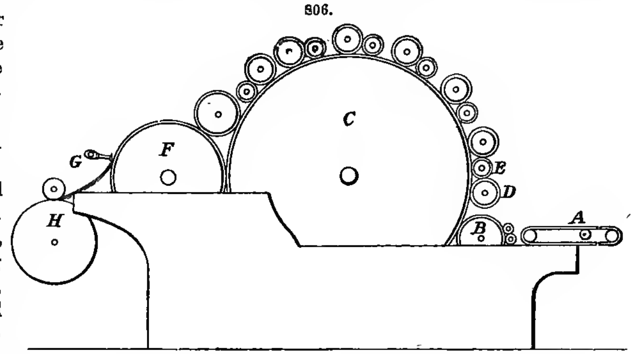

The cylinder C is clothed with small wire teeth, set in rubber strips, about 2 in. wide, the first cut in a slanting direction to a very fine point, and all nailed on with small tinned-tacks, driven into wooden pegs that are inserted in holes drilled in the cylinder for the purpose. After all has been covered, the card teeth are ground true and sharp by an emery wheel, driven from fixings on the side, and adjusted until it bears upon the teeth. The grinding is done by driviog the cylinder C in a reverse direction. All the other rollers are covered with teeth in the same manner; but separate machines are used for the purpose. A central emery wheel carries one card roller on each side. As there is an independent feed motion at each end of a grinding-frame, the wire can be ground to a dead face and sharp. Setting these rollers on the card requires the utmost care, to prevent the wire from catching, or coming into direct contact with the cylinder or the other rollers. All being square, and ground up true on the face of the wire, the wool is thrown by the large cylinder C to the first roller D. The small roller E, called a "clearer," is driven by a small strap from the larger roller D, and almost in contact with it, and by its much higher velocity clears the wool from D. The wool is taken from E by the next roller, cleared by the corresponding one, and so on throughout the series, being lastly placed upon the "doffer" F. In front of F, is fixed a comb G, running at a high speed, and stripping the wool from the doffer as fine as a gossamer web.

Forming.—A hat forming-machine, Fig. 807, is placed in front of this doffer, at right angles to the position it occupies in the illustration, and the wool is so adjusted at the back of the card by two wooden guides, as to bring a web about 12–14 in. wide for the use of the "former." A very steady feed is requisite to make a good even form, free from the knots produced by bad carding. The person tending the machine takes the wool as it comes from the engine, guiding it with the hand to the cone marked C. This cone is made of tin or wood, of the most convenient size for the hat to be made, allowing about 5–7 in. greater length or width than the hat is wanted to possess in the finished state. Note well in making cones that the ends are never too sharply tapered, because the hood in every subsequent process of making requires to be opened at this point, and a sharp taper prevents the blocker from "unbuttoning" the tip in a proper manner, frequently spoiling more finished work than any other cause. The cone, being independent of the machine, may be of any required size. It is laid upon A, which are four tapered rollers, driven by bevel-wheels beneath; its weight, resting upon the revolving rollers, induces an opposite revolution in the cone itself. Adjustable screws enable the rollers to be raised or lowered, to fit the various sizes of cones. A foot-lever at B takes the wheels out of gear, by which the wool is made to run straight

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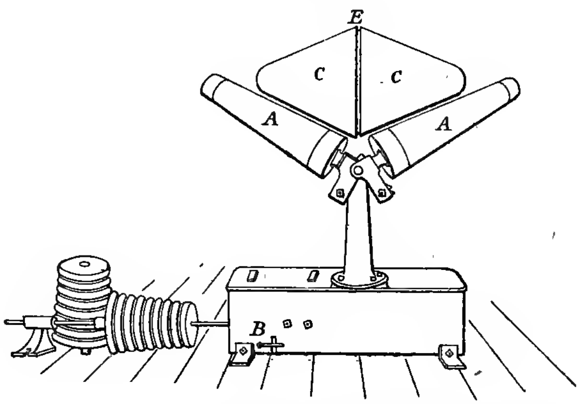

upon the centre of the cone C. When the machine is in gear, the rollers have a right and left radiating motion, revolving at the same time. Taking the wool or "sliver" from the engine with the hand, the operator passes it over the cone C; the machine making this peculiar motion, performs the lapping upon the two ends of the cone alternately, after the manner of winding a cord upon a stick. While guiding the wool as it passes over the ends of the cone, care should be taken not to allow the web to double itself, as this will make bad work. A little experience will indicate how many turns to take before lifting the machine out of gear, when, the wool running straight, the ends of the cone C are left without web, and it is run into the centre, according to the strength of brim required for the hat, after which, the machine is placed in gear again, and sufficient laps are added to make up the weight of hat wanted. A pair of shears are slipped through the web into the groove E, about $\frac{1}{2}$ in. deep, which serves to guide the cutting straight; when cut through, each hood is taken off, weighed exactly, and pared at the edges if too heavy.

To make "hard" hats, the brims are formed very thick, with a very thin "tip," as the crown is called. "Soft" hat forms are wound on about even in thickness. The same is the case with "framed" hats. "Soft tops" are formed very thick, as the crown, when finished, must feel thick and soft, and the brim hard.

Hardening.—The formed hat is next taken to the "hardening"-machine, Fig. 808. A place should be selected for a table with good light in front, to enable the workman to look inside the wool forms against the light. That will at once show all the thin places, which are made good by putting thin layers of wool over them, to make up the felt to an even thickness. As the hardening-machine runs with great velocity, and by the motions of the various parts produces a considerable vibration, heavy stone foundations are necessary to secure steadiness, which is absolutely essential to good work. Of the pair of pulleys G for driving the machine, one is fast, and the other loose. On the end of the shaft, is fixed a solid face-plate, furnished with a groove, in which a T-bolt can be raised in a slot. This increases the diameter of the circle as the shaft revolves, communicating a right and left motion to the lever A, for the bolt, having a square collar planed to fit the aperture in this lever A, acts as a slide-bar, giving about 1 in. of travel in each direction. As the lever A is fixed by a key at the point B, the motion diminishes upwards. Above B, is seen a fixing, also keyed to the same shaft B. This fixing is about 7 in. long, bored at each end, and linked together by two pins, one end being attached to the top cover D, the other fastened to the bottom chest C, thus producing a slight shivering motion, similar to the effect of placing one hand on the other and moving them about $\frac{3}{8}$ in. at a great speed. If the travel is too long, the tendency is to corrugate, or "fridge," the hat form. Should this take place, nothing will remove it, and the damage will be clearly seen after the hat is dyed and finished. Other causes producing the same result are (1) having the face of the top lid D too level, (2) an excess of pressure produced by the lever I, when brought down upon the spring A. C forms the bottom cover, travelling in four grooves. The bottom is a steam-chest, perforated on the top side with small holes, as seen in Fig. 809. The portion having the rude form of a hood is raised a little, planed true, and covered with a stout linen cloth, in several folds if thin. The cloth is strained after nailing one end, and is drawn from each side until, when wetted, it becomes as tight as a drum-head. The holes on the outer edge are filled with wooden plugs, into which are driven the nails for holding on the linen cover. Should too great pressure of steam be used, the fibre will be damaged, leaving upon the hat the marks of each hole in this bottom chest. This may be avoided by regulating the steam, or the length of travel of the cover, or the pressure. Some experience will be required to secure the best result. If the marks of "fridging" are not seen on the inner side, nor the damage by steam or other causes, the imperfection will be got rid of by turning the hat inside out when sending it to the next process. Taking a number of forms to the table, the workman, after carefully stopping up any thin places, cuts a piece of linen cloth of the same shape as the inside of the hat form, steeps it in water, wrings it, and by inserting it between the folds, prevents the hood felting fast together. Placing the hood

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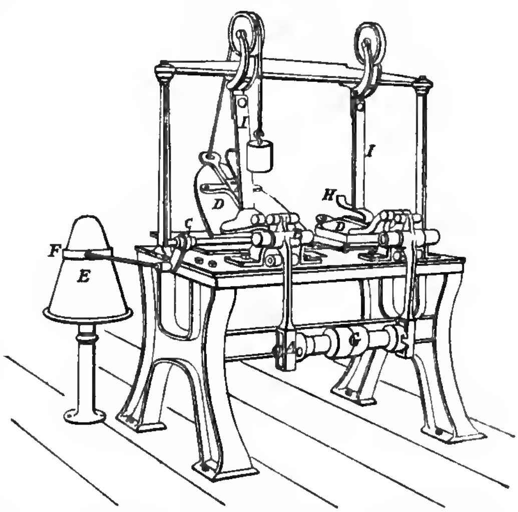

under the cover D, he brings down the lid as seen at work in H, the lever I acting as a pressure-bar on the spring H. So soon as the steam and pressure settle the wool, the hood is hardened and opened out, the linen cloth is removed, the hood is carefully looked at again, and any defective places are repaired; it is then folded so as to bring into the middle the two sides or edges that received no pressure, and is again placed in the machine. When removed this time, if the process has been carefully conducted, the sides all round will have been transformed from a thick flossy wool to a loose thin cloth. The crown or tip has been first solidified. To effect this in the same manner as the sides, a stout iron pillar, terminating in the cone E, is used. By attaching a side bar from the shaft of the machine, the same motion is given to F. This ring must be made into a pad, covered with linen. The hat form is placed over the cone E, which is perforated, to allow of the escape of the steam admitted to the inside. The workman lifts the rod F, places it with this linen covering upon the top of the hat resting on the cone, and turns on the steam; the top becomes hardened by the mere weight of the side bar. The form is thus completely hardened and ready for the next process.

This machine, known as the "No. 1 hardener," is perhaps the least complicated, and certainly the most approved by all manufacturers for a large production with little labour. It is suitable for all medium wool hats. For the purpose of hardening fine wool and fur hats, recourse is had to the "No. 2" machine, known also as the "cup and cone hardener." With the low class and medium wools, the staple is not so easily thrown out of shape, nor injuriously affected by pressure and steam, as the finer sorts. Therefore the No. 1 hardener should be used by all persons engaged in the common and medium trade. Fine wool under pressure in the No. 1 machine would flatten out too large, so much so that a large quantity of work would be spoiled, for it could never be felted down to the requisite size to make good work. The aim of the manufacturer using the finer material is to confine the hood, to prevent its expanding too much. If he can once concentrate it by hardening the felt to a proper size, his object is easily gained. The No. 2 hardener, Fig. 810, effects this completely, and is the best machine for this class of work.

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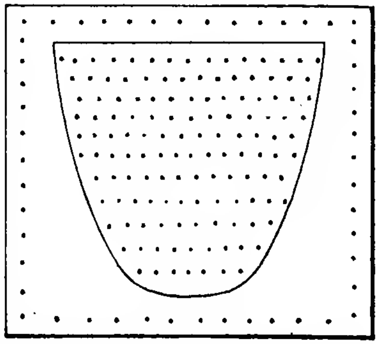

In making fine wool hats, the same processes of carding, &c., are to be followed, the workmen acting precisely as with the No. 1 machine, so far as regards the hardening of the bodies and making them sound. The difference in working will easily be understood on reference to Fig. 810. A is a driving-shaft, revolving the upright spindles surmounted by the cones C. These last are covered by linen cloths. B is a table for supporting the cover D, into which steam is injected for hardening the body, and gives the workmen easy access for removing the form. Setting the cone C in motion the hood is placed over it; when evenly placed, the cover D is pressed upon the hood, confining it on all sides. The chain that passes over the lever E keeps constantly lifting the top cover with a spring, the under cone revolving; thus the wool is settled down, and hardened evenly on all sides simultaneously, the tips included. No portion of the wool escapes pressure, it being confined on all sides at once. The machine is peculiarly fitted for all finer materials, and is absolutely necessary for the class of work just described. The hoods thus hardened go into the next department, which will be described presently. It will be convenient first to describe the process of forming the finest fur hoods, ready for the hardening-machine, in order that all qualities may be taken together into the "planking-room."

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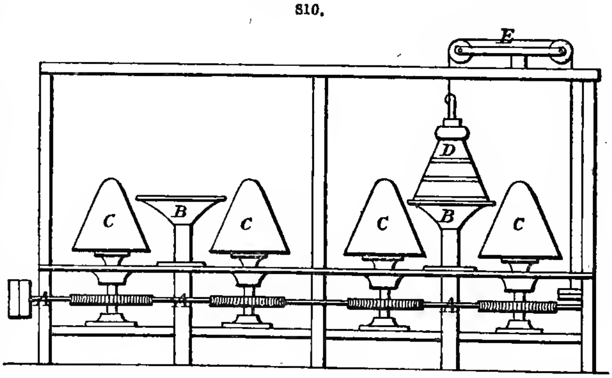

Furs for Hatting.—Fur for hat-making purposes must be most carefully prepared and sorted. The furs principally used at present in the manufacture of fine goods are coney or hare, and rabbit, the best qualities coming from northern countries (see Fur). The first process the fur undergoes is "carroting," which consists in applying to it a solution of 32 parts mercury in 500 parts commercial aquafortis (nitric acid). The object of this is to render its felting easier, and to avoid the excessive use of acids in the subsequent operation of planking. Much experience will be required in selecting fur, to avoid that which is defective in quality, and to detect that which is rotten. This is a most difficult matter, and one of the best safeguards is to purchase from none but first-class firms. The skins are taken into a hot room to dry, are sorted into qualities known in commerce as "back," "belly," and "side," and are finally made up in bundles and sold by the lb., the price varying from about 5*s*. to 20*s*. It should be noted that hare-skins have a solution of arsenic applied to them before the fur is removed, to prepare it for felting. The choicest qualities of hat are produced from beaver-fur; commoner ones from otter and musk-rat. An excellent felt for hat-making purposes is made from the fur of a large species of water-rat, a native of S. America, and more than a million skins are annually exported from that continent for the purpose.

Fur-blowing.—After selecting the class of fur suitable for the manufacture of the goods desired, it is taken to a room adapted for the blowing-machine, Fig. 811, which separates the hairs from each other. This machine consists of three parts: an apparatus for bringing the hair, a conduit pipe, and

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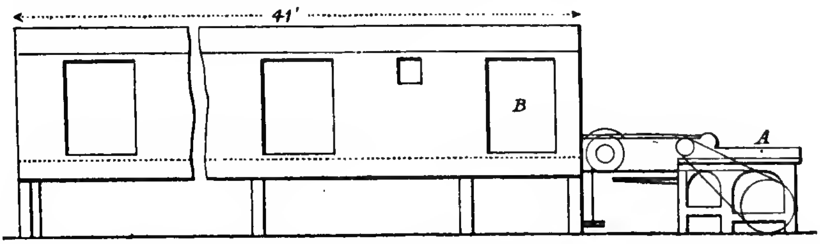

a chamber or series of chambers. The hair is first conveyed on an endless belt of cloth A, provided with fans, and is blown into the first chamber B. This is furnished with a glass window, through which the fur can be seen kept in violent commotion by the wind from the fans. The finer hairs adhere together, and pass along from one chamber to another, the finest being carried farthest, while the coarse and unsuitable qualities fall into boxes at the bottom of the first chambers.

Fur-forming.—The fur-former, Fig. 812, is next brought into use. The "stock" or "blown hair," as it is termed, is weighed out in the exact quantities required to form one hat, and is placed upon a travelling "brat" or "apron" A, by which it is carried between two horizontal feeding-rollers,

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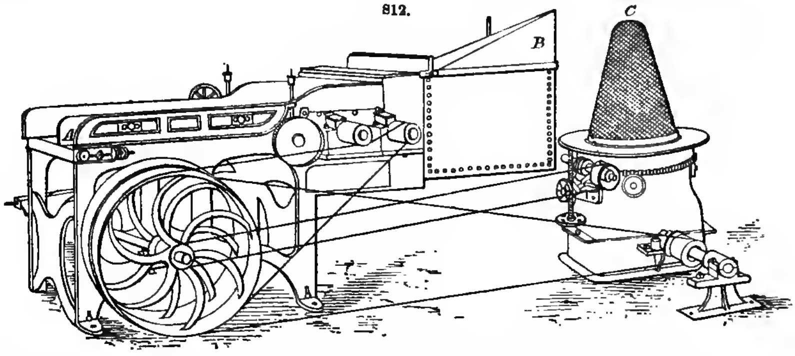
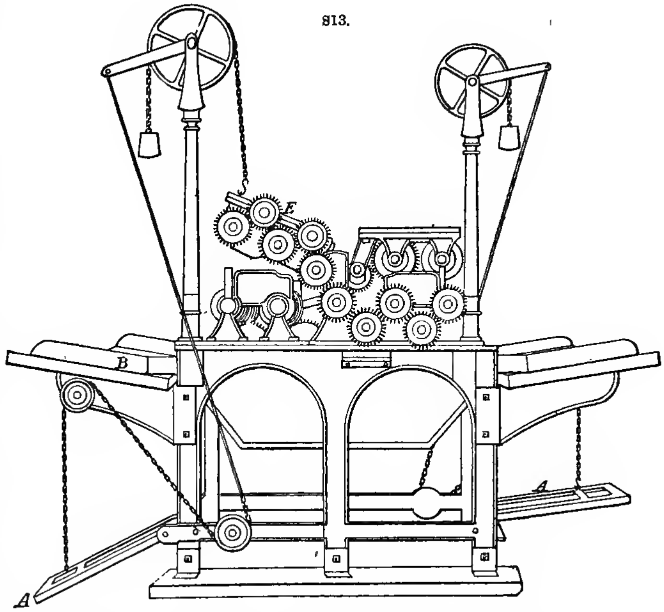


covered with felt, and is immediately seized by a cylinder, making about 3000 rev. a minute, and furnished with several longitudinal lines of stiff brushes. This generates a current of air, and scatters the stock, blowing it out through a vertical slot B, at the farther end of the machine. A thin stream of hairs is thus ejected against the cone C, which is made of copper, perforated with small holes, and revolves on a vertical axis. A strong current of air is produced by an exhaust-fan or air-pump, placed within the cone, thereby assisting the fur in attaching itself to the cone C. During the operation, the cone and its covering are kept constantly moistened with water. The revolution of the cone on its axis soon causes it to be uniformly covered with a fine felted fabric. The slot B can be regulated by means of a sliding-board, the manipulation of which enables the operator to direct the stream of hair to any desired part of the cone C. An extra quantity can be placed upon the brim if wanted, or the whole hat can be formed of even thickness; this is as much at the discretion of the operator as in the wool-former.

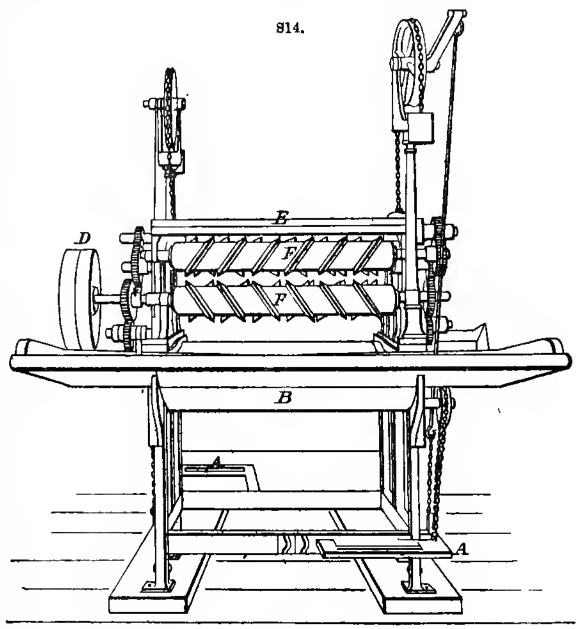
While the right hand of the workman is directing the stream of stock or hair, the left hand is applied to the felt to moisten it, and to ascertain its thickness and uniformity. When the whole weight is drawn upon the cone, the pneumatic action is stopped, and the felt is covered with a wet linen cloth, or a tightly fitting copper cone, similar to the one within the felt. Both are plunged into a bath of dilute sulphuric acid, and made sufficiently cohesive to be safely lifted from the mould. The felt requires to be hardened still more, or it would fly out of shape, and be spoiled. In some cases, workmen "run in" the felt, i. e. dip it into sulphuric acid and hot water, and roll it gently by hand until it is firm enough to be put upon the No. 2 cup and cone hardener, or is brought into such a state that it will not felt together. In all the processes, whether by hand or machine, cloth must be introduced into the hood, to prevent its fastening together. In all cases where a mixture of sulphuric acid and water is used, the strength is understood to be such as will afford a strong sour taste on the tongue, unless otherwise stated.

813.



Planking.—Having made the felt firm enough to stand the pressure of a machine, both fur bodies and wool bodies may be taken into the planking-shop, where are machines specially adapted to reduce them to about $\frac{1}{3}$ their original dimensions. The first machine is very suitable for wool bodies. Two views of this are shown in Figs. 813, 814. The foot-lever A, when depressed by the operator, raises the entire frame and gearing-wheels which drive the rollers F, attached to the frame E. The rings seen on these four rollers, two on the top frame and two on the bottom, are composed of vulcanized indiarubber, to resist the corrosive action of the acid used, and are placed in such an oblique position that the revolution of the opposite rollers causes them to attack the felt with a screw-like motion, producing an action like kneading with the hands. The operator takes 8–12 hats, and rolls them in an indiarubber cloth about 30 in. long, first dipping them into the lead-lined cistern B, which is charged with a mixture of hot water and sulphuric acid. Placing his foot upon the lever A, he raises the frame as seen in Fig. 813, and introduces the roll of hats between the top and bottom

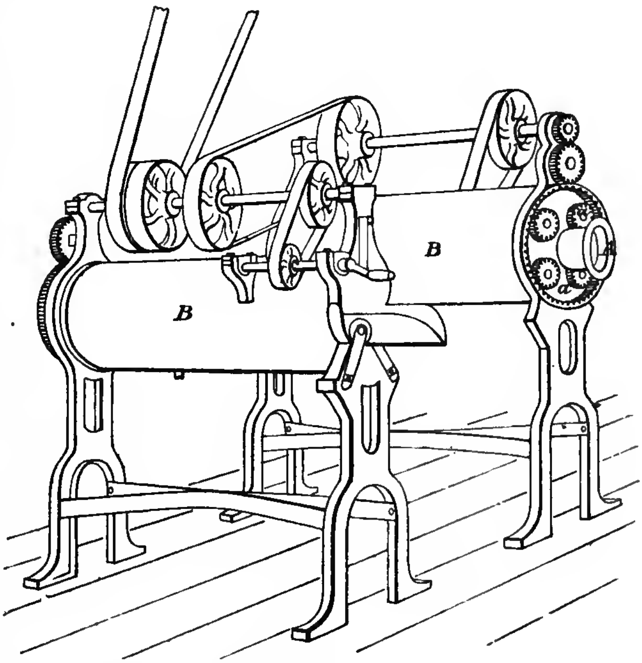
814.



rings. The foot is taken off, and the weight of the frame E presses the hats down. After being worked in this machine for some time, the hats are removed from the cloth, opened out, and folded so as to bring the edges to the middle, when they are again run through the machine. These are supposed to be "all wool" hats. The operator piles them beside him, until he has a quantity sufficient to fill the fulling-stocks.

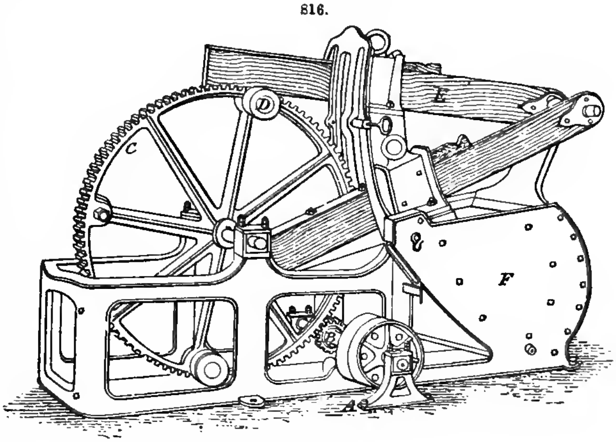
Twisting.—If the hats are fine ones, they are planked through in the "twisting"-machine, which is sometimes made double, as shown in Fig. 815. A roll of hats taken from the hardening process, if "wools," or if "furs," settled first by hand, are wrapped in a wet linen cloth, dipped into vitriol (sulphuric acid) and water, and pressed into the trumpet-mouth A. The passage diminishes in diameter as it traverses the length of the cylinder B, and is corrugated throughout. As the cylinder receives a rotary motion from an internal wheel driving the four small rollers *a*, the hats are twisted as they advance, and are compressed gradually smaller, until they are delivered at the other end; here they are placed in the mouth of the second cylinder, and return through it. The hats are next opened out, their edges are reversed as on the first machine, and they are completed by dipping in the acid and hot water bath, and working them through the machine until reduced to the required size.

815.



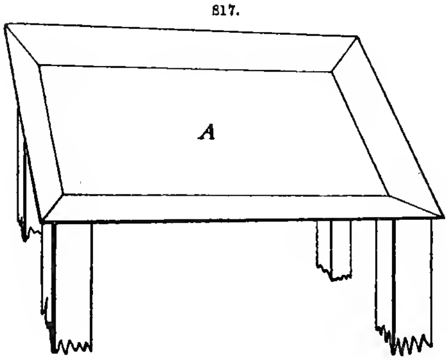
Fulling.—The woollen hats, described as being merely felted, so as not to adhere under pressure, are deposited to the number of 40, 50, or sometimes 60 doz. at a time, in the fulling-stocks, shown in Fig. 816. The driving-gear is at A; B is a small pinion, turning the large wheel C. In large stocks, four lugs are bolted at equal distances apart on this large wheel, as at D, for lifting the long lever E. The chest F has a circular form internally. The hats are doubled carelessly together and put into this chest, which is constantly fed with sulphuric acid and warm water. Here they remain until the beating action of the stocks has milled them up to the right size. A lead-lined cistern, fixed above the stocks, is very convenient for containing a supply of warm water and sulphuric acid; the liquor may be conducted to the chest by a leaden pipe, branching at the end into two, extending across the chest F, and finely perforated, so as to form a self-feeding arrangement. The felting being completed, the hats must be passed once more through the

816.

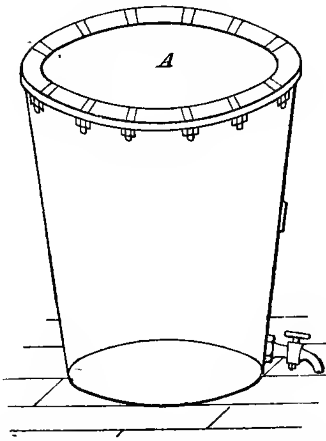


No. 1 planking-machine, to straighten them, and bring their edges evenly together. Besides these planking-machines, a "battery" (Fig. 817) is required, at which six men can work. In the centre A, is a lead-lined cistern, containing clean water, or acid and water, as required. The workmen have each a space allowed in front to work the hats upon. The battery can be used to plank hat-bodies complete to size, if the goods are fine; or to stretch the hats from the planking-machines. Each process being completed in this department, the goods are washed out in clean water, and afterwards passed between a pair of wringing-rollers, to get rid of the superfluous acid. Thus partially cleansed, they are gently dried in a stove fitted with racks on every side, as well as in the middle, leaving room between the narrow strips on each shelf for the heat to circulate over the entire surface of the hats.

817.



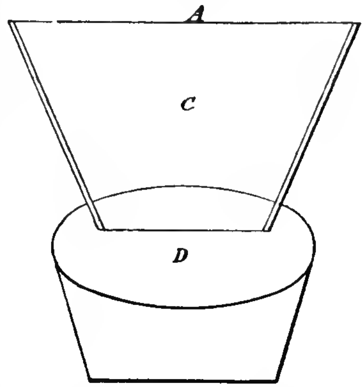
818.



Stiffening.—Stoving finished, the hats are ready for "stiffening," a process requiring great study to produce good results. Each hood should be carefully examined, to discover any very thin ones that may have escaped notice. Should any be found extra light, additional stiffening will make up for it, if noticed in time; but quantities of goods are hopelessly spoiled through careless examination at this stage. The mixtures used for the stiffening process vary according to the taste and experience of the maker, and the class of work he happens to be engaged upon. The mixtures here given will be found perfectly safe, if worked as directed. A number of large tubs, and several dipping-vats will be required for the operation. The first apparatus used will be a steam-chest, Fig. 818, for reducing the "proof." This chest is double-jacketed, for the admission of steam to the interior. The inner part A fits into the outer, the joints being made good with iron-turnings and sal ammoniac, and the rim bolted on as shown. The tap at the bottom is useful for letting off condensed steam, accumulation of liquid in the jacket or steam-space preventing the contents of the pan from being brought to the boiling-point. The ground floor is the most suitable place for establishing this apparatus, as it often happens, through carelessness, that the proof or stiffening preparations boil over. Much water is also required in this department, causing inconvenience if it has to be carried up stairs. It is impossible to insist too strongly upon the great importance of thorough study of the art of proofing, as upon it most largely depends the success and reputation of the manufacturer. A perfect knowledge of the nature of the materials is indispensable, while special chemical knowledge will more than repay any student who directs his attention to it. The complete ignorance of the workmen upon whom may depend the success or destruction of perhaps 1000 doz. hats a week, renders it imperative upon the manufacturer to master the details of the process. It will suffice here to describe the important outlines, which, if followed, will at all events conduct to a satisfactory termination the proofing of the soft and hard felt hats that form the bulk of the general home and shipping trades.

The first to be considered is the mixing of what is known as a "water-proof," for the stiffening of the common and medium woollen hats, intended to be of a black colour. Steam is turned into the proof-pan. The workman then weighs out 8 lb. rosin of good quality, 6 lb. gum "thus" (naturally solidified turpentine), 3 lb. borax, and 1 lb. soda. The borax is first dissolved in warm water in the steam-pan, and the rosin, thus, and soda, are then added. When these are quite dissolved, 30 lb. shellac (good "garnet" or "button" will do) is added, and the whole is allowed to dissolve, being kept well stirred to prevent it adhering in lumps to the bottom of the pan. Special observation is needed to note the change in colour. A little experience will soon teach when to add warm water, which is done at first in small quantities, without relaxing the constant agitation of the compound. A gradual reduction is made in the temperature of the water poured in, until cold water is received by the shellac without chilling it. The strength required will enable the workman to judge of the thickness of the mixture, for water should be added until it is within a few degrees, by Twaddel's hydrometer, of the strength required to proof the brim of the hat, this being the strongest part. "Letting-down" the proof by water after this first process does much damage to it; the grains of shellac resisting combination with the water, only a partial agglomeration takes place. A microscopical examination of the mixture in the two states, the one just as it is let down in the steam-pan, and the other after being let down with water, will show that the latter, instead of being perfectly mixed with the body of shellac, is only partially held in solution. The fact that this second mixture may proof the brims and crowns of the hats to the right degree, as shown by the gauge, is not sufficient; the hats may be completely ruined nevertheless. The secret of this lies in the fact that what ought to have formed strength will have evaporated in the stove, leaving the damaged shellac incapable of performing its office. When completed, the workman can test whether the mixture is good, by rubbing it between his thumb and finger: if sound, it will slip between them like glass; whereas if broken by being chilled too quickly, the feeling will be gritty, and much like that of fine sand. A large, shallow vat must be provided before commencing the process. By placing across this a slab of wood, on which to fix a fine sieve, the proof can be emptied from the steam-pan, run through this sieve, and left until quite cold before using. As the wool bodies left in the stove are brought to the proofing-room, they should be allowed to cool thoroughly before being subjected to the proof. The "dip," reduced to the right gauge, is contained in a vessel shown in Fig. 819. Some hats require 60° Tw. in the brim, and 30° Tw. in the crown. To manipulate the hats rapidly, two stools of this description are indispensable. The operator, standing at A, dips the hat into the vessel D containing the proof, or "stiff," as it is frequently designated, sufficiently deep to include the entire brim. When finished, he lays the hat on the slab C, and draws off the superfluous stiffening by a strip of boxwood, about 1 in. thick at one end, and tapered down to a blunt edge on the other, and called a "draw-block," avoiding too heavy a pressure. On immersing the brim again, sufficient stiffening is imbibed, and the hats are taken into the stove, first reversing the folded edges. The draw-block removes any undue stiffening that may have been attached, and thus secures an even coating. The hat is then passed to the next stool, where the operator thrusts a short, stout stick into the inside of the hood, and plunges the hat bodily into the "crown" proof. Here it is saturated inside and out, giving a little time for it to absorb the preparation, after which it is withdrawn upon the stool, and all the superfluous stiffening is drawn off, as in the first process, and runs back into the dipping-pan. The hood is rubbed on all sides with the bare hand, to destroy any patches of thick proof that might have escaped notice. Opening the broad side of the hood, and holding it by the crown, it is laid on the floor to set hard. So soon as the operator has accumulated a dozen, he rapidly sets them in the steamer for 20 minutes, and afterwards in the hot stove, for 60 minutes, to sharply fix the proof, removing them into the air afterwards to cool. They are then again ready for the steaming-chest. Before proceeding to explain this process, it will be necessary to follow fine goods through the proofing department, as well as soft hats. In all dip proofs where the steam-pan is used, warm water can be employed to dissolve the borax, and this must always be the first process, before adding the gum thus and rosin. For a mixing of soft proof, weigh out 4 lb. borax, dissolved first in warm water, 3 lb. rosin, and 3 lb. gum thus; dissolving this, add 30 lb. shellac; keeping the mixture well stirred, 1 pint linseed oil will be mixed in, pouring in a little warm water first, and "breaking" the shellac gradually until cold water can be added. Having brought it to the required strength, it is poured into a vat, kept for the purpose, for a couple of days before using, as it works much better after standing. The strength, measured by hydrometer, must be left to the judgment of the maker, for the felt for this class of hat is made of so many strengths that, while some require scarcely any stiffness, others need 5-10° Tw. in the brim—less in the crown, as it is to be more pliant.

819.

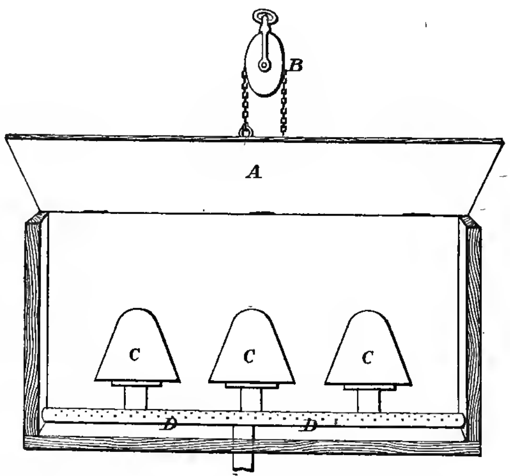


The mode of dipping is the same as for hard hats; less heat in stoving will suffice.

Spirit Proofing.—Some account must now be given of the most popular preparations, both English and American, for the proofing of fine goods, technically known as "spirit proofing." The stiffening of these goods, like that of all others, requires careful attention on the part of the maker, in order to ensure good results. The climate in which the hats are to be worn should influence the character of the proofing. The dampness of the English air demands a much harder stiffening than is requisite in America. In the largest manufactories in the latter country, where fine hat-making, both hard and soft, has reached a very high state of perfection, the most favoured preparation is 20 lb. of orange shellac, dissolved in the cold in 5 gal. spirit (methylated or alcohol), in a close vessel, with repeated and careful stirring, to keep it from "lumping," and sticking to the bottom. The vessel commonly used is in the form of a barrel or churn. When fully melted, the "stiff" is made ready for use by being thinned down by spirit. The strength is not gauged by hydrometer, but is judged by actual application by an experienced hand. A good stiff brush is used to put in the proof. Most strength is given to the brim, as in the first case.

Another American proof, of a cheaper kind, for soft hats, is made in the steam proof-pan, by dissolving 9 lb. shellac with 18 oz. carbonate of soda in 3 gal. water. The soda is first gradually introduced, and is soon dissolved; then the lac is put in, and stirred occasionally for about an hour, by which time it will be dissolved. The whole is then left for an hour or two, when it may be taken out and set to cool. It will be found better if allowed to stand for a few days after being made. When used, it is reduced by water, as explained in the first mixing of hard proof for woollen hats, the strength being 2°–10° Tw., according to the thickness of the felt. This mixture will be found very good for soft or semi-stiffened hats. It is the habit amongst some makers to add 3 oz. salt. The salt counteracts the soda, and the hats may be blocked immediately after being stiffened, thereby saving time, and dispensing with the use of the stove. The following mixture is esteemed by some English makers:—7 lb. orange shellac, 2 lb. gum sandarach, 4 oz. gum mastic, ½ lb. rosin, 1 pint solution of copal, and 1 gal. wood naphtha or methylated spirit. The lac, sandarach, mastic, and rosin are dissolved in the spirit, and the solution of copal is added last. This is rubbed into the body with a brush, like the former spirit proof for fine hats. The hats, both hard and soft, are placed in the stove at a temperature of about 82° (180° F.) if of wool; less heat will serve the purpose of spirit-proofed hats, and care must be taken lest they catch fire. Bringing the goods from the stove, a steamer is provided, which will hold two rows of pegs, on which to place them while undergoing the steaming process. This chest, Fig. 820, is composed of wood, about 2 in. thick at the sides and bottom, bolted at the sides with cross-bars to strengthen it. The figure shows the inside of the chest with the lid open. A strong fastening must be attached to the lid, to prevent its being lifted by the pressure of the steam, while the hats are undergoing the process, which lasts for 20–30 minutes.

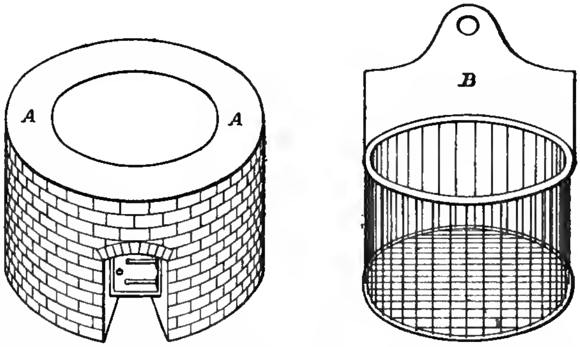
820.



The lid A is raised by a chain attached to a pulley B, secured in a stout pillar, and enabling the operator to adjust the lid to any height by means of a balance-weight attached at the other end; C is a row of wooden pegs, on which to hang a pile of hats, say 6, 8, or 10, as required; D is one of a series of perforated pipes for injecting the steam evenly throughout the chest. Placing hats on these various pegs, the lid is brought down and securely fastened, and steam is turned on for 20 minutes. On opening the chest, the hats are taken by the taper end, and dropped singly upon the floor to set until perfectly cool. When a sufficient number is accumulated to fill the hot-stove, the goods (if for hard hats) are passed into this stove, and kept at a temperature of 82° (180° F.) for 6 hours, allowing the heat to gradually decrease from that time. In the steaming process, the stiffening is cleaned from both the outer and inner surface, by the equal pressure of the steam on both sides. It needs careful attention to avoid scorching the fibre, as this will destroy the peculiar gelatine inherent in the hair of animals, and which accounts for the fine softness of the finished article; if once extracted, the latter is left wiry and harsh. This completely spoils its character, and will explain a fact hitherto not generally accounted for, that the dry, harsh sensation is the result of this extraction of gelatine. In dyeing, the same care should be taken not to destroy it by boiling. After a thorough stoving, performed in a special apartment if possible, on account of the dangerous character of the work, all the goods are removed to the dye-house, where a number of copper pans are fixed for the reception of the hats, no other material so well withstanding the corrosive action of the acid accumulated in the hats.

Dyeing.—As the largest proportion of the hats are to be black, preparations are made to dye what is required daily for the various departments. Some makers prefer pans wholly heated by fire, asserting that the liquor is not damaged, weakened, nor affected in its nature the same as in those raised by steam. Others conduct the black dyeing in a large pan heated both by a steam-coil of copper pipe and by fire. If possible, a large room on the ground floor, with a good north light, will be very advantageous, and ample room must be provided for opening-out the hats singly, as this assists most materially in striking the colour very deep. For a large pan, a cage, as shown at B (Fig. 821), is made to fit inside the pan A, and a windlass is attached to lift the entire "dye" or batch of hats at once. This will save much time and labour. The dyeing of hats is much more difficult to perfect than the dyeing of ordinary wool for wearing and other purposes, where the surface of the fibre sustains no damage. In the former case, the dye must saturate the fibre intimately, or the colour will look very grey and dingy. The subsequent process of "sand-papering" seriously affects the surface, and requires the presence of nothing but free wool, dyed thoroughly through each fibre, or an even colour will be impossible. The dye-pan A (Fig. 821), is of stout copper, built into brickwork, and allowing room around the edge for the workmen to walk and agitate the hats in the process of dyeing. The cage B is also made of copper, to prevent active corrosion. The workman prepares the pan first for a batch, say 50 doz. of woollen hats, by extracting 90 lb. logwood in a warm bath; the liquor is well stirred, and the goods are then immersed. The heat of the pan must not exceed 82° (180° F.): boiling would cause harshness in either fur or wool, as previously explained, by extracting the gelatine. The goods are thoroughly turned, while the pan is kept at a regular heat. After 1 hour, they are removed, and each hat is spread out carefully to expose it to the atmosphere, this deepening the colour. They are then again placed in the dye-pan, and the process is continued for another hour. Previous to this second immersion, 15 lb. copperas and 3 lb. verdigris are added. After constant turning over during the second hour, the hats are taken out and laid singly on the floor, as before, remaining for about 20 minutes. A third immersion will complete the dyeing in a satisfactory manner, if due care has been taken. Many dyers allow the hats to remain for only 40 minutes in the pan; in fact, the shorter the time that the hats stand in dye, with due regard to colour, the better they will go through the final processes. A much favoured dye for common hats is to mordant them first in a weak bichromate of potash bath, separate from the dye-pan, and then to place them in the liquor. The use of copperas can be largely avoided by this process; but some object to it, on the ground that the bichromate makes the wool hard and harsh. Yet many makers are able to bring back the softness, and commend the process.

821.



The following is a capital dye for fine hats, producing a good bright black, the quantities named being for dyeing 100 hats at one operation. Into a copper containing 55 gal. boiling water, put 9 lb. best liquid extract of logwood at 30 degrees, 4½ lb. crushed cashew bark, 4½ lb. sandal wood in powder, and 2¼ lb. soda crystals. Enclose the whole in a linen bag or wicker basket, so that they do not settle at the bottom of the copper. When the ingredients are dissolved, put the hats in, and allow them to boil gently for 2 hours. Then take them out and let them get quite cold. Now add to the bath, 3¾ oz. chromate of potash and 9 oz. sulphate of copper, and cool the bath by the addition of several pailfuls of water. Return the hats to the bath, and allow them to simmer for an hour. Again take them out, and let them get cold. After adding 2¼ lb. sulphate of iron, put the hats in again, and let them boil gently for an hour. Should they have a red appearance, add to the bath another 2¼ lb. soda crystals. After these operations, the hats must be piled up, and covered with a thick cloth for a day; then subject them to a vigorous washing, and eliminate the copper, using hydrochloric (muriatic) rather than sulphuric acid, as the latter always draws out the dye. When the copper is thus removed, pass the hats into cold water, in order to free them from acid. For the final operation, prepare a bath of Panama wood, just simmering, and place the hats in this for ½ hour. This bath sets the colour, and gives brightness to the felt. Upon taking them out, if soft hats, the water must be drained out of them by pressure. To produce a violet-black, the cashew must be replaced by the same weight of orchil. A blue-black is obtained by leaving out the catechu and sandal wood, and replacing them by 4½ lb. of orchil. For burnishing, the sulphate is replaced by 1 lb. 2 oz. sulphate of copper. If a greenish-black or dark-bronze tint is desired, the sandal wood must be replaced by 4½ lb. liquid extract of Cuba yellow wood at 30 degrees.

An American dye for best fine hats (12 doz.) is composed of 144 lb. logwood chips, or its equivalent in extract, 12 lb. green sulphate of iron (copperas), 7½ lb. French verdigris, placed in a boiler, and heated to 88° (190° F.). During the operation, the hats are kept turned; when removed from the pan, they are exposed to the action of the air. When the manufacture is extensive, two boilers will save much time, one batch of hats being in the pan while the other lies exposed to deepen in colour. From 6 to 12 hours are required to complete the operation. The copperas and verdigris are added for the second bath.

An English composition (for 36 doz. "medium furs"), mordanting first with the bichromate of potash, is 120 lb. of logwood chips, or the equivalent of extract, 4 lb. verdigris, 12 lb. copperas. The process is conducted as before. To dye soft goods, more logwood will be required, as the hats absorb more; and it should be noted to give more for extra weight of material in all cases, and that the strength of the liquor be kept up, or bad dyeing will result. Should the boiler become foul, it can be cleaned by using about 2 lb. of whiting and a little urine. The goods on removal are all washed out clean in hot water first and cold afterwards, when they will be ready for blocking.

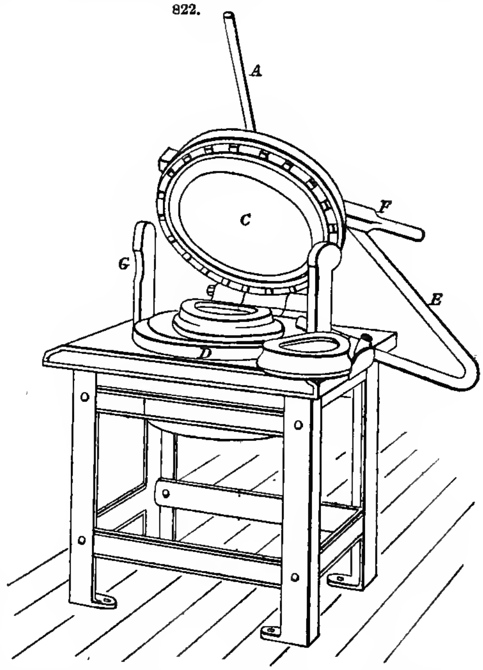
Blocking.—All the goods are removed after dyeing to receive shape at the hands of the "blocker." A ground floor is necessary for this purpose, and good drains must be provided to carry off the large quantity of water used. Steam pipes are laid on to a battery, similar to the one described under the head of planking, allowing 4 men at each. A small bucket containing cold water is placed on the right, and the left hand holds a block of the shape and size required in the finished hat. Steam is turned into the centre cistern, filled with clean water, and heated to 88° (190° F.). To make the felt more pliant and elastic, sometimes a little meal is mixed with the water. Unprincipled workmen, to secure this end, will surreptitiously use alkalies. By this, the work is damaged in dye and stiffening, showing a whiteness after standing for some time in the finished state. Two hats are plunged into the hot water by each workman, as one can be made pliable for working while the other is in process; but not more than two should be in the water at once. Lifting one hat, the workman will pull out the tip, or "unbutton" it. If this is effected thoroughly, the crown will stand sharp in its mould, so long as the stiffening holds good in wear. Should this operation be badly performed, the hat has a tendency to go back to its original shape, as seen when coming from the "former," before planking; and in the trimmer's hands, it will frequently occur that when she puts in the lining with a little flour paste, the hat will spring out of shape, spoiling the article after all the cost of trimming has been incurred. Taking hold of the brim whilst hot, having first placed the block on a pivot so as to raise it about 4 in., the workman thrusts it vigorously down evenly on all sides. Passing a draw-band around the extremity of the block, he turns up what forms the brim, running the cord down on the flat portion of his battery, lined with copper, which retains the heat longer and assists him better in his work. With a small brass runner, grooved to fit the cord into its place, he immerses the hat bodily again in the hot water. Holding the brim firmly with one hand, he breaks it with the other, using his thumb as the fulcrum, and removing all the creases, until, from the cord to the edge of the brim, the hat is quite flat and without "puckers" round the outer edge. Loosening the draw-cord, the hat is lifted from the block, and thrown into cold water to set. This process is applied to all kinds of hats, hard and soft. Other means are employed if hand labour is dispensed with; and of late years, both in America and England, great efforts, with varying success, have been made to supersede this most laborious branch of the trade, as the workmen's hands, by severe scalding and pulling, are frequently disfigured, and the work is not adequately executed. In America, machines are used for breaking the brims and opening the tips, for common goods especially, and are occasionally also applied to fine goods; but the risk is so great in this class of work that it is not advisable to resort to the plan until care and experience have proved its complete adaptability. For common woollen goods and soft hats, it may be used with safety, if care be taken to work the goods through hot water, and to commence the strain from the centre of the tip, until open to the width of the block. The brim-breaker must be worked in the same manner, the hats being taken from the hot water. As this machine acts with a motion much like the opening of an umbrella, it will be understood that it strains the edges of the brim, but should the brim be kept in one position during the operation, or be pressed too far between the brass fingers, the marks will be seen after the goods are finished, and will completely spoil them. The only safe method is to press the brim gently, raising the fingers of the machine, and moving the hat just so far as to take under pressure the portion hitherto unstrained; by this means, the whole brim is evenly broken, and made ready for blocking. Many forms of this machine have been partially perfected, the most successful being one in which the hat-block is placed upon a central spindle, from which radiate ribs, the same as those of an umbrella. Notches are made on the extremities of these ribs, which are jointed so as to produce a partly horizontal motion, whilst fingers clip the outer edge of the hat. The machine is adjustable to any width of brim. Upon a shaft above the block, is attached an iron ring, having the shape and size of the average blocks to be used, and working on a loose swivel. The ring performs in a less effectual manner what the hand-blocker effects by his draw-band, making a close and firm band where the leather of the hat is placed. Taking the hat from the hot water, the workman presses it over the block, seizes the outer edge with the fingers of the machine, draws it to the width of brim for which the machine is set, and brings down over the block the iron ring to form the band, when the blocking is considered complete. Many points require consideration before adopting these machines. For first-class goods, they cannot compete with well-trained hand labour. For medium and common soft and hard goods, where every convenience is at hand, and with workmen who can be depended upon to watch carefully that all the hoods are of one size, rejecting any that are not uniform in this respect, they may and are being worked successfully. But for a small output, and where the other requisite conditions cannot be complied with, it would not be adviseable to adopt them. Where these machines are successful, ten times the amount of work can be performed as by hand labour.

Stoving.—The next department is the stove, where all blocked hats are taken to be gently dried. To retain the shape is the great desideratum in this process. If too hot, the hats, being wet, are reduced too quickly by the heat, and, being loaded with water, steam rapidly, and fall in shape, thus destroying all that the blocker has done. Having dried the hoods, it is requisite to strengthen the hard hats. This is effected by taking a small brush, and again pasting on a thin coat of proof, in the inside of the tip as well as the sides, to assist in retaining the shape. If the crown is very sharp and flat, it will be necessary to insert a thin layer of calico, stiffened with proof, and cut round like the crown. This, in pressing, fixes the crown firmly in its place, and holds it tight. With common woollen hard hats, it is usual to pass the outside over a rose gas-jet, to singe the long nap, placing them to damp a little in the air. Singeing is not admissible for soft hats; they are much improved in quality by lying in a cold, damp cellar for some time before using. Hats that are pasted must again be taken to a low stove, to dry the paste before being removed to the stock-room. The best method is to assort all the hats, both as to shape and size, on taking them from this stove, that the operator in the pressing department may take all one sort required for his orders to press at once, thus saving considerable time and labour.

Pressing.—The next process for hard hats, and in many cases for soft ones also, is "pressing." A ground floor is most suitable for this department, as heavy pumps, retorts, presses, and dishes or moulds, are required. The most refined taste is demanded in selecting shapes suitable for the various markets. Having decided upon the shapes to be made in hard hats, blocks are turned in wood, two sizes, and sometimes three sizes, larger than the pattern hat. The moulder casts the shape in iron, called a "dish." Not more than one should be made of each shape decided upon, for it frequently occurs that alterations are necessary, and that these first attempts are useless. On receiving the dishes from the moulder, each should be examined first for blown places in the casting; if any of importance are detected, they should be rejected at once, because a great pressure having to be put upon them, 200 lb. a sq. in., or even more, any flaw will be forced open, thus causing expense and delay. Secondly, the oval and size of each dish should be ascertained to be correct; and lastly, each dish, being ground and glazed internally, requires great care in testing the evenness of the grinding. Should any inequality occur, it will be clearly shown on each hat, and damage the general appearance when finished. It is important that the dish should fit dead to the under plate in the press. This can be decided by placing a straight-edge across the inner ring of the press upon which the dish rests, afterwards applying it to the back of the dish, which is turned to a flat surface. If it is round, or "hump-backed," the first trial of the pressman will break it into pieces. The same thing will occur if it is turned out too hollow. What is desirable is a solid face, if the dishes are to stand the constant strain put upon them. Finding all correct, a slight mark at back and front, to indicate the exact centre, will be found of great service in giving the trimmer a certain guide in fixing in the hat tip or lining, for nothing looks more slovenly than to have the stamp or name on the lining crooked. Each selected dish will have its size plainly marked on, or large figures may be cast in the outer skin of the dish. The selection of a substantial pair of pumps, with a capacious overflow cistern, will greatly assist in turning out a regular quantity of work, many makers being imposed upon in this respect, by machinists advising the use of pumps much too weak for the purpose. These must be secured solidly upon a stone or concrete foundation, screwed firmly to the same by T-bolts socketed into the masonry. At a short distance is fixed a stout iron retort, 6 ft. high, and 2 in. inside diameter being the most useful size. A supply-pipe connects this retort with the pumps, beside a corresponding one to return the overflow. Above the centre of the retort is a pressure-gauge, for indicating to the presser the exact amount of pressure being exerted upon each hat. The press is also connected by a feed-pipe with this retort, and an overflow pipe to return the water, before releasing the pressure from the internal indiarubber bag. A stove, heated by fire or steam, is arranged as near as possible to the press. If used as a fire-stove, a central strip, which divides it into four compartments, is dispensed with, using merely a square chest with wooden ribs, forming a shelf across the centre. Hazel sticks laid across are strong enough to carry the weight of the hats. A solid shelf would burn the hats, and destroy itself quickly. This fire-stove requires the utmost attention on the part of the workman, to keep it at such a heat as will merely soften the proof or substance of shellac, without drawing it to the surface, or the work is at once damaged. On pressing the two hats, for no more must be placed in the fire-stove at once, the wooden cross-pieces are removed and cooled in water, or it will be found that, at the points where the hats have rested, the intense heat has drawn the shellac. This fact has brought the steam-heated stove or "baker" into use wherever there is a steam supply. This stove is composed of an outer jacket, as well as an internal case, divided into four equal compartments, and leaving a steam space between the inner and outer cases. The joints of the steam-chest are made good by a series of bolts, and luted with iron-turnings and sal ammoniac. Immediately adjoining, the chest is connected with a steam-trap, to keep it free from condensed water. For safety, cast-iron should be rejected for this structure, as under a strong direct boiler pressure it would be most dangerous. The cost will be a little more to construct the outer shell of boiler-plate; but safety should be the first consideration. The inner chest may safely be constructed of cast-iron. There is no danger of burning the hats in this arrangement, as in the one heated by fire. Four hats can be under operation at once; the operator, removing the one longest in the oven, presses this first, replacing it by another, to keep up a constant supply so long as he requires to continue pressing.

Many firms press all soft hats the same as hard hats, obtaining a much finer finish by the process, although losing thickness in the feel; still this even, thin consistency is much esteemed in some markets. The pressing of soft hats is a little varied from the treatment of the hard ones. Goods of the size wanted are selected from the damping-cellar, and given time to dry by opening them out singly. By a pipe carried into a chest underneath the dish, steam is admitted to heat the dish in which the hat is going to be pressed, which makes a much finer surface. The dish must never be allowed to get too warm, or it will "punish" the goods considerably, and disappoint those whose expectations have been raised by the repute of this process. The apparatus is shown in Fig. 822.

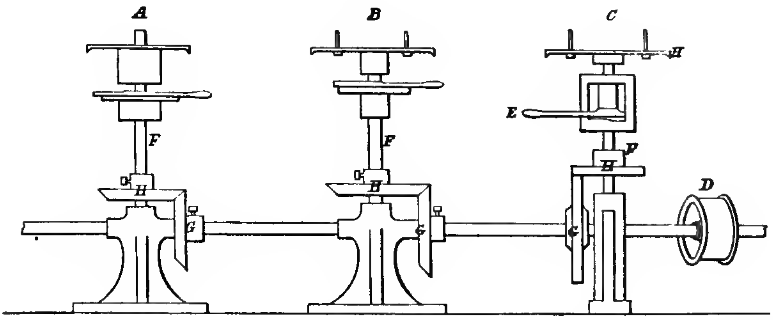
822.



The hat, hot from the steam-oven, is placed in the dish D. The lever A is brought down to a level with D, and the strong spider F is locked in the lug G. E is a strong pipe through which water from the retort is forced into the india-rubber bag C. The machine being locked the full pressure of water is allowed to force itself against the inside of the polished dish, giving the felt the exact form and surface of the pattern inside. On shutting off the water from the inlet pipe, the outlet is opened, drawing the water from the bag, thus freeing the hat from pressure. The press is opened, the hat is removed, and the process is repeated. When properly completed, the hats are ready for the "finisher."

Finishing.—Any room with good light will be suitable. In it are fixed a row of "finishing"-lathes A B C, as shown in Fig. 823. These are driven from D, giving motion to the upright shafts F, by pulleys G H. The underside of the pulley H is covered with leather, to increase the friction, and produce steadiness. The lever E when out of gear raises the pulley H, and, by destroying the frictional contact, stops the machine. The face-plate I, keyed fast to the upright spindle, has screwed to it iron pegs, on which to fix the wooden block having the form of a hat when pressed. On the outer edge of the table that carries these finishing-lathes, iron plates, similar in outline to half the side of a hat, serve to finish the underside of the brim. Turning the hat with one hand and sand-papering with the other, a fine surface is produced, on completing which, the hat is placed upon a block on the pegs on the face-plate I. The machine is then set in motion, and after brushing the hat with a stout brush, the finisher gently applies the sand-paper to the upper side of the brim, side, and crown. The block performing an uneven circle from its oblong shape, demands a nice touch in applying the sand-paper, otherwise the shoulders of the hat will be shaved bare to the proof, the work being spoiled in consequence. The hat is taken from the block, finished by sand-paper with the hand along the sides and crown, and placed again upon the block. Velvet and moleskin velures are used: the velvet one, moistened with water, is placed upon a hot iron, to convert the moisture into steam; this is applied to the outer surface of the hat, after which, the moleskin, or another velvet

823.



velure heated on the iron, is again sharply applied. The machine is set in motion after completing the side of the hat, to bring the crown to a regular even polish, finishing the underside of the brim on the brim-plate. "Wools" and fine goods are treated in the same manner. To finish soft hats, a different method is resorted to. Before they can be either pressed or finished, a steaming-bench is used. The block being shaped to the design ordered, the finisher draws the hat over the block, covers it with a tin cap, and softens it by steam. Putting the block on what is called a "spinner," the hat is drawn down, until the tip is free from puckers, a cord or draw-band securing the hat to the edge of the block. Leaving it to cool, another hat is treated in the same manner, and then removed to the finishing-lathe, to pass through the same treatment as the hard goods. If desired, these soft hats can be pressed after this process, when the surface is made very much finer; but they are not pressed until all the damp acquired in finishing has gone off, for if subjected to pressure in such a condition, it will be found that the bodies, when pressed in by the hand, have their felt opened, and look much coarser than before. Soft hats are rounded in the brim, i. e. cut to a size, by a gauged knife, shown at P, in Fig. 828.

Another kind of hat is the "half-stiffened," or "frame" hat, so called from the shape of the brim, being obtained from a wooden or tin frame, made to the style of curl required. The hat in such a case is placed under steam, like the soft ones; the brim is pulled wide to cover the frame, and a draw-band is firmly fastened round a groove made in the frame, to determine the shape of the curl. Thrusting the hat down the centre of the frame, the block for shaping the crown is forced to the tip by a screw in a small iron frame upon which the hat and block rest. The underside of the brim is then sand-papered, before removal, which must not take place before the hat is cool. The finishing-lathe may then complete the hat, as in the other kinds.

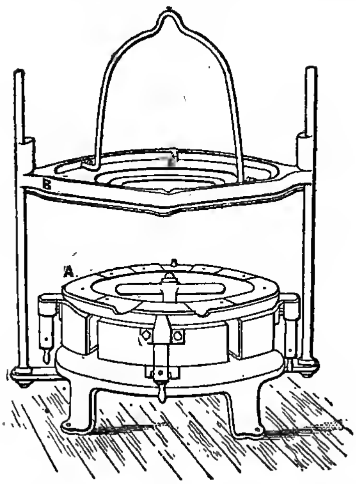
Should the soft hats not be pressed, they will be cut to the width ordered, and curled, either by hand, or by a machine worked by the engine. If finished by hand, use is made of a wooden or metallic gauge Q, Fig. 828, with a steel cutter sliding out to any suitable diameter. Drawing the finished hat over a block, and adjusting the latter upon a cutting-board, the knife *a* is thrust against the hat. Holding the block firmly with the left hand, the right moves the cutter round the hat, paring it clean and level. By inserting a stout cord or leather strap under the edge, turning just sufficient of the felt over this cord with the left hand, and following it closely with a hot iron in the right, half the circle is completed. By turning the block round, the remainder of the curl is finished. The iron must not scorch the felt, as neither the curl nor the binding of the hat will cover it. Should it occur, the effect may be removed by scraping with a knife and steaming afterwards. The hat is then ready for the trimmer.

Trimming and Shaping.—The hard hats coming from the hand of the finisher pass to the shaping department, to receive various treatment, according to the style of curl required in the brim. Should the hats be of common wool, many improved machines are now used in the best establishments to supersede skilled labour. First, the style known as "plain shape," i. e. a hard hat having the brim cut to the size, simply receives a binding, sewn down with an ordinary Thomas' sewing-machine, having the leather and lining sewn in previously. The so-called "Anglesea curl" needs different treatment. However, both styles must first be cut in the brim. To obtain a fine light appearance, the shoulders on the back and front of the hat are cut narrower than the sides and front. If good judgment be displayed in this process, the value of the goods will be much increased. The useful and simple machine shown in O (Fig. 828) effectually performs this operation on both fine and common hats. The machine is firmly fixed on a bench. The plate *a* is shaped to suit the style, giving the exact width on the shoulders; *b* holds the hat firmly by expanding in four parts, the circle being completed by a strong indiarubber band, which adheres firmly to the inside of the hat, and is held in a state of tension by the lever *d*, drawn round a ratchet-wheel and locked by a catch; *c* forms a double lever, with a hinge that allows it to be lifted from the lower part, which is slotted out and marked off in inches, thus making it adjustable for any width of brim. Underneath the upper half of this lever, is a small cutter. After setting the machine, the hat is fixed firmly, as described, by lifting the upper portion of the lever, so that the brim of the hat rests upon the lower. The top lever is then pressed down, forcing the cutter through the felt. At *e*, are fixed two small pulleys, grooved to fit the edge of the plate *a*, running loosely round it. The operator draws the plate *a* with the left hand, and holding it stationary with the right, pulls the lever *f*, connected with the lever *c* above, and thus evenly cuts the entire brim.

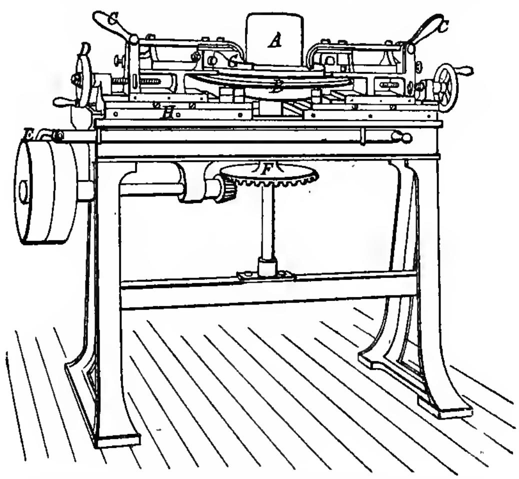
If the hats are rounded for plain shapes, they are at once sent to be trimmed. Those intended to be shaped and bound by hand go to the shaping-room for roll curls. The shaper cuts a piece of swans'-down in a half circle to fit half the hat-brim, and puts this over the brim, wetting it with a sponge, ironing round the outer edge, and curling it with a tool similar to H (Fig. 827). With a chisel or small plane, he shears the edge, to produce a smart appearance. When a dozen of the assorted sizes are complete, they are forwarded for trimming.

The "flat" or "Anglesea" curl is the next in importance, and is the most popular curl used in hard felt hats. It can be pulled up as in the last process by a hand tool, and ironed flat on the outer edge to a sharp angle, the securing of which should be the first object, whether by hand or by machine; if the operation is badly performed, and a thick edge is left, that which should be effective and light in appearance looks clumsy, and more like the former curl spoiled. The shaper conducting this operation by hand pares the curl to $\frac{1}{2}$–$\frac{5}{8}$ in. on the centre of the sides, running it to $\frac{1}{8}$ in. in front, with a clean even sweep of a chisel or plane. This finishes the curl, and the hat is ready for the trimmer. Hand curling is used mostly for very fine work at present, and for silk gossamer-body hats. But where price and quality are considerations, the following processes can be used without skilled labour, and will give fair results, besides saving at least five men's labour in pressing the curls. The press shown in Fig. 822, and described under the head of "pressing," p. 1115, is worked as previously explained, only instead of a dish, D is a mould, constructed in the form of a curl. The hat must have the shellac or proof softened, as by a hot iron, which can be done in the brim-heating apparatus, Fig. 824. The brim in A is heated; the

824.



825.



upper ring B is brought down upon it, the brim is heated until soft, and is then placed upon the mould A in the press (Fig. 822). Applying strong pressure, the curl is moulded into shape to produce a sharp edge. A press of similar construction is now in use to produce a feather-edge, without ironing; it works very satisfactorily for medium and common goods, but after such pressing, the curls must be raised by a thin wooden or metallic plough to the angle desired. Cutting the curl to size, the hats are ready for the trimmer.

A very elaborate machine, working by hydraulic pressure, and following the lines pursued by hand labour with the hot iron, is shown in Fig. 825. The driving-pulley E gives motion to the upright spindle F. Firmly fixed above the top step, runs a face-plate B, dished out to receive a sunken ring, having the exact form of the hard hat whose brim is to receive an Anglesea or flat curl. A boy can readily be instructed to attend to the machine. The rings are made to suit each size of hat, and may be adjusted in succession to the same face-plate. On the extremity of the spindle F, is secured the expanding block A to fit any size of hat. By drawing back the handle D along the compound slide H, the hat is free to rest upon the sunken ring. Having cut the brim to an approximate size, the two slides attached to the lever C are moved forward to the edge of the felt that is curled over into the sunken ring, for G is so constructed as to double the felt over, and being heated by gas, effectively irons down the whole of the curl. Pressure upon the hot iron is regulated at C. D being used to follow up the curl until completely sunk into the mould or sunken ring, A revolves, turning the hat with it, while G remains stationary. The shape of the hat being oval, presented a difficulty in attempting to iron it down by a circular motion, but this was overcome by a cam, enabling the iron G to follow the exact course of the oval, by means of the compound slide. The machine is complicated, and is expensive to work so far as quantity is concerned. The rings are required to be of all widths and sizes, and the apparatus is suited only to the requirements of a large manufacturer. The small machine illustrated at D (Fig. 827) is one of the most useful heaters for curling plain shapes. Three of these form a set, the circles of each being so designed as to take in several sizes of hat. Under the steam-chamber *a*, is placed a strip of felt, and the same on steam-chest *b*, to prevent the binding of the hats being scorched. Each chamber has an indeepndent steam connection, which requires to be provided with a steam-trap, to prevent any accumulation of condensed water. It is further advisable to have the connecting pipes of such length and construction as will allow of an expansion of a couple of inches. The half of the hat-brim to be curled is put between the lips, as it were, of these two chambers, so far as to cover just the width to be heated. A foot-lever is better than the hand-lever *d*. The lips are pinched close, and the hat when hot is taken out and curled. Very much time is saved by this process, as one hat can be heated whilst another is in work, at the same time doing away with all ironing, and making it easy for juvenile labour. The best way of using the machine, is to make the working bench level with the top side of the steam-chest *b*; by this means, the hat, resting flat upon the bench, can be moved directly into the aperture.

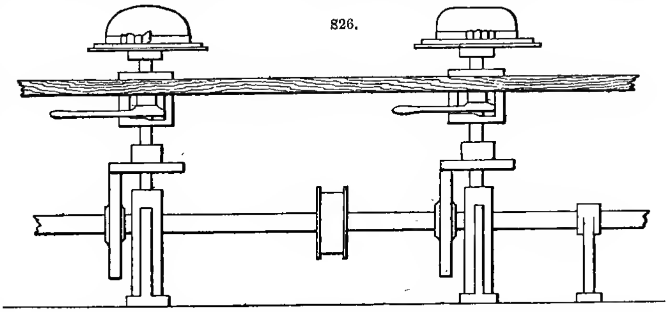
The curling finished, the hats are ready for the shaper. As the hats require trimming, it will be convenient first to follow that process, reverting to this department when finishing the shaping of the brim. In large manufactories, a considerable number of females are employed to trim the goods, as both hard and soft children's and ladies' hats demand a delicacy and lightness of handling only to be obtained by female labour. A commodious well-lit room is requisite for the fineness of the work. The hats being assorted in regular sizes, the trimmer is supplied with the leathers, linings, bands, and bindings, with paper or underlining, as the case may be. These she places upon the hat, lashing in the leathers, being specially careful not to apply too thick a paste around the tops of hard hats, for this has a tendency to make the crown give way in shape, destroying all the previous work, and rendering the hat almost valueless. The markings of the press dishes are very useful to the trimmer, enabling her to determine the exact centre of the hat. The whipping-in of the leathers evenly in the stitches adds much to the character of the work. In measuring out the bands and bindings, a person of great steadiness and firmness is required, so that all odd scraps of silk, &c., are used up, and no more than the exact measure given out, otherwise what has been calculated upon as a profit may be more than lost in this department. Tickets or size labels are gummed on to each hat. Those requiring bindings, such as plain shapes or soft hats, can be bound by Thomas's machine, or fancy-stitched on the band and binding. The most approved method is to drive all the sewing-machines by steam, for they are then more evenly worked than by treadle.

Soft and half-stiffened hats are completed in this department, except brushing and veluring. Hard hats are returned to the shaping-room.

While the operation of curling the hard hats dealt only with the outer edge of the brim, the final one of shaping alters the whole surface. Great experience and refinement of taste can alone ensure satisfactory results. A good light, to enable the shaper to place his work against it, so as to make the lines strike sharp and clear to the eye, is an essential. He places 3 or 4 hats on a steam-chest, heated to soften the shellac of the proof once more; when sufficiently soft, the hat is pulled a little at back and front, and by resting the crown on the bench, the workman uses his thumbs to break the band of the hat all round the leather. Pulling in the curl from the shoulder on the extreme edge, and following the curl up to the body of the hat, prevents any further contraction taking place. Should the work be scamped in this respect, the hat is almost certain to lose its shape, and look very slovenly indeed. With a flat dummy, the back and front of the brim are worked even and straight; a plough is used for the upper side, to blend the curves on the sides when the hat will be finished.

Veluring.—The last process before packing is "veluring," after the hats have cooled. This is best conducted, as is also the packing, in a room free from dust. Good bench accommodation is provided, with a range of veluring-lathes (Fig. 826), of similar construction to the finishing-lathes, driven by engine power. The hats being fixed upon the lathe, the finisher applies a velvet pad; first brushing the dirt from the hat, then damping the velvet, and steaming it upon the gas-stove B (Fig. 827), he starts the lathe, pressing the velure upon the tip and sides of the hat, and afterwards applying a hot velure to give polish and an even surface. Under the brim, he proceeds in the same manner, and this completes the last stage of the manufacture of both soft and hard hats.

826.



In this department, are conducted the boxing and nesting of the hats, in order that no indentations may be made on them, for being placed one upon another and handled roughly is sure to cause damage. The sides of the brims need protection, otherwise the motion backwards and forwards would "fridge" the brims, and on reaching their destination, the hats would be found unfit for sale. The sizes should be marked plainly on each parcel or box, to correspond with the invoice, and a careful register should be kept of every particular of the hat, e. g. colour, brim, curve, band, binding, &c., to ensure exact compliance with orders.

Supplementary Remarks.—Having completed the description of each process as ordinarily conducted, it will be well to supplement it by a few very important hints, which may lead to beneficial and profitable results. For instance, the fulling-stock may be made the vehicle for dyeing or staining all fancy colours, as drabs, beavers, slates, mouse, tan, rosy drabs, and many others. Some makers partially dye, and then complete the staining in these stocks. A useful beaver stain is made of 1¼ lb. copperas and 1 pint iron liquor (pyrolignite of iron) diluted with boiling water, 4 oz. Hofmann's aniline blue, and 4 oz. indigo extract (free from vitriol, or this will turn it green), for 1 doz. hats. Another good beaver brown for the fulling-stocks, for 24 doz. 3-oz. bodies, is 1 lb. common graphite (blacklead), 3 lb. Venetian red, 1 gill indigo extract. A cream-colour for 24 doz. 3-oz. bodies, is 2 lb. red-lead, 2 lb. common terra castle, 2 gills indigo extract in liquor, 3 gills orchil. A fawn-colour for the same hats is 1½ lb. burnt sienna, ground fine, ¾ lb. burnt umber, ¼ gill orchil, ¼ gill indigo extract in liquor. Mouse-colour: 3½ lb. common graphite (blacklead), 2½ lb. best terra castle, 2½ gills indigo extract in liquor, 4 gills orchil, 8 oz. red-lead. An ordinary drab for soft hats: ¾ lb. common graphite, ¾ lb. best do., 3 gills orchil, 2 gills indigo extract; put the graphite into a pan, cover with water, and let down with sulphuric acid at 30° Tw. Light beaver: 2 lb. red-lead, 1 oz. indigo extract, 1 lb. common graphite, 2½ lb. terra castle. Rose: 2¾ lb. common graphite, 2 gills indigo extract in liquor, 5 gills orchil. Slate: 4 lb. common graphite, 4 gills indigo extract, 3½ gills orchil. Cinnamon: 3½ lb. red-lead, 2½ lb. best terra castle, 2½ oz. picric acid, ½ gill indigo extract, 3 pints orchil. The picric acid is first dissolved in hot water, and the other ingredients are added.

General Hints.—To give the best results in fine fur hats, all the hoods should be shaved on a lathe before proofing. Many of the best makers assert that this class of goods will retain better colours by being mordanted before placing in the logwood bath.

During the last two years, a demand has arisen for a class of goods for ladies' wear that had not been in demand for 30 years. Many of the old hands had died off, and only a few very far advanced in years could be found to teach the rising generation a process that had almost passed into oblivion in this country, viz. roughening or "napping." In this process, after the ordinary body has been proofed, a woollen or fur body will serve the purpose, a long nap of beaver, otter, nutria, or hare fur, finer than that of which the body is made, is selected; ½ oz. more or less of the uncarroted article is weighed out, being sufficient to cover the whole outside surface of the hat. Taking this with perhaps ⅛ oz. of cotton, the two are completely mixed, either by the "hurdle," or by any other suitable process. The two materials completely blended are laid out upon boards, as evenly as possible. The cotton is used merely to enable the workman to handle the fur, which otherwise would be too thinly spread, and so attenuated of itself, as to preclude its being lifted. This mixture is laid upon the body wet, at the side of the planking-battery. A little water is sprinkled over it, and it is beaten down with a brush. The hood is taken up carefully with this thin coating attached, is lapped up in a piece of woollen or coarse horse-hair cloth, and operated upon lightly, and nearly the same as when planking a body. The principal object to be attained is to get the fibres of the fine fur to penetrate the body of the coarser foundation, and take root, as it were, therein. Much experience and care are demanded of the workman at every motion of his hands, to make the points of each fibre of fur penetrate the body.

So soon as it obtains a secure entry, the fur constantly advances, until after repeated rolling, folding, dipping in hot water, tossing, and unfolding, it separates itself from the cotton. By this motion, the fur gradually obtains a firm lodgment in the solid felt body, leaving behind the cotton, with which it was mixed at the commencement, loose and valueless. The workman who has not had much experience in this class of work may continue the planking too long, until, in fact, the fur works quite through the body, and is lost. Note should be taken that, in every process of planking, the water, though hot, should never boil.

Figs. 827 and 828 show a number of the tools and appliances used in making both felt and silk hats; they are as follows:—A, box-iron for silk hatters; B, gas-stove for veluring both felt and silk hats; C, brim-heater for shaping curl; E, brass for curling brim; F, draw-board for proofing; G, another form of brass for curling; H I, hand-moulds for making fine curl to front of brim; J, dummy for laying the nap of silk hats, and securing roundness on the half-block; K, seaming-block for silk hats; L, hand-plane for paring or cutting the curls before binding; M, cutting-board; N, brim-iron; O, rounding-machine; P, rounding-gauge; R, brim-stretcher; S, brim-brush; T U, split stretching-blocks for silk hats; V, steel measure for soft felt hats; W, steel head-measure; X, wire card, chiefly for silk hats: Y, wet brush for felt finisher; Z, large proof-brush for silk hatter; A′, whalebone gauge for caps.

Silk Hats.—The manufacture of the "silk" or "Paris napped" hat was commenced in England about the year 1835, and became fairly developed by 1840. Being so superior in appearance to the old "beaver" both in style and finish, it soon won public favour, and became generally adopted. But however great an improvement it was upon its predecessor, its introduction was not an unmixed benefit. Although the wearer became possessed of a more graceful-looking hat than previously, the workmen were placed in the unfortunate position of having devoted seven years to acquiring a trade which they now saw was rapidly declining, and eventually doomed to become extinct. The processes of manufacture not being at all similar, the difficulty of merging the one trade into the other was insurmountable to the majority, and many spent the remainder of their lives in the poorhouse.

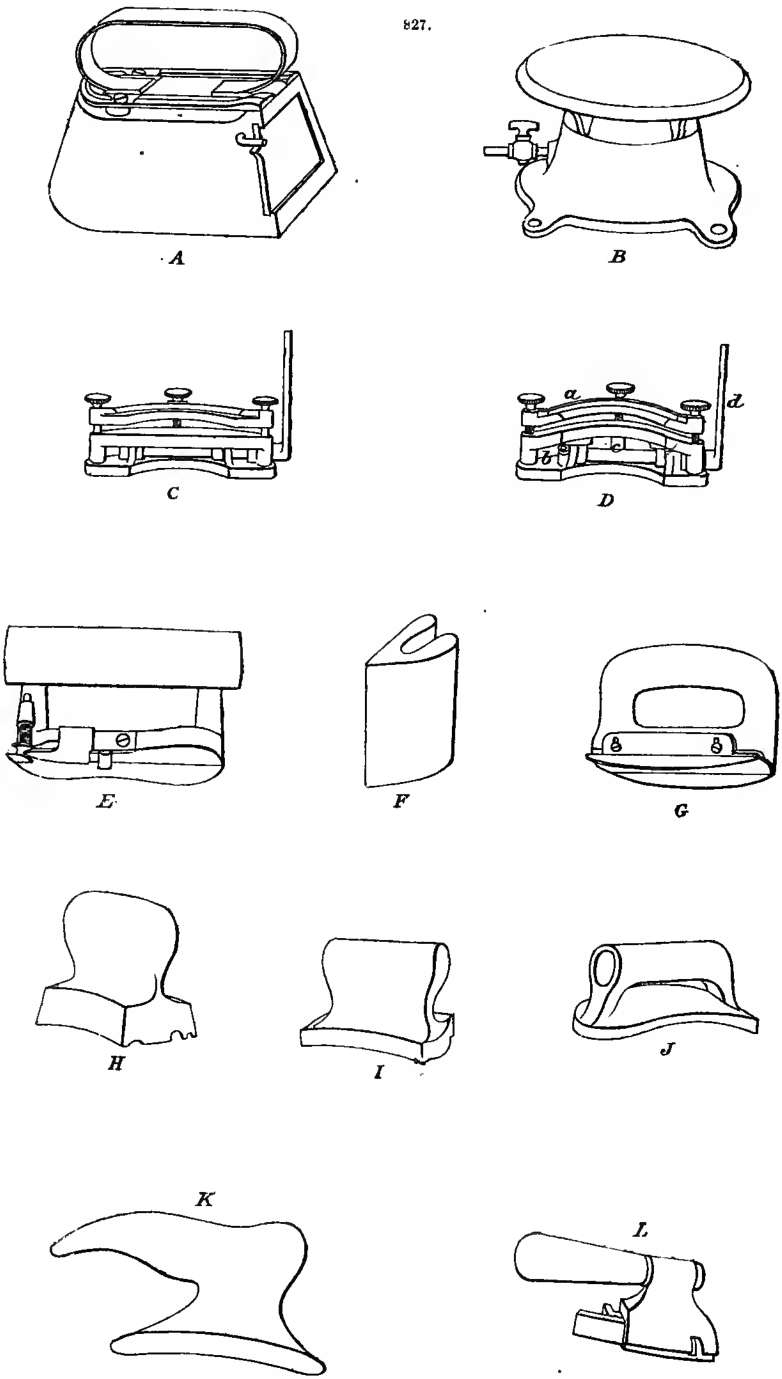
It is unnecessary to describe the various early methods employed in making silk hats. At first a felt body covered with a long-napped plush was used; then a body made of woven "willow grass," stiffened with paste. Soon the short-napped plush was introduced into this country from France, by some French workmen who had been brought over for the purpose of teaching their mode of manufacturing silk hats, and being found so much more suitable, it displaced the long naps, and has been continuously used in various qualities from that time. Shortly after the Paris silk plush was brought into use here, a new and improved body, made upon an entirely new principle, and from altogether different materials, was invented by a workman, and was at once adopted generally. It is the same as that universally in use, and known as the "gossamer body."

Silk hat making is divided into three branches for male labour: body-making, finishing, and shaping; and two minor branches in which women are employed: crown-making and trimming.

Body-making.—The first process, and by no means the least important, is the body-making, as unless the body is well made, it is impossible that durability can be ensured. A length of calico is dipped into the "cougle," or solution of shellac, and allowed to become thoroughly saturated. It is then taken out, and drawn through the half-closed hand to express superfluous cougle, and is next stretched upon a frame, shown at H, Fig. 829. Another length is served in the same manner, and then placed upon the frame over the first piece; the workman finally presses them tightly down upon the pegs of the frame, and with his open hand rubs each surface of the calico until both are in direct apposition, taking care that no blisters, or air bladders, are left upon any part of the surface. Only two substances or pieces are usually put upon the frame when required for the crown, but for brims it is necessary (when it is desired to have them prepared upon the frame) to take a stouter calico, and stretch it upon the frame first; then a still heavier make, a "twill," is put on second, followed by a third piece of the same substance as the first, precisely in the same manner as described for the crown frame. The frame is then put into the drying-room, and allowed to remain until the calico upon it becomes quite dry and stiffened.

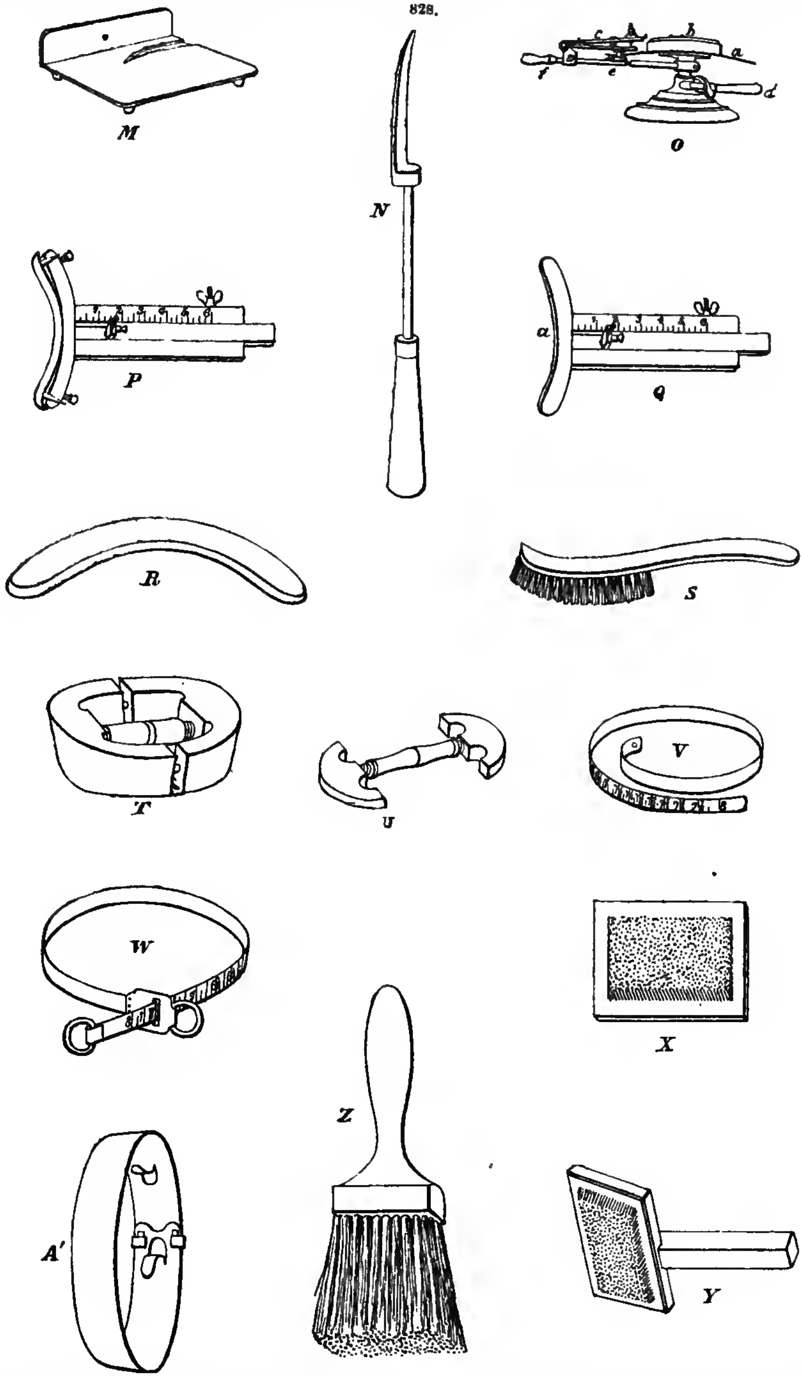
When the prepared calico is ready for use, it is taken off the frame. That intended for crowns is cut into strips of 8 in. wide, these being sufficient to make ½ doz. crowns and tips from one frame. A block of the required shape and size is then taken, and a strip of the prepared calico is cut to the required length, just to go round the block tightly, with ⅛ in. to spare to lap over and form the seam. The two ends are then just lapped, placed upon an iron bar, and next ironed with a hot iron, after which a "dummy" (a small flat iron), used cold, is pressed over it in order to fix the seam. It is lastly damped, and the block G, Fig. 829, is put into it, a piece at a time, first the back and front, then the side pieces, and the middle piece or "boss" last. The boss being forced in, the block assumes its shape, with the gossamer stretched tight around it. The seam being brought about ½ in. to the back of the gossamer, is left above the tip of the block; it is ironed flat, and is then ready for receiving the "tip," which is a piece cut off from that which forms the side crown. This is ironed to the rim, turned over from the side, and fixed thereto. A thin strip of calico stiffened with spirit varnish, and called a "robin," is next ironed on to the edge of the tip. A piece of unstiffened calico or muslin is then placed over, lapping over the crown and tip about $\frac{3}{4}$ in., the side

827.



crown is brushed over with cougle, and just lapped at the side, the tip being covered in the same manner, trimmed close to the block, and put into the drying-room to remain until thoroughly hardened. The block is made from well-seasoned wood, alder being mostly used. It consists of five pieces, and is turned in a lathe to the shape required. The crown being dry, it is made ready for receiving the brim. The block is taken out, removing the middle piece first, and bending the sides inwards; a thin piece of bone or hard wood, about 1½ in. wide, called a "slip-stick," is passed between the

828.



block and the crown, to free any part that may have adhered to the block. A shell made of felted wool is placed inside the crown, and the block is again inserted. The shell is used to prevent the crown adhering to the block while being ironed, which it wouldo therwise do, as the iron is used very hot. The crown is laid upon its side, upon the bench or plank, and a little powdered gum damar is sprinkled over the surface, to prevent the iron sticking to the crown. It is ironed until the surface is perfectly smooth and bright all round. The tip is then ironed in the same manner, and the crown is complete, requiring only the brim to form a perfect body.

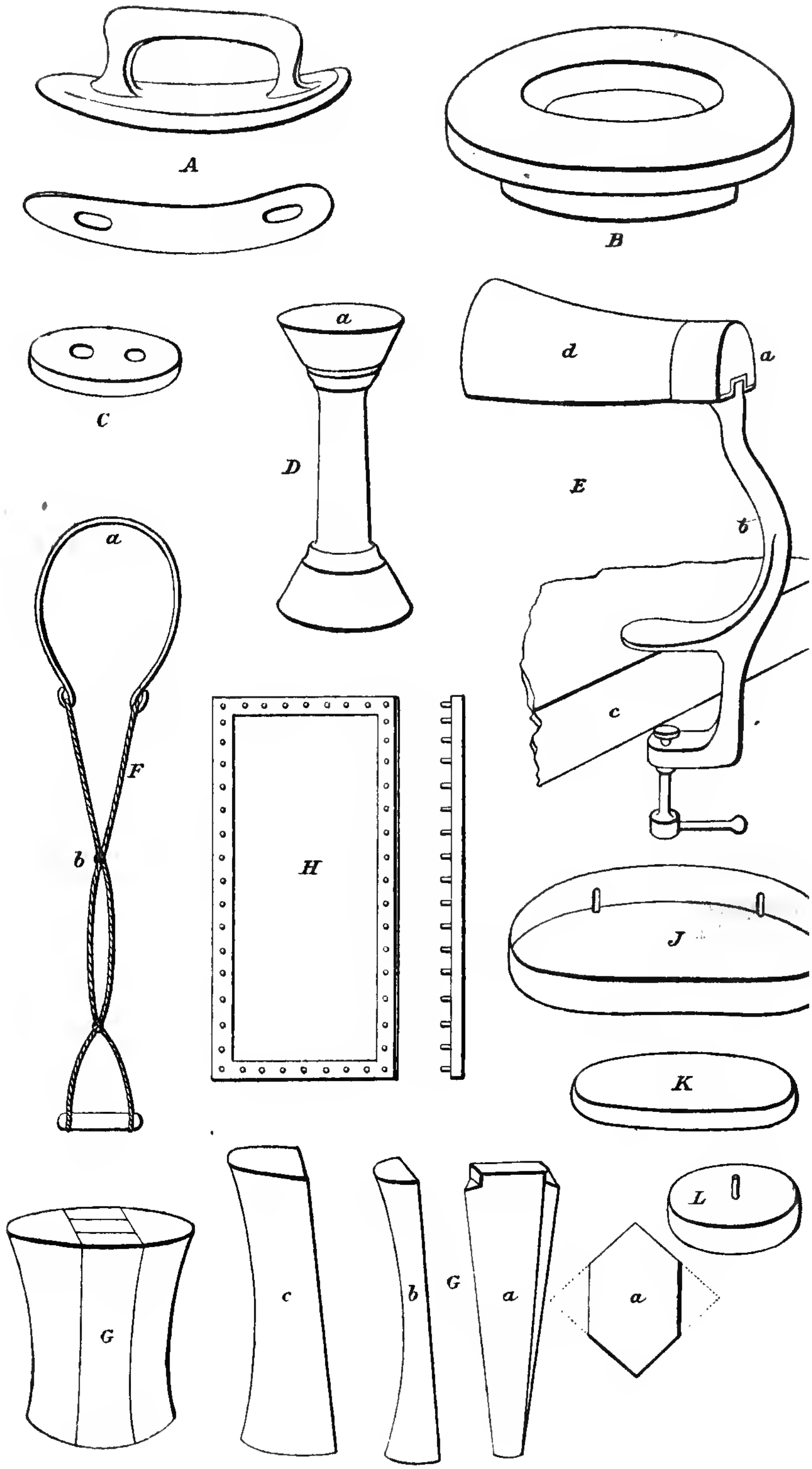
A light or heavy body is regulated by the number of substances of calico used, or by the weight of cloth. If very light is desired, all muslin for the crown is substituted for calico, and a lighter make of calico is used for the brim. For what are termed "zephyr" bodies, a stout muslin is used for the foundation, with a very light muslin for the cover; this makes an exceedingly light body, but of course is not so durable, being unable to stand hard wear.

The prepared calico taken from the brim-frame (56 in. by 36 in.) will make 1 doz. brims. One of these is now taken, and the block being placed in the centre, the size of the block is marked upon it. The middle is next cut out to within ½ in. of the mark. The square is then placed upon a piece of board covered with "swans'-down," and is well ironed until it has a smooth surface, and becomes perfectly pliable. A brim-frame J (Fig. 829) is now required. It is of an oval form, arched, and sunk about 3 in. in the centre, but the depth can be altered by inserting thin pieces of wood, called "risers," C (Fig. 829). The block is placed in the centre of the frame, and adjusted to the required dimensions. The softened brim is pulled over the tip of the block, and brought down to the frame, and pressed closely to the side of the crown by the iron dummy; this leaves about ⅜ in. of the brim upon the side, which is termed the band. Some thick spirit varnish has been previously brushed upon the crown, round the band, so that when the band is ironed it shall become perfectly secure. The crown being placed upon the side with the brim-frame, kept in position by being pressed against the chest of the workman, the band is well ironed, and afterwards the upper edge is pared, and a robin is ironed over it, and well dummied. The brim is now firmly secured, and only requires ironing upon the underside, to do which the block is taken out, and the brim is placed upon an iron plate let into the plank, and hollowed out so as to allow the band of the hat to be brought up close, in order to obtain a sharp-edged band. The body being now complete, it is put into the drying-room, where it is allowed to remain for several hours. Having been examined and passed as properly made, it is ready to be placed in the hands of the finisher, who covers it with silk.

Finishing.—The silk plush is made into a crown, that is a side and tip, and sewn around the top edge or square of the tip, care being taken in sewing to turn the nap through with the needle, so that the stitches may not be seen when the crown is put on the body. The finisher first prepares for the side seam, by putting a small quantity of cougle on the back of the plush just where it is desired to cut the seam. The nap on the part that is to be last laid is carded back the reverse way. This is done by first damping the part with a sponge and water, and then taking a wire card and carefully drawing the nap back for about 1 in. The iron is next passed over it in order to fix the nap down, and then a straight clean cut is made with scissors. The block is placed inside the body, and thus on a spinner L (Fig. 829), a small circular block of wood with a peg in the centre to enable the block to be easily turned round. The crown is now pulled over the body with the nap outwards, and the tip being perfectly adjusted so that the seam shall come close to the edge, the silk tip is damped all over, and ironed, the body having been previously varnished on the outside with spirit varnish. It will then be adherent to the body. The nap is now carded, so as to take a circular form, narrowing from the outside of the tip to the centre. The side seam is the next consideration. This is made on the left side of the body. The hat being placed on its side, the right is the first to be stuck down diagonally from the tip to the brim. The second or left seam requires the greatest care, as it must be brought close to the edge of the first, without in the least degree lapping over it. This is done about an inch at a time, the edge of the iron being used. When completed, the nap is again carded back, over the edges of the seam, and wetted and ironed. The remainder of the crown has now to be stuck. It must be pulled down to the band, so as to fit the body exactly without creases. It is then ironed over, and well damped, and the nap is brushed and carded perfectly straight, and again ironed with a good hot iron. The nap is well brushed after this, velured with velvet; and again ironed dry. This is to restore the brilliancy of the silk. The silk on the top side of the brim is put on the same way as the crown, with the exception that it is stuck all around the outer edge of the brim with the iron, and the remaining portion is pulled into the band with a stirrup F (Fig. 829), made of copper wire and stout cord or leather. Without the stirrup, it would not be possible to get the silk into the band without creases. The wire is placed over the crown, and the silk is gathered up by it. The foot being placed in the lower loop, it is pulled tight. The nap is brushed, carded, and ironed as before described. It only remains to put on the underside of brim, which is now almost always of merino. Formerly silk plush, corded silk, and satin were commonly used; but merino remains the most approved material for this purpose. It is put on in one piece, a damp cloth is placed over it, and then ironed, the centre being cut out, leaving about ¾ in. to be turned down on the inside of the band of the hat. Some thick spirit varnish is used to fasten it down.

SILK HATS.

829.



The hat is now ready for the last process at the hands of the finisher, viz. "half-blocking." A half-block E (Fig. 829) is selected to the shape of the hat, and being fitted to the arm, is screwed upon the plank. The hat is then placed upon it, the block having been previously removed, and ironed without wetting the silk. After the iron, the dummy is passed over the part just ironed, until the body is thoroughly rounded to the half-block, and assumes its proper shape. A velure or polisher made of swans'-down is damped, and the iron placed upon it, to make it very hot. It is then passed over the side crown, which gives great brilliancy to the silk. The tip being ironed on the tip-block D (Fig. 829), and polished in the same manner, the hat is put into paper, the brim is brushed, ironed, and polished on the top side, and the hat is complete so far as the finisher is concerned.

There are two methods of preparing the material for brims: the one already described, termed "water-brims"; and the other "pounced brims." The latter are preferred by some makers, as being more easily curled by the shaper, and with less liability of the substances separating from each other during that process; but a large experience of the use of water-brims has demonstrated their superiority in wear, as they retain their firmness much better than the pounced brims, and can be produced thinner and more "tinny," with less weight, which is a great consideration.

The pounced brim is made in the following manner. A piece of "swans'-down," i. e. a coarse calico, with a nap raised on one side only, is cut to the required size, 13 in. by 12 in., for the ordinary width of brim; the centre is cut out, and it is then placed upon a square board, and some ground shellac is sprinkled evenly over the swans'-down, from a tin box, the lid of which is perforated with small holes. A very hot iron is then passed over the shellac, which melts it and causes it to be absorbed by the swans'-down, thereby stiffening the latter. Another piece of swans'-down is then laid upon that already treated, and served in precisely the same manner, repeating the process until ½ doz. or more pieces have been ironed together. As soon as cold, which is in a few minutes, the pieces are pulled apart, and some cougle is rubbed over each side, after which a piece of plain calico is brushed on, with more cougle, on each side of the pounced swans'-down, and hung up to dry, when another substance of calico is brushed on one or both sides, according to the weight of brim required. When dry, it is ironed well on both sides, and in the same manner as described in the water-brims, the difference being merely in the mode of preparation.

The brim of the body is cut by a rounding-machine, of the same kind as is used for felt hats, to the required width and form, prior to being finished.

There is another mode of finishing which is very similar to that already described, but the block is dispensed with, and the tip-block and half-block are substituted in lieu thereof. There is a little time and trouble saved; but on the whole, it is scarcely so satisfactory a mode, as that of finishing entirely on the block.

Shaping.—This branch has only to do with the brim, viz. its curling and setting. In this, taste and skill are required. Much depends upon the shaper: if he is a good and skilful workman, the style and smartness of the hat are greatly enhanced. The hat, after leaving the finisher, is examined, and if perfect, is passed to the shaper, who gives to it the shape required in the brim, which may be an Anglesea curl, a rolled curl, or a plain-edged curl. If an Anglesea, the hat is placed upon the plank, with the brim downwards, and the iron is passed over the outer edge of the brim on the bare silk, without being wetted, until the brim is made quite soft. The edge is then taken with the thumb and forefinger of the left hand, and pulled up from right to left for about ½ in., lessening the width towards the front and back; it is next pressed over with the foot-dummy until the part turned over lies flat on the brim. The other side is then curled in the same way, and the front and back are just slightly curled on the edge, gradually widening to the side. The curl at the side is then ironed again, slightly raised, made quite free from folds or creases, and pared on the ragged or inner edge. It is now ready for the trimmer. When trimmed, it is returned to the shaper to be completed. He again irons the curl, but must now use a piece of damped swans'-down over the curl to prevent the silk binding from becoming glazed by the iron. The curl is then finally adjusted and raised as required. The hat is now placed upon a brim-warmer, which frequently forms the top of the oven in the shaper's shop. It has an arched top, and it is heated by hot water or steam. In a few minutes, the brim will be sufficiently warmed to render it soft and pliable. The hat is placed on the plank on its tip, with the brim upwards, and is then set, i. e. it is pressed with one hand on each side until it is well rounded, with the front and back dipping down. The brim is now ironed with the damp swans'-down over it, and made perfectly level, and free from indentations or irregularities. A silk band being put upon it to match the binding, it is completed.

The rolled curl only differs from the Anglesea in being round instead of flat, a round pad being used in curling. A plain curl merely has the side edges curled up ⅛ in. at the sides, and is bound with a narrow galloon binding.

Crown-sewing.—The silk plush being marked out to the size required, the crown-maker places the plush upon the tip nap next the body, and cuts it exactly to the size, so as just to cover the edge or square. About ⅛ in. is now turned over, and the sides are taken with about the same amount turned. The sewing is commenced about the middle of one side of the tip, and continued round to the place where it first started, leaving the two ends of the side unsewn, the finisher making the joint there upon the body, as previously explained. The crown must be sewn very neatly and closely upon the back of the plush, the nap being turned evenly through the seam with the needle, otherwise the stitches and seam would be seen. The hat is now trimmed very closely with scissors and the topside of the brim is joined in the same manner, the seam being diagonally across it.

Trimming.—The binding is put on, and the inside lining and leather are put in by the trimmer, requiring neat and careful sewing, the puffed silk lining especially needing care and nicety in drumming it.

Fig. 829 shows some of the tools and appliances employed by silk hatters, in addition to those already illustrated in Figs. 827, 828. They are as follows:—A, shapers' curling-dummy; B, wooden sunken frame, used by body-makers; the surface is covered with zinc; C, wooden "riser" for adjusting the height of the crown, one or more being placed inside the frame; D, tip-block, with felt cover *a*; E: *a*, half-block; *b*, half-block arm; *c*, plank; *d*, felt cover to half-block; F, stirrup: *a*, copper wire; *b*, cord; G, block: *a*, middle piece; *b*, side pieces; *c*, front and back pieces; H, crown-frame, 72 in. × 24 in., with side section showing pegs; the brim-frame is similar, but 56 in. × 36 in.; J, finishers' and shapers' brim-frame; K, how placed on the pegs of J, used by the finisher when putting the silk on the brim; L, spinner.

The various cloths used for hatters' purposes must be free from dressing, and of a porous character, so as to readily admit the cougle. For the crowns: a light Indian shirting, 24 in. wide, for framing; and a light jaconet, 32 in. wide. The side is covered twice, and the tip once for an ordinary hat. For the brims: a stout calico 36 in. wide, and a twill of the same width, two lengths of each being put upon the frame. No covering is required for brims, unless unusual strength is desired. Robbins are of muslin, 32 in. wide. Plushes are of various qualities, the shortness, thickness, and fineness of the nap determining its value. The back is of cotton, and the nap of silk. Nearly the whole of the silk plush used comes from France, although a small quantity is imported from Metz. The plush is 32 in. wide. The tips are cut on the straight; the sides and brims on the "bias." Shellac: the "A C garnet" and "bright button" are mostly used. "Cougle": 28 lb. shellac, 20 oz. ammonia, and 28 qt. water; boil the water, then add the ammonia, and as quickly as possible the shellac, for the ammonia soon escapes; when nearly dissolved, add a few oz. more ammonia, and a little water, letting it down with cold water to a thick consistency; it can be tested by rubbing between the fingers the same as hard felt proof; it is not gauged, but is reduced to the thickness of a thin flour paste. Spirit proof is made as in the case of hard hats. Shellac is let down cold in methylated spirits to the consistency of a thin varnish, for application as a coating to the body after drying, to stick the silk covering and brim, as well as the robins, and to strengthen the band and tip of the hat.

Exports.—The annual value of the hats exported from the United Kingdom amounts to a sum varying between 1 and 1¼ million pounds sterling. The home consumption is represented by a very much higher figure.

(See Fur; Hair; Silk Manufactures; Wool; Woollen Manufactures.) W. M.

HONEY (Fr., *Miel*; Ger., *Honig*).

Honey is a substance possessing a pleasant saccharine taste, produced from the nectar of flowers by the aid of certain insects, of which the bee is the most important and familiar. The saccharine matter is obtained from flowers in infinitesimal proportions, about 2½ million flowers being required to contribute 1 lb. of honey. The nectar of flowers contains cane-sugar or saccharose ($C_{12}H_{22}O_{11}$), which is converted, during or after its retention by the insect, into "inverted sugar," or a compound of dextro-glucose (dextrose) and læva-glucose (lævulose), both of which are represented by the formula $C_{12}H_{24}O_{12}$ or $C_6H_{12}O_6$ (see Sugar). The presence of cane-sugar in honey is as stoutly denied by some chemists as it is asserted by others. This disagreement may perhaps result from the examination of samples of different ages. Dr. J. Campbell Brown gives the following analyses of genuine bee-honey :—

	English.	Welsh.	Normandy.	German.	Greek.	Lisbon.	Jamaica.	California.	Mexican.
Water expelled at 100° (212° F.)	19·1	16·4	15·5	19·11	19·8	18·8	19·46	17·9	18·47
Water expelled at much higher temp., and loss	7·6	6·56	4·95	11·0	7·8	6·66	7·58	8·13	10·03
Lævulose	33·6	37·2	36·88	33·14	40·0	37·26	33·19	37·85	35·96
Dextrose	36·55	39·7	42·5	36·58	32·2	34·94	35·21	36·01	35·47
Cane-sugar (?)	doubtful	none	none	none	none	1·2	2·2	none	doubtful
Wax, pollen, and insoluble matter	good. trace	trace	slight trace	trace	0·05	1·0 nearly	2·1	good trace	trace
Mineral matter	0·15	0·14	0·17	0·17	0·15	0·14	0·26	0·11	0·07

The honey of the honey-wasp of Tropical America (*Polybia apicipennis*) yields large crystals of cane-sugar; that of the honey-ant of Mexico (*Myrmecocystus mexicanus*) is nearly a pure solution of uncrystallizable sugar ($C_6H_{14}O_7$); while the subterranean *tazma* honey of Ethiopia contains 32 per cent. of mixed fermentable sugars, and 28 per cent. of dextrose, with no trace of cane-sugar.

Wild honey is collected by primitive peoples in almost all climes which favour the growth of the necessary flowers. The *tazma* honey is deposited without wax by an insect resembling a large mosquito, in subterranean cavities; it is sought for by the natives of Ethiopia, and used by them to cure throat-diseases. The honey-making ant of Texas and New Mexico is very abundant in the neighbourhood of Santa Fé. The Mexicans esteem this honey very highly, and use it not only as food, but as a medicinal agent. Very little has been done in the way of domesticating or cultivating the two honey-producing insects just alluded to, and the same may be said of the honey-wasp of the American tropics.

The familiar honey-bee is of two species, *Apis mellifica* and *A. ligustica*. The former, which is the most widely known and the most highly prized as a honey-maker, is said to be a native of Asia, whence it has spread over all Europe and a great portion of N. America, and has been introduced with signal success into our S. African and Australian colonies, and many of the islands in the S. Pacific.

Apiculture has advanced considerably in France of late years, and the number of cultivated swarms of bees in that country is now placed at 2–2½ millions. The industry is becoming more general, and owners of more than 400–500 colonies are rare. The production of honey and wax is now valued at 22–23 million francs annually, while the yield of honey from each swarm has grown from 15–16 kilo. to an average of 20–25 kilo. The introduction of the Ligurian bee is receiving much attention. Of the 2,073,703 swarms officially returned in France at the end of 1873, there were 96,038 in Ille-et-Vilaine, 63,207 in Finistère, 60,000 in Côtes-du-Nord, and over 40,000 in Ardèche, Loire-Inférieure, Manche, Morbihan, and Saône-et-Loire. The products of Gâtinais and Brittany are most renowned. The total yield of honey in France in 1873 was 93,112 metric quintals (of 1·96 cwt.). The export of honey from Honfleur, Trouville, &c., was 11 tons in 1876, and 10 tons in 1877. In some districts of Switzerland, bee-keeping is conducted with great energy and success, and instructions are widely circulated by paid lecturers every year. The local consumption of honey is too great to leave any for export. The German government goes so far as to compel all schoolmasters to pass an examination in apiculture, besides fostering the industry in many other ways. Germany (including Hanover and Hesse Cassel), in 1873, had a total of 1,453,764 stocks; Bavaria, 338,897. Somewhat behind are Austria and Hungary in this respect, yet the exports of honey from Vienna were 5163 metric centners (of 110¼ lb.) in 1877, 301,695 in 1878, and 321,849 in 1879; and from Fiume (including wax), 594 cwt. in 1877, and 1224 cwt. in 1878. In ordinary seasons, Servia produces about 5000*l.* worth of honey for export, besides the large quantity consumed locally. The peasants of Poland, Russia, and Siberia, are most industrious apiarians. A number of systems are in vogue in different parts of the country; at Plock, in Ostrolenka, and in the woody part of Lithuania called Polesie, bees are reared in excavated tree-trunks in the forests. The famous "Kovno" or "lipiec" honey acquires its flavour from the flowers of the linden-tree, so abundant in the Lithuanian woods. In this province (Kovno), the Tchmude tribe is almost exclusively occupied with bee-keeping. The industry flourishes also in the Altai mountains, and is followed by the Meretinzes and Grusinians in the Caucasus. The Russian province of Pultowa has about 500,000 stocks, and Ekaterinoslov, 400,000. The annual honey production of European Russia is placed at 600,000–700,000 lb. Italy produces large quantities of honey, though the peasants are very backward in apiculture. The total yield in 1868 was as follows:—Piedmont and Liguria, 380,000 kilo.; Lombardy, 179,880; Venetia, 174,160; Emilia, Umbria and the Marches, 189,840; other provinces, 600,000. The best are from Bormio, in Lombardy, from Empoli, in Tuscany, and from Otranto. Immense quantities of honey were formerly produced in Corsica; much is still collected there, but, except the small proportion obtained in early spring, it acquires such a bitter flavour, from the arbutus-blossoms which the bees frequent, as to be scarcely edible. Grecian honey has been celebrated from the earliest times, but apiculture is quite neglected by the modern Greeks. Syra, in 1877, exported 167*l.* worth of honey to France, and 160*l.* to the Danubian Principalities; and in 1878, 172*l.* to Turkey, 106*l.* to Great Britain, 82*l.* to Egypt, 55*l.* to Austria, and 7*l.* to Italy. In Asia Minor, very large quantities of honey are produced, chiefly for local consumption; the port of Dedeagatch shipped 80 barrels, value 200*l.*, in 1879. The natives of many parts of India are most industrious bee-keepers. But the New World bids fair to eclipse all competitors in the science of bee-rearing and the production of honey. In the United States, honey-raising is a distinct industry, and men are found who own 2000–12,000 swarms, which they farm out to owners of fruit-gardens during the blossoming season. The orangeries and other orchards of Florida, and the gardens of California, offer the best inducements, but the culture is by no means confined to those states. Florida, in 1878, produced over 170,000 lb. of honey; and one bee-farm in San Diego Co., California, afforded 150,000 lb. of honey in 1874. Every scientific contrivance has been adopted, and some bee-farmers despatch floating bee-houses along suitable rivers, to take advantage of the progression of the seasons, and supply the bees with a succession of flowers. It is even proposed to send the swarms to the W. Indies during the winter. Already very large quantities of honey are produced in the W. Indies, but it is chiefly in the foreign islands, and our colonists there have not shown much zeal in adopting this most remunerative culture, despite the almost unsurpassed conditions which it presents. San Domingo, in 1878, exported 38,770 gal. of honey to the United States; and in 1879, 506,640 gal. to the United States, and 2700 gal. to France. Chili produces 5000*l*. worth of honey and wax yearly, which is mostly exported.

The production of honey in the United Kingdom is quite trifling, and nowhere is bee-keeping so little understood, and so little practised as an industry, though the conditions for its success are almost everywhere present, and the profits very large. On the other hand, it must not be supposed that the present high prices of honey would be maintained in the face of a greatly increased production, such as would result from anything like universal bee-farming. Of course, if honey could be produced at a price to compete with fruit preserves, its consumption would immensely increase. But this is very doubtful, considering the long period during which the bees would need feeding, and the uncertainty of our summers. In our tropical colonies, there is much wider scope and better prospect for the industry. Everywhere the indirect benefit conferred by bees in fertilizing the flowers of various crops is of great importance.

Omitting all questions relating to the natural history of the bee, which will be found discussed at length in the works cited at the end of this article, the following remarks relate to the construction of hives, and the management of apiaries, with a view to the most economic production of honey. The swarm is first hived in an ordinary straw "skep"; in the evening, the settled bees are suddenly shaken down into one of the modern improved hives now to be described.

The "Woodbury" hive is the first English adaptation of the principles advocated by Dzierzon and Langstroth. It consists of a square wooden box, 14½ in. inside diameter, 9 in. deep, with a movable cover having a feeding-hole 2½ in. wide, closed when not in use. The floor-board is 18 in. square, with an entrance 4 in. long × ⅜ in. deep, with a step projecting 3–4 in. for the bees to alight upon. The interior space is equally apportioned to 10 frames, for supporting the combs. These frames are of thin lath, ⅞ in. wide; the top bars are 15¼ in. long × ⅜ in. thick, and the sides and bottom rails are $\frac{5}{16}$ in. thick. The space alternating with the bar is thus ⅝ in. A movable upper storey or "super," 3–5 in. high, is added as a honey-store; this is separated from the hive by replacing the cover or "crown-board" by a thin board or "adapter," having long slits $\frac{3}{16}$ in. wide near each end, for admitting the workers, while excluding the queen and drones. The whole is crowned by a wooden ridge-roof. A much improved modification of this is the "Cheshire" hive. The natural heat of the inmates is conserved by double walls with an air space between. Woodbury frames are retained, but rested upon zinc edges, to prevent the bees fixing them. The floor-board moves in grooves, and the entrance is provided with sliding-shutters. The old straw skep is very inferior; it should at all events have a round hole 2½ in. in diameter in the centre of the crown, to admit the bees to the super, and facilitate feeding them. Glass hives are admissible only for purposes of observation; one of the best forms is that known as the "Woodbury unicomb." The first essential condition in all hives is that they shall exclude the wet, and afford protection against changes of temperature. The next consideration is the existence of every facility for the construction of the combs and the rearing of the young bees, as well as the inspection and removal of the combs when required.

During bad weather immediately following the hiving of a swarm, the latter must be fed. A wide-mouthed bottle is filled with syrup, and closed by a double thickness of fine muslin, or by inversion over a perforated support, placed above the feeding-hole in the crown-board. In cold weather, this food is replaced by a sweet produced by boiling 1 lb. of loaf-sugar in ½ pint of water, and adding a little vinegar to prevent crystallization. Plentiful and judicious feeding is most necessary for successful bee-keeping. Abundance of water, fresh or stale, is equally essential.

The objects of the apiarian are threefold:—(1) the prosperity and multiplication of the colonies, (2) stimulation to increased production, and (3) the easy removal of the products without inconvenience to the bees. A rapid increase of stocks and a large production of honey are incompatible, and one of the two objects must be made subservient to the other by suitable management. The former is favoured by artificial swarming, i. e. by hastening the departure of the swarm. In the case of frame-hives, which are the only proper kind, this is effected in the following manner:—The frames are first removed, and the queen is sought for; when found, she is transported with the frame to the centre of a new hive, and is flanked on each side by a comb containing sealed brood. Both hives are then filled with fresh frames and empty combs, or even guide-combs; sufficient bees to form a large swarm are then shaken into, or at the entrance of, the new hive, where all the young ones will remain. This (the queen-) hive is then removed to a distance, and the old one is reinstated; into the latter, will come such of its former occupants as did not remove to the new hive. Feeding on syrup in early spring stimulates the queen to lay, and thus swarms may be thrown off early and rapidly. If a young fertile queen be supplied immediately after a swarming has taken place, the hive will soon be ready to repeat it.

When a large production of honey is aimed at, swarming must be controlled as far as possible. Success is generally secured by putting a super on the hive, before the bees have constructed queen-cells, and made other preparations. The combs are removed on the frames as fast as they are filled, and are then emptied and returned. This is much facilitated by the use of a simple apparatus termed a "honey-extractor," which is made in several forms, but all on one principle. The full combs, with their cells uncapped, are placed in a cylindrical metallic receiver, with their mouths abutting on walls of wire-netting attached to a framework. The latter is made to revolve, when the centrifugal force dislodges the honey, which falls into the receiver. The combs are thus made available for immediate re-use,—a double gain, as the collection of honey is rendered continuous, and the bees do not need to consume large quantities of honey for the formation of new combs. When it is desirable to economize the space of the supers for honey-gathering purposes, the bees may be induced to build comb there by introducing some clean white pieces, always taking care to warm the supers by padding or wrapping. At the end of the season, all honey may be removed, if the bees are fed regularly with syrup, which is much less valuable, but equally good food; otherwise, at least 15 lb. of sealed combs must be left for winter provision.

As to the profit of bee-keeping, it is only necessary to say that, beyond the first cost of a swarm and hive, the expenses are but trifling. Supposing a guinea be paid for a swarm, at the end of five years the net profit arising from the sale of the products should amount to 50–60*l.*, in addition to the possession of 5 new stocks. In America, one stock has given as much as 600 lb. of honey in one season, and 200–300 lb. is quite common. Chilian honey is sold in the London market at 30–70*s.* a cwt., and Jamaican at 35–60*s.* Our imports of honey in 1870 were valued at 28,121*l.*; since then, statistics have not been published, but the amount has doubtless increased.

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(See Sugar; Wax—Beeswax.)

HOPS (Fr., *Houblons*; Ger., *Hopfen*).

The term "hops" is given to the leafy, cone-like catkins, or imbricated heads ("strobili"), of the hop-plant (*Humulus Lupulus*), for the sake of which many varieties of it are cultivated.

Hop-growing requires a moderately warm climate. In this country, a south-east aspect is most suitable, with shelter from the westerly gales of autumn. The selection of soil will depend upon the kind of hop to be grown. The Golding will succeed best on dry friable soils, with gravelly or rocky subsoil, as in the hilly districts of E. and Mid-Kent. Mathon, Grapes, and White, prefer stronger soils, as the deep lands of the valley of the Teme, and the Weald. The good but delicate Cooper's White requires a good strong loam. The land must be thoroughly drained. Preference is given to old pasture; this is trenched two spits deep, the turf is placed downwards and the surface is harrowed and rolled. When planting in tilled land, the latter is ploughed 10 in. deep, and subsoil-ploughed as deep as possible. The land being prepared, the arrangement of the rows, and distance between the plants, are decided upon. The disposition may be angular or square. The rows are usually 7–8 ft. apart, with 2½–3 ft. between the plants. The holes are first staked out, to ensure regularity, and are then dug 2 ft. in diameter and 2 ft. deep, the top earth being placed on one side, and the bottom soil on the other. The good top earth is again filled into the hole, and rich manure is added. When the soil has settled, planting may commence. Bedded or yearling sets, 5–6 in. long, prepared from old stools, and with two joints or eyes, are the best; cuttings entail the loss of a year. One male to 100 females is usual. A hole 2 in. wide and 4–5 in. deep is cut in two sides of each hillock. If the plants are weak, these may be put into one hillock. The head of each root is brought as close as possible to the stick, and some good, fine soil is put round, and made firm by the foot. A 20-acre plantation may be apportioned as follows:—Cooper's White, 5 acres (or Cooper's 3, and Jones' 2); Mathon's 6; Golding's, 6–7; Grapes, 2–3. In this way, the crop may be gathered by degrees, as the different kinds mature, commencing with Cooper's or Jones', and finishing with the hardy Grapes; but the proportions should accord with the suitability of the land. If only one variety be grown, picking must either commence prematurely, or be protracted beyond proper limits. The crop should be secured in 3–4 weeks at the utmost.

In 2–3 weeks after planting, the bines begin to appear, and pitching the poles commences. The size of the poles may be 8 ft. for Jones', 10–12 ft. for Grapes, 12 ft. for Cooper's, 12–14 ft. for Mathon's, and 15 ft. for Golding's. Usually 4 poles are allowed to each hill at 7 ft. apart, and 2 bines to each pole; when 3 poles are used, the bines may be distributed in two 2's and a 3. The next step is tying; but before commencing this, the tier proceeds to eradicate all rank, hollow bines. When the hops are tied, the ground is worked both ways with the nidget or scuffle, followed by the harrow; the workings should be finished by the 1st–10th July. Potatoes and mangold are often planted between the rows, and cattle-cabbage between the hills; in this case, extra manuring is of course necessary. A better plan is to grow turnips, and feed off.

The hops are ready for pulling when they acquire a strong scent, and the catkins become firm and brown. This occurs in early seasons about the 1st–8th September; in late ones, 15th–20th. The bines are cut level with the ground, the poles are lowered, and the hops are picked off as rapidly as possible, for conveyance to the drying-kiln, such arrangements being made as will ensure their not having to wait 5–6 hours, or they may ferment and spoil. The drying is conducted in special kilns or "oasts," by means of a current of hot air being passed continuously through them. The process should occupy about 12 hours, at a temperature not exceeding 44°–46° (112°–115° F.). When the hops are dry, the fire is lowered, and they are allowed to remain till they become soft, when they are removed to the cooling-room, and will be fit for bagging next day. The latter operation is now generally performed by a machine.

The cost of cultivating 1 acre of hops is thus stated:—Yearly charge for poles, 5*l.*; ploughing down, 10*s.*; digging slips, or portion not ploughed, 5*s.*; cutting, picking up and burying roots, 4*s.*; spreading poles, 2*s.*; pitching or setting poles, 12*s.*; tying, 8*s.*; nidgeting or scuffling 4 times, 1*l.*; harrowing 4 times, 6*s.*; forking round hills, and hilling up, 5*s.*; stripping and piling poles, 8*s.*; resharpening broken poles, 3*s.*; ploughing up before winter, 10*s.*; manuring with 20 loads dung at 8*s.*, 8*l.*; summer manuring, 4*l.*; ladder tying, 2*s.*; total, 21*l.* 15*s.* By digging instead of ploughing, 15*s.* more will be added. The cost often rises as high as 35*l.* an acre for the whole culture and harvesting of the crop, and in some cases even to 60*l.* The returns are exceedingly unreliable, ranging from 1 to 13 cwt. an acre. A plantation should last at least 20 years, and some gardens have been in existence over 300 years.

The hop-plant is found wild, especially in thickets on the banks of streams, throughout Europe, from Spain, Sicily, and Greece, to Scandinavia, extending also to the Caucasus, the S. Caspian region, and through Central and S. Siberia, to the Altai Mountains. It has been introduced into India, N. America, Brazil, and the Australian Colonies. The cultivation in the United Kingdom was distributed in 1875 as follows:—Kent, 43,614 acres; Sussex, 11,360; Hereford, 5984; Hants, 3059; Worcester, 2468; Surrey, 2313; other districts, 373; total, 69,171. In Continental Europe, hops are most largely produced in Bavaria, Würtemberg, Belgium, and France. The estimated area occupied by them in 1876 was:—Germany, 94,775 acres (Bavaria, 52,000; Würtemberg, 12,500; Baden, 4000); Austria, 19,277; Belgium, 16,250; France, 10,000; the remainder of Europe, 1547. In 1877, Vienna exported 21,816 metric centners (of 110¼ lb.); in 1878, 15,529; in 1879, 28,772. Antwerp, in 1878, exported 629,352 kilo to England.

Laudable efforts have been made for some time past to establish hop-growing in Cashmere and in the Himálayas, and there is fair prospect of ultimate success. In the United States, the culture has a pretty wide distribution. The crop of 1874 was estimated as follows:—New York, 50,000 bales; Wisconsin, 22,000; California, 5000; Michigan, 5000; other states, 15,000; total, 97,000. The total estimate for 1879 was 110,000 bales; and for 1880, 120,000–125,000. In Canada, frosts interfere much with the crop. The cultivation started in the colony of San Leopoldo, in the Brazilian province of Rio Grande do Sul, promises well. In Tasmania, hop-growing is now a well-established and thriving industry; and Victoria, South Australia, and New Zealand are not far behind.

The scarcity of hops in unfavourable seasons, and their high price at all times, has led to their frequent adulteration and to many substitutes being proposed for them. Among the adulterants are found many plants possessing powerful and even poisonous properties, while others communicate only a strong bitter flavour. As substitutes, principally two plants have been suggested, and experimentally used:—(1) The fruit of the shrubby trefoil (*Ptelea trifoliata*), said, in both France and America, to give an amber ale possessing a flavour quite equal to that of Strasburg beer; and (2) the leaves of the bog-bean (*Menyanthes trifoliata*), gathered in spring, and dried in the shade, used in Germany. Neither possesses all the valuable properties of the hop.

Besides our own production of hops, we import largely; our imports in 1879 were:—From the United States, 108,306 cwt., 496,886*l.*; Belgium, 63,485 cwt., 262,372*l.*; Germany, 50,567 cwt., 237,618*l.*; Holland, 26,796 cwt., 162,518*l.*; France, 9234 cwt., 41,462*l.*; British N. America, 3813 cwt., 14,596*l.*; other countries, 564 cwt., 486*l.*; total, 262,765 cwt., 1,217,938*l.* The prices fluctuate exceedingly; the approximate relative values in the London market are:—Kent, 4*l.* 10*s.*–11*l.* a cwt.; Sussex, 4*l.* 10*s.*–10*l.* 10*s.*; Farnham, 6*l.*–11*l.* 15*s.*; Farnham country, 6*l.*–11*l.* 11*s.*; American, 8*l.*–11*l.*; Belgian, 4*l.*–5*l.*; old, all kinds, 1*l.*–3*l.* 10*s.*

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(See Beverages—Beer.)

HORN (Fr., *Corne*; Ger., *Horn*).

The term "horn" is generally applied to any hard body projecting from the head of an animal, terminating in a point, and serviceable as a weapon. Technically, horns consist of very different substances, and belong to two organic systems, as distinct from each other as either is from the teeth. The horns of deer consist of bone, and are processes of the frontal bone; those of the giraffe are independent bones or "epiphyses," covered by hairy skin; those of oxen, sheep, and antelopes are "apophyses" of the frontal bone, covered by "corium," and by a sheath of true horny material; only the horns of the rhinoceros are composed entirely of horny matter, which is disposed in longitudinal fibres, so that the horn seems rather to consist of coarse bristles compactly matted together in the form of an elongated sub-compressed cone. It is curious that the horns of wild animals are always more fully developed than in domesticated races, and that with all our improvements in the breeding of cattle, no advance has been made in the size or texture of the horns.

Horns are rendered eminently applicable to a number of purposes by reason of their toughness, elasticity, and flexibility, together with their property of softening under heat, and their capabilities of being welded and moulded into various forms under pressure. The immense horns of the African ox, or Cape buffalo, of the Java buffalo, and of the Arnee buffalo of India, are the most valuable. About one-fifth of our imports of these horns is used for making combs, and knife- and cutlass-handles, while a small portion is converted into shoe-lifts, scoops, cattle-drenches, drinking-cups, &c. The solid horn tips and the hoofs of cattle are made into buttons (see Buttons).

Horn Manufactures: Combs.—Horns which are to be manufactured are first thrown into water, by which slight putrefaction is caused, ammonia is liberated, and the horn begins to soften; the softening is then continued by immersion in an acid bath, for a period of about 2 weeks. When sufficiently soft, they are cleaned, and split into two parts by a circular saw. These slices are introduced between heated plates, and the whole is subjected to a pressure of several tons a sq. in. The plates may bear devices, or be of varying form, thus producing at once any desired effect. The horn may then be dyed black or brown by dipping it into a bath containing a weak solution of mercury or lead salts, and rubbing on hydrosulphate of ammonia; or it may be mordanted in an iron-bath, and dyed by logwood. Fancy markings are produced by immersing the horn in a bath of lead salt, and then in hydrochloric acid, thus forming white lines in the interstices of the horn.

The manufacture of combs is by far the most important application of horn. The laminatory character of the horn, its very diversely running grain, and the raising up of the fibres by the use of the various tools, render it very difficult to apply machinery in its conversion, and the large amount of hand-labour required helps to cause the proportionately high price of the manufactured article.

The softened horn is first split lengthwise in the direction of the grain. The split horn is then warmed in hot water, opened out flat, laid between cold iron plates, and pressed level. If the goods are to be subsequently stained, the slices are further placed between hot steel plates, and very strongly pressed, to reduce the thickness and destroy the superficial grain. The prepared slices are next stamped out by cutters, arranged to form as many combs as possible, of various sizes and shapes, so as to fully economize the material. The slices are again pressed and straightened, and ground, ready for cutting the teeth, which operation is performed by a "parting-engine," or die-stamping machine, in the case of coarse combs, and by circular saws in that of fine-toothed combs.

Commerce in Horns.—Vienna exported 22,604 metric centners (of 110¼ lb.) of horns in 1877, and 32,255 in 1878. Poti exported 17 *poods* (of 36 lb.) of buffalo-horns, and 155 *poods* of deer-horns, in 1877–8. Canton exported horns to the value of 17,248 *taels* in 1878. Newchang exported 1095 pairs of old deer-horns in 1877, and 1034 in 1878. Hankow exported 1935 *piculs* (of 133⅓ lb.) of cow-horns in 1878. Taiwan exported 47 cwt. of cow- and buffalo-horns in 1878. Kiungchow, exported 275½ *piculs* of horn in 1877, and 432 *piculs* in 1878. Shanghae exported, in 1878, 2854 *piculs* of cow- and buffalo-horns, 175 *piculs* of chamois-horns, 298 pairs of young deer-horns, and 48 *piculs* of old deer-horns. Algiers exported 1,274,019 kilo. of horns and hoofs in 1877, and 1,415,850 kilo. in 1878. Guatemala, in 1878, exported 368 quintals to the United States. Pernambuco, in 1877–8, exported 520 hundreds of horns to Great Britain, and 59 hundreds to Portugal. Santos, in 1879, exported 44,430 kilo. of ox-horns to Europe.

Our imports of horns in 1879 were as follows:—From Bengal and Burmah, 654 tons, value 21,001*l.*; Bombay and Scinde, 569 tons, 19,192*l.*; Australia, 485 tons, 14,102*l.*; United States, 451 tons, 6778*l.*; Madras, 373 tons, 15,172*l.*; Straits Settlements, 305 tons, 11,550*l.*; France, 270 tons, 10,285*l.*; Argentine Republic, 245 tons, 7049*l.*; British S. Africa, 223 tons, 11,365*l.*; Brazil, 178 tons, 6670*l.*; Uruguay, 137 tons, 5207*l.*; Ceylon, 96 tons, 5556*l.*; other countries, 654 tons, 17,882*l.*; total, 4640 tons, 151,809*l.* The approximate values are:—S. American ox, 35–80*s.* a 100; ditto cow, 15–35*s.*; Cape, 35–120*s.*; Australian, 6–65*s.*; Deer, E. Indian, 40–120*s.* a cwt.; Buffalo, E. Indian, 20–60*s.*; tips, E. Indian, &c., 18–40*s.*; ditto, N. American, 10–75*s.*

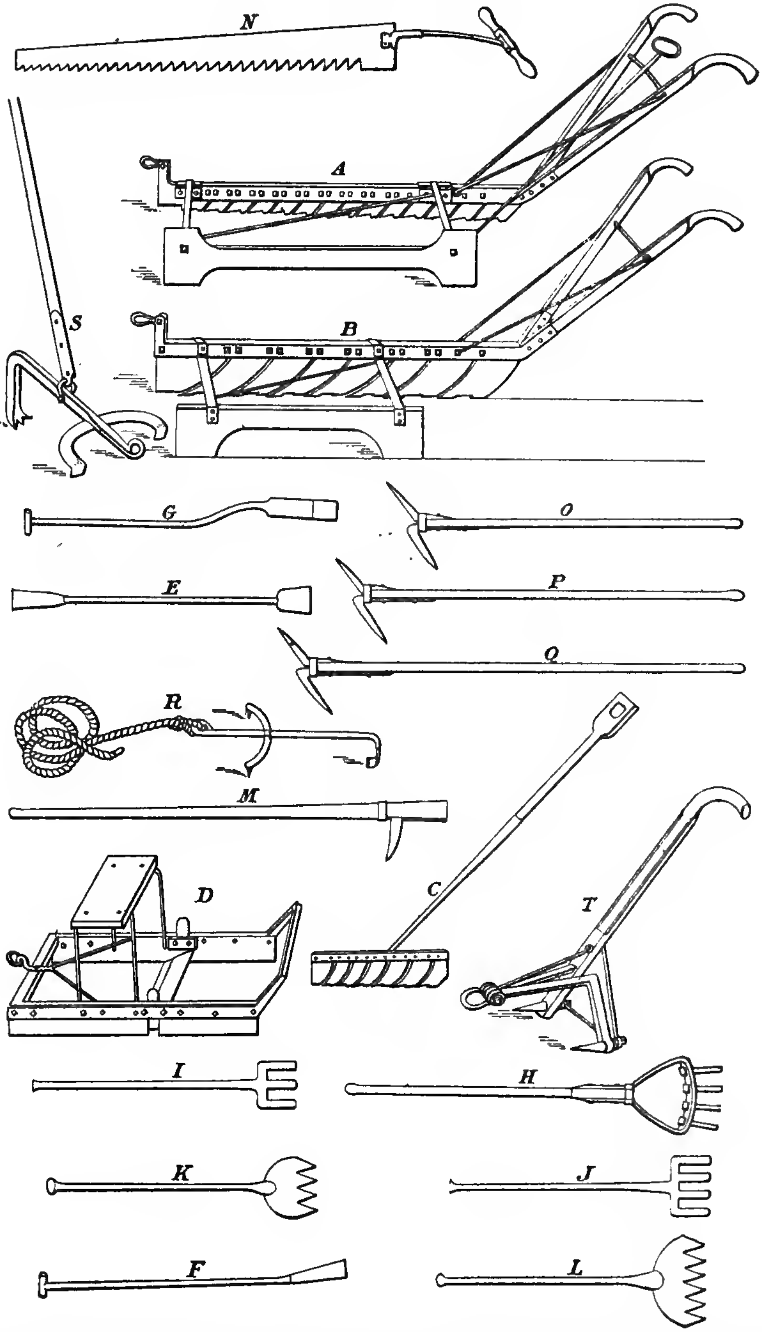
(See Bones; Celluloid; Ivory.)

HOSIERY.—See **KNITTED FABRICS.**

ICE (Fr., *Glace*; Ger., *Eis*).

Ice is too familiar an object to require definition. This article will be divided into two sections, treating (1) of the trade in natural ice, and (2) of the artificial production of ice, and refrigeration generally.

830.



Natural Ice.—Some of the colder countries, as N. America and Scandinavia, have what is called an "ice-harvest" every year. When the ice on the lakes and fjords is about 1 ft. thick, the snow and rough surface-ice are carefully planed off by an ice-plane, drawn by horses. This done, a straight groove is cut along one side of the clean ice-sheet, by means of the hand-plough. Then, by means of the swing guide-marker, a continuous series of similar grooves are marked parallel to the first and equidistant from each other. The large ice-plough is next drawn over these grooves, deepening the cut to 12–14 in. The same operation is repeated at right angles to the first grooves, and the blocks are ready for separation. To prevent the water meantime from entering the grooves, and freezing them up, they are firmly caulked with snow, driven down by the caulking-bar. When the two outside rows have been sawed out, the blocks are lifted upon the adjacent ice, and the remaining rows are separated by breaking-bars. The blocks are then floated to the ice-house, and stored in tiers, carefully covered with pine-shavings.

Fig. 830 shows the principal tools used in the harvesting of natural ice: A, marker, with swing-guide; B, plough, with stationary guide; C, hand-plough; D, snow-plane; E, grooving-bar; F G, striking-under bars; H I J K L, fork splitting-bars; M, channel hook-bar; N, ice-saw; O P Q, ice-hooks; R S T, grapples.

In America, the consumption of ice is truly enormous, being estimated, in the Middle States, at 1600 lb. a year for each individual. The supply is obtained from the rivers and lakes in the interior, the four chief sources being Boston and neighbourhood, the Kennebec region (Maine), Hudson River (New York), and the Upper Schuylkill and Lehigh region (Pennsylvania). The quantity of ice cut on the Hudson River is about 1¼ million tons annually, and on the Kennebec and Penobscot and their tributaries, about 1 million tons. For a short time, we too were dependent upon the American continent for our supplies of natural ice; but the loss and cost in transport rendered the price so high as to be unable to compete with Scandinavian ice, when the latter came into the market, and our imports of ice in 1879 were 166,452 tons, value 139,714*l*., from Norway, and only 5 tons from all other countries.

Artificial Ice.—Refrigeration, or the artificial production of ice, consists simply in transferring the heat of the water (or other body to be frozen) to some other body. Water at 15½° (60° F.) contains an excess of heat beyond that of an equal weight of ice at 0° (32° F.) amounting to 170·65 heat units for each lb., therefore, to reduce the water from the first temperature to the second will necessitate the abstraction of that amount of heat from it; to reduce 1 ton of water will require the removal of 62,720 heat units, or 2240 lb. × 28 (the difference between 32° and 60° F.). It would still be water. To convert it into ice, it is further necessary to abstract the latent heat, which determines the liquid state of water, amounting to 142·65 heat units for each lb. of water; or, for 1 ton, 2240 lb. × 142·65 = 319,536 heat units, bringing the total to 382,256 heat units. It is thus evident that about five times greater expenditure of power is necessary to transform water at the freezing-point into a solid condition (ice), than is necessary to reduce its temperature from the ordinary point to the freezing-point; and this fact must be borne in mind in the practical application of refrigeration to commercial purposes, where a low temperature will often be as effective as the actual production of ice.

In the use of so-called "freezing-mixtures," the reduction of temperature in the body is due to the absorption of its heat by the process of solution suffered by the salts employed. They are principally as follows:—

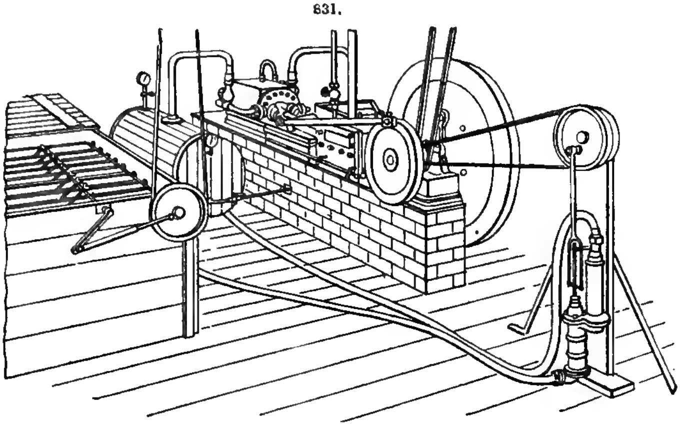
Mixtures.	Thermometer sinks: ° F.	Actual Reduction of Temperature: ° F.
(1) 2 parts snow or pounded ice, 1 part sodium chloride ..	to −5°	
(2) 5 parts snow or pounded ice, 2 parts sodium chloride, 1 part ammonium chloride	to −12°	
(3) 24 parts snow or pounded ice, 10 parts sodium chloride, 5 parts ammonium chloride, 5 parts potassium nitrate	to −18°	
(4) 12 parts snow or pounded ice, 5 parts sodium chloride, 5 parts ammonium nitrate	to −25°	
(5) 1 part ammonium nitrate, 1 part water	from 40° to 4°	36°
(6) 5 parts ammonium chloride, 5 parts potassium nitrate, 16 parts water	„ 50° to 10°	0°
(7) 5 parts ammonium chloride, 5 parts potassium nitrate, 8 parts sodium sulphate, 16 parts water	„ 50° to 4°	46°
(8) 5 parts sodium sulphate, 4 parts dilute sulphuric acid	„ 50° to 3°	47°
(9) 3 parts sodium nitrate, 2 parts dilute nitric acid	„ 50° to −3°	53°
(10) 3 parts snow, 2 parts dilute sulphuric acid	„ 32° to −23°	55°
(11) 1 part ammonium nitrate, 1 part sodium carbonate, 1 part water	„ 50° to −7°	57°
(12) 8 parts snow, 5 parts hydrochloric acid	„ 32° to −27°	59°
(13) 6 parts sodium sulphate, 4 parts ammonium chloride, 2 parts potassium nitrate, 4 parts dilute nitric acid ..	„ 50° to −10°	60°

Mixtures.	Thermometer sinks: °F.	Actual Reduction of Temperature: °F.
(14) 9 parts sodium phosphate, 4 parts dilute nitric acid ..	from 50° to −12°	62°
(15) 7 parts snow, 4 parts dilute nitric acid	„ 32° to −30°	62°
(16) 4 parts snow, 5 parts calcium chloride	„ 32° to −40°	72°
(17) 2 parts snow, 3 parts crystallized calcium chloride ..	„ 32° to −50°	82°
(18) 3 parts snow, 4 parts potash	„ 32° to −51°	83°
(19) 6 parts sodium sulphate, 5 parts ammonium nitrate, 4 parts dilute nitric acid	„ 50° to −40°	90°

These freezing-mixtures are very useful for application on a small scale, but are not adapted for commercial operations. In selecting bodies for abstracting and absorbing heat with the object of producing refrigeration on an extensive scale, several points require to be taken into consideration. (1) The first is the amount of latent heat absorbed by 1 lb. of the body in changing its state, being 966·1 heat units for watery vapours, 900 for gaseous ammonia, 364·3 for alcohol vapour, 162·8 for ether vapour. The amount of artificial cold produced will be in inverse ratio: thus the formation of 1 ton of ice will necessitate the vaporization of about 395⅔ lb. of water, 424⅘ lb. of liquid ammonia, 1049¼ lb. of alcohol, or 2348 lb. of ether. (2) The next important consideration is the degree of facility with which the bodies are vaporized, and the range of temperature within which the vaporization can be readily accomplished, or, in other words, the boiling-point of the body and the tension of its vapour. It is sought to obtain a body having the former as low as is convenient, combined with the latter also moderately low. Many practical difficulties have been encountered through selecting bodies possessing the former quality, without much regard to the latter. Thus, at a temperature of 24° (75° F.), which is often exceeded in town waters in warm countries, the tension of liquid ammonia will be 150–160 lb. a sq. in.; chloride of methyl, about 80 lb.; methylic ether, 78 lb.; sulphur dioxide (sulphurous anhydride or oxide), 60 lb. These immense pressures necessitate extreme care in the construction of the apparatus, thereby enhancing the cost; and the difficulty of keeping the joints tight often occasions loss of material and reduced production. (3) Equally necessary to be taken into consideration, is the condensation of the vaporized body, in order that it may be used over again. This condensation is effected by means of a supply of cold water. In some industries, and in certain localities, the scale of consumption of water for this purpose is such as to altogether preclude the use of certain machines. (4) The chemical properties of the substances employed must be studied in relation to their action upon the metal or other material with which they will come into contact. Having said so much concerning the general principles and conditions involved in the artificial production of a low temperature, or ice itself, some space may now be devoted to a description of the principal machines devised with this object.

An ether ice-machine, made by Duvallon and Lloyd, of Birmingham, is shown in Fig. 831. It consists of an engine and air-pump, combined on the same bed-plate; a refrigerator; an ether-condenser; a circulating-pump; and one or more ice-boxes, according to the quantity of ice required. In the illustration, the air-pump is 9½ in. in diameter, driven direct by a steam-engine, with 7½-in. cylinders, the stroke being 21 in. The two cylinders are arranged in line, the two piston-rods being cottered to the cross-head. The guides consist of hollow angle-pieces, working on the corners of the square bars. The air-pump is double-acting. The connecting-rods, one at each side of the cylinder, work on crank-pins, inserted in discs keyed upon the main shaft, one of these discs being of considerable weight, so as to act as a fly-wheel. In the centre of the main shaft, is a pulley for driving overhead-shafting, from

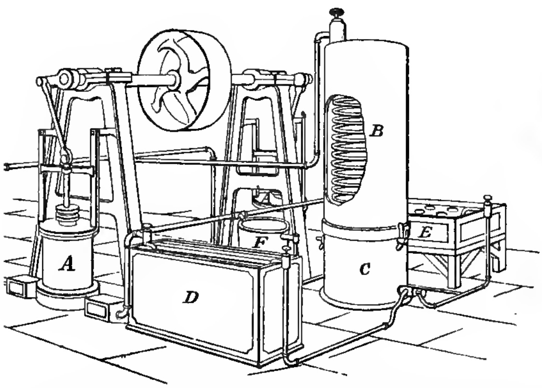
831.



which the circulating-pump and the agitator derive their motion. The two inlet passages of the air-pump, one at each end, are connected by a copper pipe, from which branches another copper pipe, placing them in communication with the refrigerator. This is a cylindrical vessel, similar in construction to a multitubular boiler, covered with felt, and lagged with wood; the tubes are made of copper, and riveted to brass end-plates. On the other side of the air-pump, the two outlet valves, connected in the same manner as the inlet valves, are placed in communication with the ether-condenser, which is similar in construction to the refrigerator, but is of rectangular section, and has no copper shell. The tubes communicate at each end with metallic chambers, one of them acting as a receptacle for the air which finds its way into the condenser. The whole is immersed in a tank of wood, or of galvanized iron, through which a constant stream of water is made to pass, for cooling and condensing the ether vapour. A vacuum of about 25¼ in. is maintained by the air-pump in the refrigerator, vaporizing the ether at a low temperature. The absorption of heat due to this operation lowers the temperature of the strong brine, made to circulate, by means of the pump provided for that purpose, through the tubes and the ice-box. The latter is a tank of red deal, varnished inside, with partitions having holes bored in them for allowing the brine to circulate slowly. Between the partitions, are suspended zinc moulds of rhombic form, varying in width according to the shape of the blocks of ice required, and filled with pure water. The capacities and prices of this machine vary approximately from 120*l.* to make 3 cwt. of ice per 24 hours in England, to 2800*l.* to make 200 cwt. in the same time.

Another form of ether-machine, invented by A. Mühl, of San Antonio, Texas, is shown in Figs. 832 and 833. The pumps A are connected with the driving-shaft, as shown; the condenser

832.



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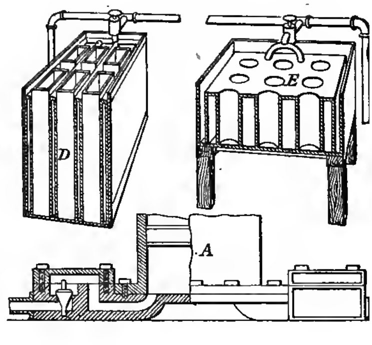


B contains a worm, which communicates, through the pipe on the outside, with the reservoir C below; D E F are freezing-vessels of various forms. Each pump, as its piston rises, draws in from the freezing-vessels the ether which has been vaporized by the heat abstracted from the water or other liquids contained in them; as its piston descends, the vapour of the ether is forced into the worm of the condenser, and thence into the reservoir C, which it reaches in a liquid state; it then passes into the freezing-vessels, where it is reconverted into vapour, and flows thence back into the pumps. The pumps have their induction pipes provided with suction-valves (see A, Fig. 833), and their eduction pipes with exhaust-valves.

The usual practice of making the worm, which is the principal agent by which the vapour is reduced to a liquid, of pipe of uniform diameter throughout is objectionable, for the following reasons: If a small pipe is used, it is difficult to force the vapour through fast enough, and an unnecessary amount of power is consumed without effect; on the other hand, if the pipe is of the customary size (1–2 in. in diameter), only the layer of vapour immediately in contact, or nearly so, with its sides, is condensed, and the remaining uncondensed portion is discharged into the reservoir, there to be condensed at the expense of considerable power; or is caused to enter the freezing-vessel before condensation is effected, thereby defeating the object intended. To obviate these difficulties, the worm is composed of pipes of several different sizes. Several coils of large pipe, say 1½ in. in diameter, are used at the point of entry, and are followed by coils of 1 in., ½ in., and ¼ in., by the last of which the exit is made. By this means, no resistance is offered to the passage of the vapour at its commencement, and all parts of its body are afterwards brought sufficiently near the sides of the pipe to ensure its condensation before the reservoir is entered. Thus power is saved, and the full effect of the freezing-apparatus is developed.

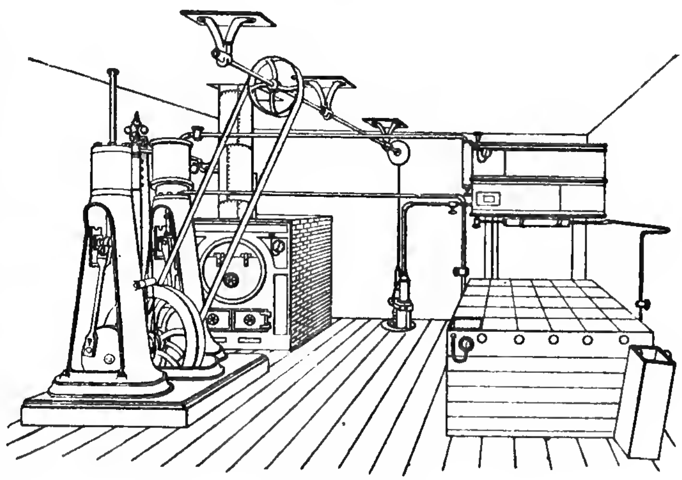
The condenser B is kept full of running water while the machine is in operation, and the action of the latter is regulated and kept under complete control by the aid of valves and stop-cocks.

The freezing-vessel shown at D contains cans, in which blocks of ice are produced; these cans stand between hollow metallic partitions, through which the freezer passes. The vessel E, seen also in Fig. 833, is provided with receptacles for holding bottles, or other small vessels, around which the ether circulates. That at F is of conical form, and has double walls for the passage of the ether.

Siddeley and Mackay's refrigerating-machine, which has been already described under Carbolic Acid (p. 673), also works with ether.

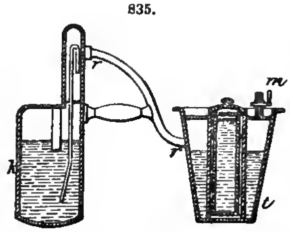
An ice-making apparatus, in which ammonia is the medium used, constructed by the Boyle Ice Machine Co., of Chicago, Illinois, is shown in Fig. 834. On the left, are a steam-boiler and a combined engine and ammonia-pump; in the centre, a pump for water supply for the gas condenser; and on the right, a freezing-tank. The ammonia-pump is used for compressing the ammonia gas, which is liquefied in the condenser, and expanded in a freezing-tank seen on the right, in which the cold is produced. This freezing-tank is provided with coils of iron pipe, in which the gas evaporates; they are placed at regular spaces apart, determined by the thickness of the ice required. Between the coils, are placed moulds or cans, containing the water to be frozen; and the space about both moulds and coils is filled with strong brine. The pump being put in motion, a valve leading from the condenser to the evaporator-coils is opened, and the gas flows into the evaporator-coils. Meeting there with the heat in the salt water to be cooled, it expands very rapidly, taking up the heat which is in the brine, which, in turn, extracts the heat from the water in the moulds. The expanded gas is aspirated by the pump, and forced over into the condenser, where the heat is taken from it by a stream of water continually flowing over it, and where, under the pressure of the pump, it is reliquefied, and returns to be again expanded in the evaporator-coils. This process is continued until the water is frozen, when the mould is lifted from its place in the freezing-tank, and immersed in warmer water, which loosens the ice from the mould; the latter, being refilled with water, is returned to the freezing-tank.

834.



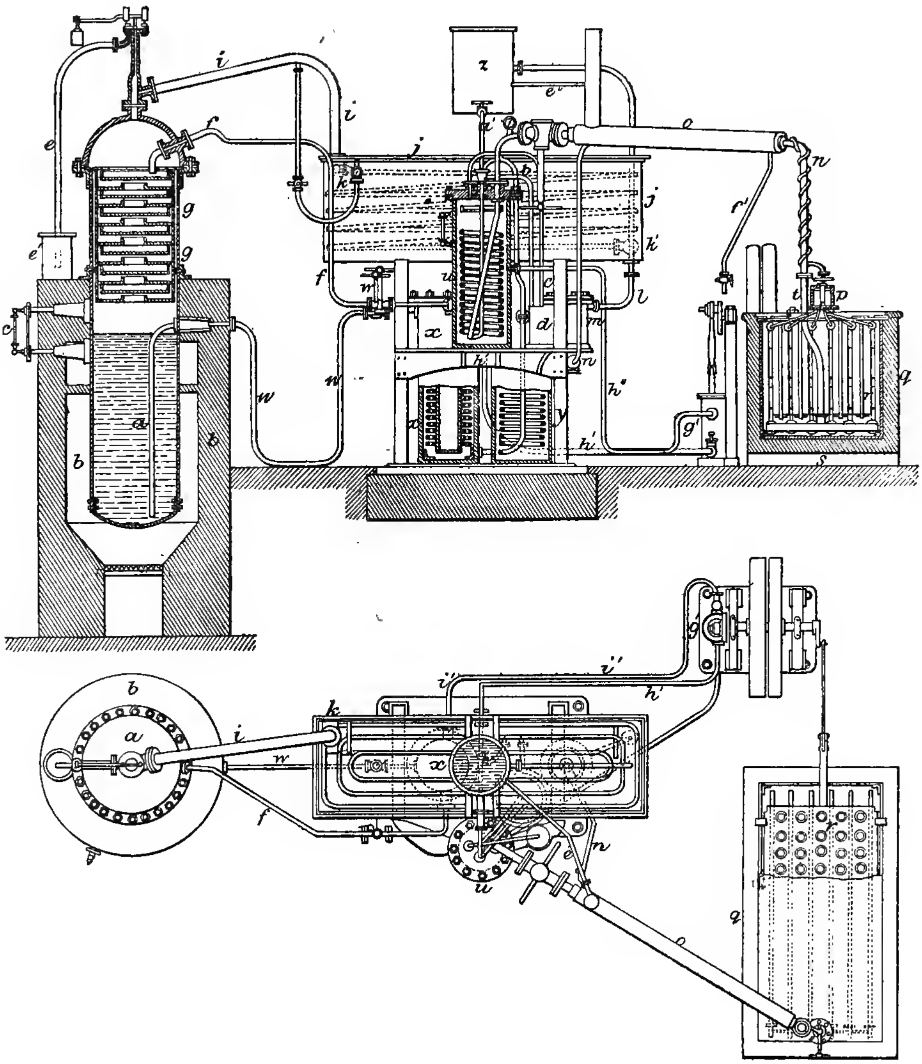
Carré's intermittent portable apparatus, in which ammonia is employed, is shown in Fig. 835. A boiler *k* containing the ammonia is connected by the pipe *r* with the refrigerator *t*, into the well of which are put vessels *z* filled with water to be frozen. The boiler *k* is placed over a portable furnace, and the apparatus is purged of air, which is driven by the evolved gas out at the stop-cock *m*. This being closed, and the refrigerator immersed in a tank of cool water, the temperature of the liquid ammonia is raised to 110°–115° (230°–240° F.), at which heat the ammonia is expelled, and condensed in a liquid form in the refrigerator *t*. The boiler being now removed from the furnace, and placed in the water-bath, the temperature of the water in it will fall, and the power of the water to dissolve ammonia will be restored. The gas will be rapidly re-dissolved, reducing the pressure, as the liquid ammonia will evaporate with corresponding rapidity, drawing for its latent heat upon the sensible heat of the water to be frozen. The result will be the complete evaporation of the liquefied ammonia, and the restoration of an aqueous solution in the boiler, of the original strength. Between the ice-pan and the well, is a body of alcohol, which will not freeze, but will act as a conductor. During the refrigeration, the vessel *t* has a non-conducting envelope.

835.



Carré's continuous process, shown in Figs. 836 and 837, also depends for its efficacy upon the evaporation of liquid ammonia. The boiler *a* is exposed to the heat of the furnace *b*; *c* is an indicator to show the level of the liquid; *i* is a tube conducting gas to the liquefier *j*; the vertical pipe above the branch *i* leads to a safety-valve; and any escaping gas passes by pipe *c* to the water-tank e', where it is absorbed; f is a tube which brings back to the boiler saturated solution of ammonia from the absorbing-apparatus u; this solution passes downward, trickling through the perforated trays g, while the ascending gas rises in a sinuous course, alternately around the edge of one tray and through a central hole in the next, and so oo. This condenses and carries back the watery vapour which accompanies the gas. The latter passes by tube i to the liquefier j, through

836.



837.

a box k, and a series of zigzag and spiral tubes in a bath of cold water, constantly renewed from reservoir z, which also supplies other parts of the apparatus. The tubes terminate in another box k', and the ammonia is by this time in a liquid state, under a pressure of 10 atmos., which is constantly maintained in the boiler. In the liquid state, the ammonia passes by the pipe l to the efflux regulator m, which is the dividing barrier between the part of the machine in which a regular pressure of 10 atmos. is maintained, and the following part where the pressure does not exceed 1½ atmos. The regulating device is a floating cup, which opens or closes a hole of influx. The liquid passes from the regulator m by pipe n to the distributor p, the pipe n being wound spirally around the tube t, through which the vaporized ammonia is returning from the refrigerator q; the vapours serve to reduce the temperature of the liquid in n before it reaches the refrigerator.

The refrigerator itself consists of a number of zigzag or spiral tubes, immersed in a tank constructed of non-conducting substances. Each one of the zigzags receives an equal supply of liquid ammonia from the distributor. The small tubes conveying this supply are shown at *p*. The vessels *r* to be refrigerated are sustained on a carriage, which is slid to and fro by the same power that works the pump *g'*, by which the re-saturated solution of ammonia is returned to the boiler. The space in the tank surrounding the zigzags and the water-vessels is filled with an uncongealable liquid, such as alcohol, or a solution of chloride of calcium. The ammonia in the zigzags *q* discharges in a vaporized form into the collector *s*, and passes through the tube *t* to the cylinder *u*, where it extends nearly to the bottom of the vessel, and there discharges the gas into the water which has been brought from the bottom of the boiler *a*, and partially fills the cylinder *u*. From this water, the ammonia has been nearly exhausted, and it therefore greedily absorbs the gas ejected into it by pipe *t*. On the left of vessel *u*, is a water-level indicator. Within the vessel *u*, is a worm which receives water by the pipe *a'* from the elevated reservoir *z*; after passing to the bottom of the spiral, the pipe curves upward, and then (marked *b*) descends nearly to the bottom of the vessel *y*, where it discharges.

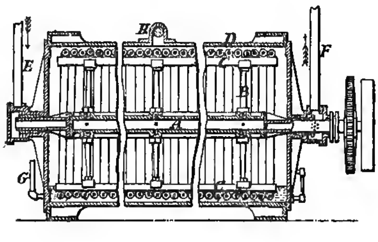
The water from the boiler *a* passes by pipes *w* to the coolers *x y*, before reaching the vessel *u*, where it re-absorbs ammonia. Between the boiler *a* and the vessel *u*, the water is cooled so as to fit it for absorbing gas more freely. The pressure in the boiler is sufficient to expel it when the stop-cock *w* is opened. The vessel *x* is formed of two concentric cylinders, between which are two spiral tubes, formed of the pipe *w* continued, and these spirals are immersed in a liquid which fills the annular space between the cylinders, and is the reconstituted ammoniacal solution on its way from the absorber *u* to the boiler *a*. From *x*, the water in the spiral is conveyed in the pipe *w*, still continued in a single spiral ascending in the vessel *y*, and continued farther in a pipe *w*, alongside of the absorber *u*, where it discharges into a sieve *v*, and from which it descends in a shower. The exhausted solution from the boiler flows freely by the pipe *w* to the absorber *u*, passing the coolers *x y*, as described; but it requires some power to force the reconstituted solution back from the absorber *u* through the pipe *f* to the boiler. This power is a pump *g'*, driven by a steam-engine or other motor, taking the saturated solution from the absorber by pipe *h'*, and discharging it by pipe *i'* into the vessel *x*, whence it passes by pipe *f* to the dome above the boiler. Gas finding its way into the pump is discharged into the upper part of *n*. A pipe *e''* leads to the enveloping-tube *o*, whence water is conducted by *f'* for the use of the ice-vessels *r*. As the water passes through *o*, it is cooled by the ascending vapours of ammonia. In starting the machine, it is first blown through to expel the air. The air escaping from the vessel *u* passes by the pipe *c* to the purger *d*, and beneath the surface of the water therein, which retains any escaping ammonia.

Holden's (of Philadelphia) machine is adapted to the use of almost any volatile liquid, whether ether, ammonia, carbon bisulphide, &c. The refrigerator-cylinder, Fig. 838, is covered with a non-conducting substance. It is journalled on a longitudinal shaft A, provided with radial arms B, which carry upon their outer ends longitudinally arranged ribs C. Around these ribs, and near the inner periphery of the cylinder, is wound a continuous coil-pipe D, in which circulates strongly saturated brine, or other non-congealable liquid, which is received from a convenient cistern or tank. A coil of pipe extends the entire length of the cylinder, and, at each end, communicates with the hollow ends of the shaft A, and through this hollow with the supply-pipe E, and the exit-pipe F, so that a continuous circulation of the non-congealable liquid may be kept up in the coil. Inside this cylinder, the volatile liquid is placed. It is introduced through a pipe G, and is maintained at such a level as to immerse the bottom portion of the coil of pipes, which level may be regulated by means of a glass gauge upon the outside. As the coil of pipes is revolved, the coil passes to the upper portion of the cylinder with its surface moistened by the volatile liquid, which it carries up from adhesive attraction; and as the cylinder is exhausted of its gaseous contents through the pipe H by means of pumps, the evaporation of the liquid upon the surface of the coil rapidly takes place to supply the partial vacuum, and a corresponding reduction of the temperature of the pipes and its contained vehicle of non-congealable liquid takes place. To guard against leakage, which would prevent the best action of the pump in effecting evaporation, the ends of the shaft A are provided with stuffing-boxes, while the outer parts of the bearings are enlarged to form water-boxes, which are filled with the non-congealable liquid, and these, together with the stuffing-boxes, effectually seal the bearings against all leakage of air in the interior.

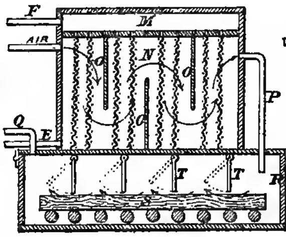
As the gas is exhausted from the cylinder, it passes to the pumps previously referred to, thence to a condenser, and thence through a pipe (as liquid) to a receiver. The cooled non-congealable liquid passes into the case M, Fig. 839, through the pipe F, and thence back to the coil in the cylinder through the pipe E. The circulation of liquid is effected through a circulating-pump, which is operated by the engine which works the large pumps, the refrigerator-coil, and a rotary blower for circulating air in the congealing-case.

The two large pumps detailed in Fig. 840, communicate with pipe H from the cylinder, through inwardly-opening check-valves I, located in the branches of the pipe. These pipes are also provided with a gravity cup-shaped valve J, which is of greater diameter than the piston-cylinder, and plays between the cylinder-head and the flange of the body of the cylinder, upon which it is seated, being guided in its movement by ribs in the enlarged cavity of the cylinder-head. On the descent of the piston, the gas is drawn through the pipe H, the check-valves I are opened, and the pump-cylinder is filled. But when the piston rises, the check-valves are closed, and the compressed gases above the piston lift the valve J, and allow the gas to pass out into the pipe, and thence to the

838.



839.



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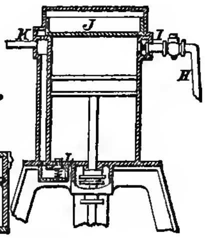
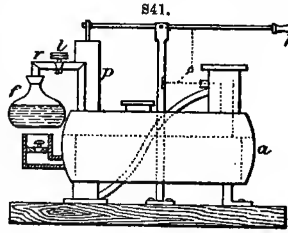


condenser through K. As, however, the gases contained in the portion of the pipe between the pump-cylinder and the check are compressed, but not forced out, if the piston should descend with this pressure of gas contained here, the gas would expand, and, by partially filling the chamber, prevent the perfect exhaustion of the gas-cylinder. To provide for this, the piston in its upward stroke passes the orifices of pipe H, so that the compressed charge of gas is held in the confined space, and is liberated beneath the piston, and, upon its descent, is driven out through the valve L at the bottom into a pipe that communicates with K. The face of the piston, in rising, strikes against the bottom of the cup-valve and lifts it, and, upon the reverse stroke, the valve seats itself upon the flange of the cylinder, while the plain ground face of the piston departs from the plain ground bottom of the valve, producing as nearly a perfect vacuum as it is possible to attain in a pump, there being practically no cushion of gas left between the valve and piston.

As the gas is delivered to the condenser, it is made to traverse coils, and is cooled by the circulation of water of the normal temperature which passes through the condenser. As the gas is liquefied, it passes into the receiver, where it accumulates, and is fed from time to time back into the refrigerator-cylinder. As the non-congealable liquid in the coil of the refrigerator circulates, it passes out through the pipe F to the distributing-pan M, where its temperature is to be transferred to the air circulating in the subjacent case N. The upper case is provided with a distributing-pan, into which the cooled liquid is admitted. The bottom of the pan has perforations, which are arranged in rows immediately above a series of vertical partitions of wire gauze, between which are arranged the vertical baffle-plates. As the cooled liquid drops through the perforations in the pan, it falls upon the wire partitions, and being retarded in its descent, trickles slowly down, while the current of air driven through the case by the blower is made to penetrate all parts by reason of the baffle-plates, and in so doing, takes on the temperature of the non-congealable liquid, which is below the freezing-point of water, passes into the congealing-case at and through pipe P, then traverses the pans in the congealing-case to freeze the water therein contained, and after having done its duty, passes up through the blower and pipe Q, to be again reduced in temperature. The congealing-case has doors R at each end, and is provided with supporting-rollers, upon which the pans S are fed in at one end and removed at the other.

This apparatus was first designed solely for reducing the temperature of liquids, such as beer when the liquid to be cooled is allowed to trickle down over the refrigerating-coil. It has been widely adopted in American breweries. For the production of ice, additional plant is necessary, consisting of a large tank, and suitable receptacles for the water. A novelty in Holden's arrangement is that the water-holding vessels are introduced at one end of the tank and removed at the other, passing through a progressively increasing degree of cold.

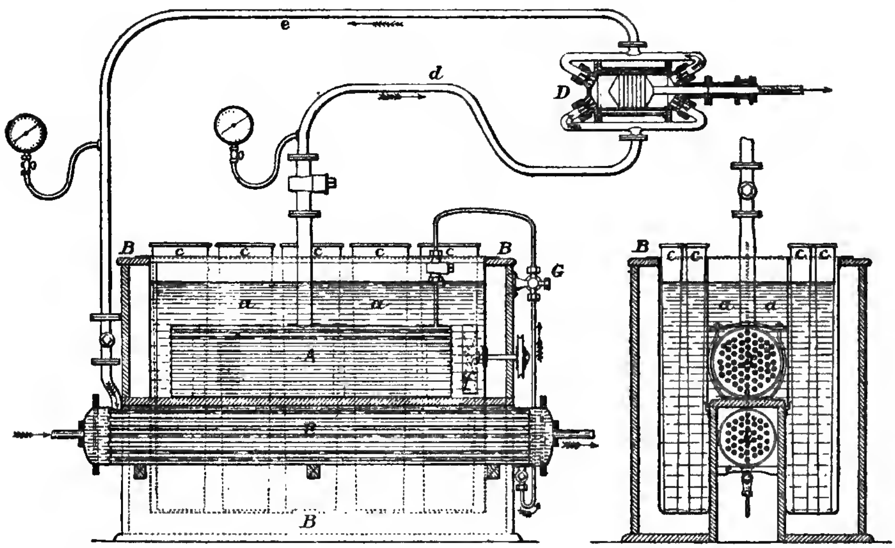
841.



Sulphuric acid is employed in E. Carré's apparatus, Fig. 841. It consists of a large vessel *a*, for holding the concentrated sulphuric acid; an air-pump *p*, with tube-connections *r* adapted to the mouths of the decanters *f*; and a mechanism by which the lever *h* of the air-pump keeps the acid in continual motion; *l* is a stop-cock. This apparatus is useful for cooling drinks.

One of the most important machines for producing a low temperature is that introduced by Raoul Pictet, of Paris, in which anhydrous sulphurous acid (SO_2), also called sulphur dioxide, sulphurous acid, sulphurous oxide, or sulphurous anhydride, is employed. Its arrangement is shown in Figs. 842 and 843. The valves of the compression-pump D are so disposed that at one stroke the sulphurous oxide is aspirated through the tube *d*, and, in return, is compressed through the tube *e*. The tube *d* connects with the refrigerator A, placed in the sheet-iron vat B, lined with non-conducting material; the tube *e*, with the conductor E. The oxide is introduced at the plug-cock G, and is drawn by the pump in the direction of the arrow into the copper-tubular refrigerator

842. 843.



A, the liquid filling the space between the tubes. Here takes place vaporization, with the consequent production of intense cold, and the temperature of the non-congealable mixture of glycerine and water surrounding the refrigerator is so far reduced that water placed in the metallic vessels *c*, immersed in the tank, rapidly becomes frozen. The propeller-wheel *f* sends a current of the glycerine solution through the tubes, and thus hastens the refrigeration. The vapour of the oxide is drawn out of the refrigerator by the pump, and forced into the space between the tubes of the condenser E. Through these tubes, a stream of cold water is constantly forced; this determines the condensation of the vapours, and the re-liquefied oxide passes into the admission-pipe, and enters again into circulation. A saturated solution of chloride of magnesium gives better results than the glycerine mixture. The tension of the oxide vapour varies from about 14·7–13 lb; on the return stroke, the gas is compressed to $\frac{1}{4}$–$\frac{1}{5}$ its original volume, having its temperature raised to 93° (200° F.). The cold water current reduced this temperature to about 16° (61° F.) at the outlet; and under a pressure of 3–3½ atmos., the gas resumes a liquid state. It is claimed that 1 lb. of acid produces nearly 1 lb. of ice; and that with a consumption of 22½ tons of coal, 250 tons of ice can be made every 24 hours. The cost is said not to exceed 1c. a kilo. (say ½*d.* a lb.). The system is largely adopted in skating-rinks, breweries, &c.

The production of a low temperature by the alternate compression and expansion of air is perhaps best accomplished by the Bell and Coleman apparatus, which has been described in the article on Food Preservation, its primary application being for preserving fresh meat on long voyages.

The "binary absorption" system of Tessié du Mothay and A. I. Rossi is the most recent development of the science of producing artificial cold. Experiments on ethers indicated that those formed by the acids, as well as their alcoholic radicals, possess the property of absorbing sulphurous anhydride (sulphur dioxide), some of them to the extent of 300 times their volume of gas in certain conditions, ordinary ether standing first. Upon this fact, the new system is founded. The liquid employed is ethylo-sulphurous dioxide, obtained from ordinary ether by saturating with sulphurous oxide gas. This liquid, at a temperature of 15°–18° (60°–65° F.), has no pressure, and can be readily kept in glass bottles at 27°–32° (80°–90° F.); its tension is only 2–5 lb. Thus a machine charged with it, when stopped, will show no pressure on the gauges, and even a vacuum at rest, if the temperature is low; while with other liquids, even the stoppage of the machine does not prevent the pressure of the vapours inside soon reaching its point of equilibrium with the temperature outside, and even at as low a temperature as 0° (32° F.) sulphur dioxide (sulphurous oxide) alone, as used in the Pictet machine, has still 15 lb. a sq. in. of pressure, exerting a constant and increasing pressure on the vessels containing it, and, in case of a small leak starting, causing the entire loss of the charge. What is said here of sulphurous oxide applies with still more force to liquid ammonia, methyl chloride, and methylic ether.

Such a binary liquid as that just mentioned, when evaporated under a vacuum, is resolved into its two constituents, the mixed vapours entering the pump together; then, under a small compression, ether liquefies first, a few lb. pressure being sufficient for it, even with such waters as are met with in tropical climates. The ether thus liquefied absorbs in the condenser the vapours of sulphurous oxide, reconstituting the "binary liquid," and thereby avoiding the excess of mechanical compression, which would otherwise have been necessary to effect this liquefaction of the oxide. Thus for the work of compression of the pump, is substituted a power of chemical affinity, and absorption of the less volatile absorbent for the vapours of the more volatile. With the advantage of the low pressure of the ether, is combined the advantage of the intensity of cold produced by the volatilization of the sulphurous oxide, avoiding its drawbacks. In presence of water and the ether, the sulphurous oxide is transformed, not into sulphuric acid, as before, but into "sulphorinic" acid, the action of which acid upon metals is insignificant, if not absolutely nil. The sulphurous acid being an extinctor relieves the ether of one of the drawbacks to its use, and acting as self-lubricant, renders the greasing of the working parts unnecessary. In a machine making 6 tons of ice daily, the pressures in the condenser in normal and regular working have been 14–15 lb., descending to 10–11 lb. under most favourable conditions, and reaching 20–23 lb. under least favourable conditions. The water used for condensation has been but $\frac{1}{4}$–$\frac{1}{3}$ of that needed by a Pictet machine of the same capacity. The smallness of pressure required renders the machine much simpler, ordinary valves, &c., sufficing, The New York Ice Machine Co. are working very successfully with the system in the United States.

Bibliography.—B. H. Paul, 'Artificial Freezing and Refrigeration' (Jour. Soc. Arts, vol. xvii., No. 839, London: 1868); M. Ledoux, 'Ice-making Machines' (New York: 1879).

INDIARUBBER MANUFACTURES.

Under the term "indiarubber manufactures," will be included a description of the manufacture of those articles in which indiarubber or caoutchouc, guttapercha, and some allied exudations are largely employed. For an account of the raw materials, the reader is referred to the article on Resinous Substances.

The name "caoutchouc" in England is generally confined to the pure hydrocarbon forming the greater portion of ordinary indiarubber; its composition, according to Faraday, is represented by the formula C_7H_8. The chemical and physical properties of this substance extend more or less to the commercial kinds of rubber, and, in proportion as a sample of rubber approaches the qualities of pure caoutchouc, its commercial value increases. The internal portions of best Pará "bottle" rubber, when dried in the dark, are sufficiently pure for any practical examination of the substance. The amount of the pure principle contained in any given sample may be ascertained by dissolving in highly rectified ether, and precipitating with alcohol, which should be repeated for a high purification. Ether containing alcohol, does not dissolve caoutchouc at all. Caoutchouc readily oxidizes on exposure to the air, becoming brown on the surface, which is blackened and rendered rotten by extreme oxidation. This coloration is removed by alcohol or alcoholized ether. Long digestion of masticated rubber, in alcohol, renders it quite colourless; but it becomes sticky, and, on exposure to the air, rapidly darkens in colour. Caoutchouc is soluble in ether, chloroform, carbon bisulphide, coal-tar naphtha, benzol, turpentine, and in almost any liquid hydrocarbon; incorporated with solid hydrocarbons, as naphthalene, or paraffin, it behaves under the influence of heat in the same way as a true solution. It is insoluble in water, alcohol, and acid and alkaline solutions; but is rapidly acted upon by strong mineral acids, especially when heated, and by chlorine, bromine, and iodine in the cold. Heated above 4° (40° F.), it is soft and elastic, and remains the same at 100° (212° F.); below 4° (40° F.), it is hard and inelastic, but not brittle; when heated to 115° (239° F.), it softens, and is decomposed into a sticky, tarry mass by standing for a few days; congelation prevents this only while it lasts: heat accelerates the change. In this condition, however, it may be vulcanized. By destructive distillation, it yields a series of liquid hydrocarbons, which have been employed as solvents for caoutchouc, as lubricators, &c. They do not possess any particular interest, although a study of them might furnish very important information as to the synthetic production of this or similar hydrocarbons; the substances known as "artificial rubber," &c., are widely different in composition from caoutchouc. Contact with oily or fatty substances induces the decomposition of caoutchouc. Its sp. gr. is 0·925–0·950. On incineration, it should yield only an insignificant amount of ash. In commerce, the manufactured article is frequently called "rubber" or "indiarubber"; when cured or vulcanized, it is called "vulcanized rubber," if soft; and "vulcanite" or "ebonite," when cured to a hard or horny condition. Raw indiarubber as met with in the markets is technically called "gum." The best descriptions, in order of purity, are the Brazilian, Central American, Asiatic, and African. There are many applications, where the inferior kinds, irrespective of their being cheaper, are better adapted than the finer descriptions. Pará rubber yields a hard and strong material when vulcanized, but is always contaminated with the taste and smell of the raw product. Negrohead has a still more unpleasant taste and smell when vulcanized, and is softer.

The preliminary treatment of all kinds of rubber is much the same as regards sorting, washing, and drying; there is, however, a great difference in carrying out the details of these processes, according to the nature or condition of the rubber, some descriptions having to be cautiously heated and dried, whilst others are much more easily manipulated. In selecting raw rubber, preference should be given to packages made up of small masses, or thin pieces, and to those samples which, when cut and squeezed, emit little or no moisture; bark and chips are more abundant in the drier kinds.

Washing and Drying.—The first part of the washing process consists in throwing the raw article into large iron tanks, containing water, sometimes heated by injected steam for a few hours, so as to soften the rubber, and facilitate its cutting up before passing through the washing-machines or rollers. This preliminary boiling serves another purpose: as indiarubber floats easily in water, any portions containing clay, sand, iron, or other heavy matters, sink to the bottom, and are at once detected. It is a common thing to find, instead of these heavier matters, rags, nuts, leaves, and wood concealed in the mass; these portions are not washed with the other, but are kept by themselves, as they require more careful cleansing. The adhering dirt should be scrubbed off, if necessary. The softer kinds of rubber must be treated with cold water, and not boiled.

When removed from the tank, the masses of rubber are cut open with a large knife, if they can be sufficiently examined with one incision, which is the case with those rubbers which are met with in smaller masses; if in large bulky masses, as the Pará and negrohead, and those which become massed by agglutination, it is either cut up by a revolving circular knife, or by an ordinary long-bladed knife. A circular knife is the most expeditious, but is, of course, more dangerous in case of stones being concealed in the rubber. Whichever method is adopted, this cutting up is either performed by the foreman of the washing-shop, or under his immediate inspection, for it not unfrequently happens that a classification is necessary, even with a package of the very best description. It is then passed to the washing-rollers, or washing-machines.

The washing-machine consists essentially of two grooved or corrugated iron rollers, working in journals, and adjustable by means of a screw, working through the front part of the iron framework. Each roller has a strong pinion keyed to one end, and the pair are worked by a strong toothed-wheel, attached to a shaft, which drives several machines. The rollers revolve in opposite directions, and thus drag the rubber through, while a jet of cold water—hot is sometimes necessary—falls upon it, preventing heating from friction, and dissolving out the soluble matters, as gum, sugar, and salts, existing in the natural juices of the plant. Under the machine, is a wooden box, or frame, with a perforated zinc bottom, to let off the water, and prevent the escape of small fragments of rubber.

The speed at which these machines are driven is not a matter of much importance. Sometimes two speeds are employed, generally obtained by working two sets of machines from separate shafting and gearing, and better by having rollers of larger diameter. By giving extra strength to the machine, so as to use larger and longer rollers, labour is economized. The rollers should not exceed 12–18 in. in length; for very fine washing, 9–10 in. will suffice, as they are liable to open out by springing.

The rubber is first passed through a few times with the rollers tolerably wide apart, and as the pieces of wood, bark, &c., are washed out, the rollers are gradually closed, or the rubber is finished off in another machine, with finer rollers set closely. With careful washing, it is almost possible to bring the lower descriptions of S. American, Bornean, and a few others, to a degree of cleanliness equal to that of Pará rubber. Formerly, washing-rollers were enclosed in an iron box or case; now, a wooden hood surrounds the machine, when treating such rubbers as are liable to fly about.

A form of washing-machine which has become almost obsolete may be referred to, as it is especially useful for washing up short or crumbled rubber. It consists of a fluted spindle or axis, with rough teeth, revolving in a strong iron box; the rubber is supplied through an aperture in the top, and is removed by opening the front, which works on a strong bolt as a hinge. This rubber is dried on canvas trays, or strewn on a clean floor.

The ordinary washed rubber comes away from the machines in long sheets, with rough surfaces, and is dried by being hung up for some days in drying-rooms, heated to about 32° (90° F.) by steam-pipes. The influence of direct sunlight on the rubber is prevented by painting the windows white or yellow. Some rubbers cannot be obtained in sheets like this, and are too soft for hanging up; these are dried on the floors. The rubber must not come into contact with the steam-pipes; when thoroughly dried, it is taken down, and stacked away on shelves, in a dry and moderately warm store-room, for seasoning, or for immediate use. Washed rubber improves by stacking, and for insulating purposes, ebonite, and the finer classes of goods, it is preferable.

There are great differences in the degree of loss of moisture and impurities even from the same description of rubber; thus, old Pará rubber will suffer a loss of 7–12 per cent., whilst new or green rubber will frequently lose 15 per cent., or even more. Negrohead of good quality may be taken as losing 20–25 per cent.; 15 per cent. was formerly a fair figure, but the practice now is to pack this rubber in very large masses, and frequently to empty into it non-inspissated juice, so that it reaches the English markets quite saturated.

The peculiarities of the different sorts of washed rubber are not easily described, although they are very evident to any experienced person. Washed Pará, negrohead, Ceará, Borneo, Rangoon, and Penang, are the most important. Washed Pará has the peculiar odour of the raw rubber, and, on drying, takes a dark-brownish colour; negrohead has a strong, rather offensive smell, and, as met with in commerce, is generally of a blackish colour; Ceará has a rich light-brownish colour; Borneo is generally black; Rangoon and Penang have a reddish tint when washed and dried.

Masticating.—This process is necessary only for the production of sheet-rubber, slabs or blocks; as it does not destroy the strength of the rubber, it frequently forms a preliminary treatment, when extra grinding would destroy the firmness. Pigmented masticated rubber is sometimes required. There are several ways of obtaining this; (1) by incorporating the pigment roughly with the whole of the rubber, or only a portion of it; (2) by mixing in the "grinders" or mixing-rolls, and finishing off the batch in the masticator; (3) by dusting the pigments on the rubber as it is put into the masticator, which may cause a little loss; (4) a useful plan in many cases is to mix the pigment with a little of the rubber by grinding, and to run it out as a rough sheet, which is cut up, and masticated with the remainder of the rubber. Since the object of the process is not to weaken the rubber, it is evident that the incorporation of the pigments ought not to protract the process more than can be helped. The heat generated in masticating, even when the machine is not heated by steam, renders it almost impossible to incorporate some pigments, as sulphur and red-lead, in this way. Very small proportions of dry pigment can be added at a time in the masticator; consequently, to produce heavily pigmented masticated rubber, an excess of pigment is first ground in by the grinders, and a proportion of this product is passed with pure rubber through the masticator. A great deal of experience is necessary for the production of good cut sheet; the speed at which the masticator is driven is one of the most important conditions for the production of a block from which can be cut sheets, that will not be curly, and will yet be sufficiently worked not to buckle when heated, nor be rendered soft.

Sometimes, especially in cold weather, the rubber is slightly heated on a steam-chest, before being put into the masticator; but more frequently the axis of the machine is made hollow, so as to admit of its being warmed by passing steam through. If a masticator has been standing for some time, and become a little rusty, it is best cleaned by passing through a batch of some rough compound containing rag fibre. When newly set up, a little grinding takes place in the bearings, and it is important that the metal so detached should not become incorporated with the rubber. This renders it necessary to work the machine for a few days on some unimportant compound.

844. 845.

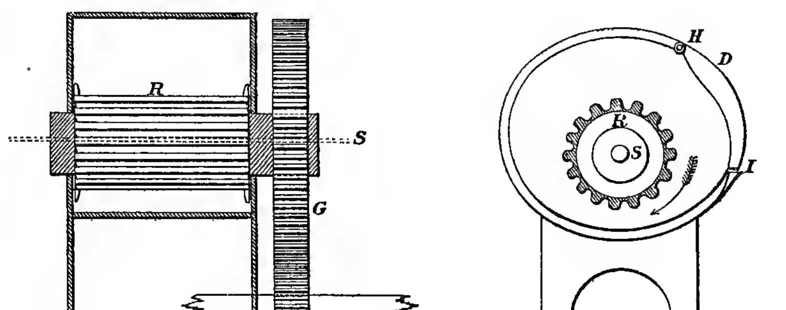
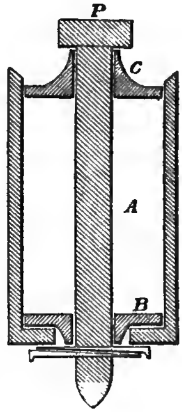


Fig. 844 shows a front view of the masticator, the case being removed; and Fig. 845, an end view, representing the excentric position of the fluted roller. The speed at which this roller revolves should not exceed 30–40 rev. a minute for strong masticated sheet rubber; a greater speed may be used where the object is simply to partially work for grinding purposes. The roller R is cast with a shoulder projecting about ½ in. above the plates at each end, inside the frame, to prevent the lubricant reaching the rubber. The door O, which is similar to a strong grating, is hinged to the upper part H of the frame, and is secured, when working, by a wedge fitting between the door and a recess formed by it in the lower part I of the frame. The strong toothed-wheel G is keyed to the fluted roller R, and worked off a pinion on the main shaft. The steam inlet is at S. The roller, by its excentric working, kneads the rubber, and by the alternate expansion and contraction in the upper and lower parts of the machine, a new surface is being continually presented to the roller. A 12-in. block will require 3–6 hours' working, to yield a good uniform sheet when cut up. The length of the machine is an important matter: the longer the block, the less is the waste in cutting the ends true, and generally the same is required whether the masticator will work up 40 or 240 lb. of rubber. These machines are made of a size to take much larger quantities of rubber; but there is a limit to the size when required for fine cut sheet: a block of 240–260 lb. cannot well be exceeded for this purpose. The diameter is generally uniform; the length only is increased when extra quantities are to be worked up. A masticator which will give a block 12–13 in. in diameter, with a 3-in. hole in the centre, is the most practicable; if this diameter be exceeded, the heat from friction will be extreme, unless the speed is very low. Should the charge be stopped by the block not going round with the axis, it may be forced down with a crowbar, so as to grip the axis, when it will be instantly carried round. When indiarubber is being over-masticated, it emits a peculiar odour, as if being roasted, and the block will be full of holes or cavities, and will have a darker colour.

Block Rubber.—After the block is taken from the masticator, it is forced into strong cast-iron moulds, which are first moistened inside with a little soap and water, to act as a lubricant. The blocks are produced in two forms, depending upon the means at hand for cutting them up:—(1) They are forced into long iron boxes, fitted with covers, which are forced down by a screw-press; as the mass yields, an extra turn is given to the screw. The block remains in the press for a few days or a week, when it is taken out, and placed in an ice-house or cool cellar. (2) Cylindrical moulds are now most generally employed, since from them are obtained blocks which can be cut up into continuous lengths, whereas the other method will only yield sheets about 6 ft. long. These moulds, Fig. 846, consist of a cast-iron cylinder A, carefully turned inside, and sometimes enamelled, with a recess or projection at the bottom, upon which rests a strong circular plate or disc B, with a 4-in. hole in its centre. This is first fitted into the mould, then the rubber is forced in by sledge-hammers, and removed to a powerful screw or hydraulic press, where it is forced fairly down into the mould. On the top of the block, fitting evenly into the mould, is placed an iron plate C, similar to the one at the bottom; and through the central hole, is forced a strong bolt or pin P, which passes through the rubber and the hole in the bottom plate of the mould. After the whole is well pressed, the pressure on the blocks is secured by keys or wedges, which pass through a slot cut in the lower part of the bolt, and can then be removed from the press to make room for other blocks. During the day, these blocks and moulds are again passed into the press, and forced with the screw, until they yield no more when other wedges are driven in as before. They are then transferred, without removal from the moulds, into a cool cellar or ice-house, until perfectly set and hard, when the moulds are emptied. The blocks remain in ice until required. They are sometimes hardened by being placed in a strong current of cold air, such as a chamber opening into the main shaft of the factory.

846.



Other methods are in use for obtaining blocks of rubber from the raw and washed articles, which consist in forcing it into moulds without masticating, and consolidating it by placing the moulds, keyed or wedged together with their charge, into a heater at about 116° (240° F.) for a few hours. Washed Pará yields good sound blocks in this way, but the rubber is deprived of more of its strength than if masticated, and is darker in colour.

Sheet Rubber.—The blocks are next cut up into sheets of different thicknesses. The square blocks are clamped to a plate, which can be raised to any height, according to the thickness of sheet required; this passes forward to an oscillating knife, which slices-up the rubber. The knife can be set in the opposite direction, so as to make another cut as it passes back again, and so on. The cylindrical blocks are forced upon a stout spindle, of the size of the bolts passing through them; this spindle rotates in front of a similar, though much longer, knife; the thickness of sheet is regulated by the feed-wheels, which are changed as required; and when the machine is once started, a block can be cut without any further attention, unless demanded by a defect in the machine itself, which occurs generally in the friction arrangement which works the feed-gearing.

These machines are worked at very high speeds, and a good supply of water is kept continually flowing over the knives. The sheets are generally hung up to dry and season, and are soaped, and laid carefully one on the other, or rolled up for stowage. This cutting-up must be done in a cool place, for if the rubber gets soft, it must be again placed in the ice-house to harden; soft spots or patches in the blocks will lead to inequalities in the thickness. These sheets are manufactured for tobacco-pouches, tubes, and other articles which are required from masticated rubber; such have a series of very fine lines or marks, which correspond with the strokes of the knife in cutting. Raw Pará, or just crushed between rollers first, gives a curiously mottled sheet, very strong, and not so easily acted upon by grease or exposure; it is consequently much used for the backing of wire "cards," and is even said to be as durable as leather for this purpose. The production of this sheet is a specialty with a few manufacturers, who cut up the raw article, and wash it at the same time in a kind of mincing-machine, in which a series of knives work backward and forward, or transversely, as required.

Tape Rubber.—Indiarubber fillets or tapes are cut from sheets, by winding the quantity required upon a wooden mandril, and securing the last lap, so as to keep the whole firmly together, either by means of a little naphtha or solution of rubber in naphtha. Knives are forced against the rubber as it revolves in an ordinary lathe, whilst a jet of water flows over them. A series of fine cutters, worked by a self-acting slide-rest, may be used in the same way to produce thread.

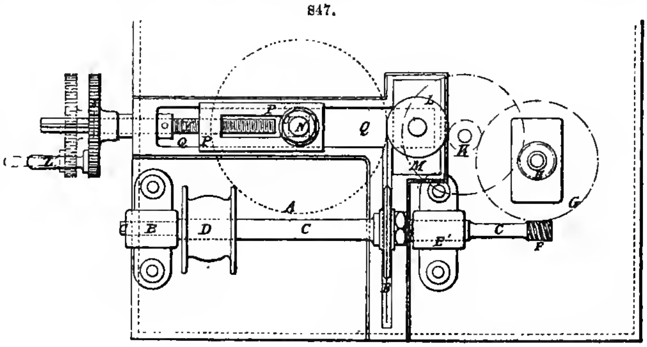
The rubber, when cut, is very weak, in fact it cannot bear stretching at all. It is run off the rollers or mandrils into a wooden zinc-lined tank, containing water heated to 60° (140° F.); this process seems to anneal or seal the edges, for, on hanging up for a few days after this operation, it is found to have acquired extraordinary strength. By carefully stretching it, and keeping it distended for some time, it remains elongated; when thrown into warm water, it instantly regains its original dimensions, but is much strengthened; by repeating this, its tensile strength may be increased 5-6 fold.

In passing tapes and threads into hot water, some care is required, as if they are allowed to stick too closely together, they are spoiled. After standing in the warm water for a little time, they are passed through the hands into cold water, to remove the stickiness, and are hung up to dry. Soap lye, alkalies, methylated spirit, and white finish, are sometimes used to prevent this stickiness. In telegraph work, water alone is used, as foreign matters prevent consolidation when heating. Rubber which has been passed only through methylated spirit, much better resists decay; this may be due to the wood-naphtha present.

Stretched rubber keeps longer than unstretched; this is not easily explained, although it seems that decay is a matter of simple oxidation. It must be preserved from direct sunlight and heat; if heated, it rapidly changes into a viscid substance, unless vulcanized. If, at this stage, it be kept in a cool dark place, it undergoes no change; but if it be heated, and then set by under the same conditions, it will gradually soften, and become rotten, after a time apparently drying up into a brittle resinous-looking substance. These changes are, according to the late Dr. W. A. Miller, due to the direct combination of oxygen with caoutchouc. The liquid condition which precedes this drying-up is not satisfactorily accounted for.

Dunlop's tape-cutting machine, Fig. 847 is very convenient for producing fillets for insulating telegraph-wire. Discs of rubber, cut from a cylindrical block, are secured on the vertical shaft N, by screwing down the nut O; by turning the handles T, the rubber is moved up to the fluted brass roller M; the shaft C, worked by a band, gives a uniform motion to M, through the worms F G, and the spur-wheels H I K L. As the discs are cut away, N revolves at a higher speed, and with it the whole of the feed-gearing, so that the tapes are cut of a uniform thickness.

847.



Thread Rubber.—Thread is frequently obtained from spread vulcanized rubber; the red which is made with antimony, and the black with sulphide of lead, are the most durable; vulcanized pure rubber more quickly gets rotten. The spread sheet is first desulphurized, and is then wound very evenly and tightly on a wooden mandril, and is uniformly stretched; the whole is well bound up with canvas, or, preferably, a sheet is cemented over it; it is then cut up in an ordinary lathe, or the sheet is laid on a table, and cut up by a series of traversing circular knives.

The sheets, either spread or masticated, are lapped around a mandril, and mounted in a lathe with a self-acting slide-rest. A cutter moving from the circumference to the centre cuts off threads from its ends. After each cut, the tool is moved. Dunlop's improved machine provides for the rapidly simultaneous motion of the cutter in its outward and onward direction, by a rocking-shaft attached to a sliding-arm, on which the tool-holder is linked. This shaft receives its motion by means of two curved tails attached to it, and which are acted on by studs on the faces of two wheels, one on each side of the curved tails. The studs, acting on the two tails, alternately produce the rocking movement; the wheel which produces the inward motion, or cut, carries usually six studs, and moves slowly, so as to work the cutter gently into the rubber. The feed motion is given by means of a cam on the axis of the last-mentioned wheel, which acts on the lever of a clutch, and clutches for a time a spur-wheel, which drives the feed-screw. The length of time during which the clutch is held in, so as to drive the feed-motion, is regulated by a disc in connection with the feed-screw; this disc has notches in it at regular intervals, into which drops a projection on the clutch-lever; and when this lever is raised by the cam, it cannot return until the feed-screw has travelled so far as to enable it to fall into the next notch on the divided plate or disc.

A series of very fine cutters carried on a slide-rest worked by hand is a convenient way for cutting up thread on a small scale. The sheet should be very evenly and tightly wound up, so as to avoid inequalities of thickness; and the last lap should be cemented down, or a sheet of compound, which can be recallendered, should be tightly bound over it and secured. This same method is applicable for cutting small rings, washers, &c. Round thread is obtained by forcing plastic rubber or its compounds through dies, whence it is received into water, to prevent sticking. It is dried and cured by the cold process.

Thread is tested by attaching a given weight to a certain length: it should not break, and little or no permanent elongation should be perceptible. Thread rubber is used for elastic webbing, braids, &c. In braiding, the threads of rubber are kept stretched to about double their natural lengths, so that on releasing, the braids have a full and even appearance. Elastic webbing is produced by cementing thin vulcanized sheet between two elastic woven fabrics, or by heating the vulcanized sheet between grooved surfaces, under pressure, so as to give it a corrugated surface. The oily matter given off in bodily perspiration is very detrimental to these webs, causing them to become quite sticky and soft, when their elasticity is completely destroyed. Webs may be tested by suspending them in a chamber heated to 38°–49° (100°–120° F.) for several days; in some cases, with slight distension. If moistened with a little coal-tar naphtha, they should show no disposition to soften.

848.

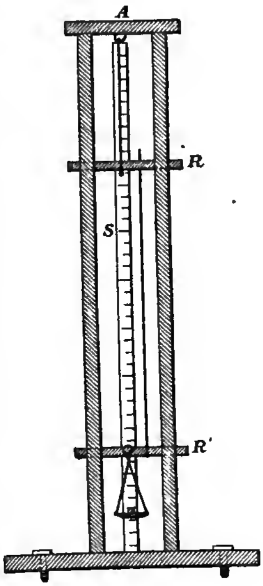


Fig. 848 shows a contrivance for testing rubber thread and tape. It consists of a light wooden frame A, 6 ft. high, belted to the floor; the sides are slotted, so that the rollers R R′ can move freely through the greater part of the length of A; a paper scale S is attached to the back of the frame; R is rigidly attached at A to a movable support; the lower roller R′ carries a light scale-pan or hooks for supporting weights; between R and R′ is the material to be examined. Instead of weights, a delicate spring-balance may be conveniently employed.

Dissolving Rubber.—The solvents of indiarubber have already been alluded to. Those chiefly used are "solvent" naphtha (sp. gr. 0·850 at 60° F., boiling at 240°–250° F., and leaving no more than 10 per cent. residue at 320° F.), shale spirit, and benzol. Mixed with purified solid paraffin, by grinding together, rubber will acquire the property of melting by heat, and setting solid again when cooled. Solubility is promoted by grinding or working. Raw or washed rubber is less soluble than that masticated or ground, and well ground rubber is more easily taken up than that which has been less worked. All descriptions of raw rubber, in the same stages of manufacture, do not exhibit the same degree of solubility; the better qualities are less soluble than the inferior. Generally, washed rubber is used for dissolving for waterproofing. There is no doubt that in the case of Pará rubber, and some of the other cleaner kinds, the process of washing could be dispensed with, provided the raw article could be freed from adhering dirt, crushed between grinders, and afterwards hung up in a dry and warm room to season. The mixture of indiarubber and solvent is technically known as "solution" when thin, and as "cement" when thick.

When pigments are to be incorporated with the solution, the easiest plan, in most cases, is to grind the rubber and pigments together, run out into a thin sheet, and digest in naphtha, with a slight stirring as it is added. The finishing is performed by dough-mixers or rollers, after which, for the better class of goods, the softened mass is forced through wire gauze, by means of a powerful screw-press. Coloured solutions are sometimes used as paints: the dry pigments are mixed in with the rubber in a volatile solvent. The stiff solution of rubber used for spreading is technically called "dough." In handling this, the workman uses a little soap, so as to prevent it sticking to his fingers.

Spreading and Waterproofing Fabrics.—The treatment of fabrics which are to be "proofed" by spreading, consists in passing them through a pair of calenders, with the object of pressing down knots, and giving a smooth and even surface; after this, they are passed over a steam-chest, to expel moisture, when they are ready to receive the first coat. This is usually a different mixture from the bulk of the proofing, and is called a "sticking-coat," its object being to secure adhesion between the fabric and rubber; it is generally incorporated with colouring pigments, white or black, so as not to allow the general mixture to show through the cloth, or alter its appearance. A little oxide of zinc, or whiting, is used for white or light-coloured goods; Frankfort and other blacks are used for dark goods. The coats, as applied, are dried by passing over a steam-chest, when the fabric is again brought to the front of the machine for another coat, and so on. Some descriptions of goods have a finishing coat of better quality or mixture, in some cases containing no sulphur, nor any pigment whatever. The number of coats varies from three to seven, according to the class of goods, and the weight of material which is to be put on.

Machines are now employed which work on the continuous principle; but as they require more space, so as to allow each coat to dry in time to receive another, it is not certain that there is much gain in using them.

Methods have been devised for collecting the naphtha vapour and condensing it; the principal objections to these arrangements are that they interfere with the workman's being able to see his work as it passes over the steam-chest, and do not allow the naphtha itself to pass off so completely, owing to the partial obstruction. The enormous quantities of naphtha which are dissipated in the spreading-rooms of some of the largest establishments, afford sufficient evidence of the want of some suitable means for this object. One plan which has been used, and which certainly does collect some of the naphtha, consists of a rectangular iron hood, of such dimensions as to cover the steam-chest, or the greater part of it, and raised towards the middle, where it opens into a zinc chimney or flue, and passes down, outside the building, into a receiver, kept cool by running water. The vapour is mixed with so much air, which passes away charged with the naphtha vapour, that it is only possible to collect a very small proportion of the latter. Bruce Warren's method has been used with greater success. Its peculiarity is in collecting the naphtha vapour by indiarubber, which is capable of abstracting solvent vapours from air charged with them. The air, loaded with the vapour, is made to traverse a series of trays containing laminated rubber, which is required either for solution or for dough; or the naphtha may be recovered by distillation, and the rubber be used over again.

849.

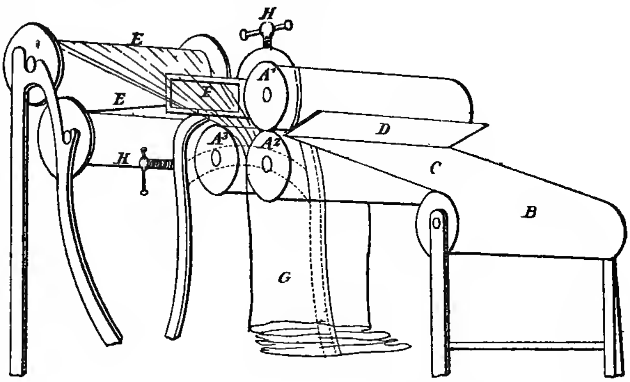


Fig. 849 shows an arrangement for spreading and doubling at one operation. B is a roll of fabric, passing under a knife D, in the front of which is placed, along the whole width of C, a roll of dough or cement. E E are two beams of yarn, warped in the usual manner, passing through the reed F, and on to the adhesive surface of C. The pressure regulated by H on the rollers A^1 A^2 A^3 firmly unites the whole into one fabric G. Instead of the yarns, a woven fabric or fleece may be employed, as on B. The rollers are hollow, so as to admit steam for spreading guttapercha, pitch, resins, &c.

Drying Spread Fabrics.—After the goods leave the spreading-machines, they are hung up for a few days in a warm room, so as to expel the little naphtha which is retained by the rubber, and which it gives up very slowly. This drying helps to remove the smell of the naphtha, and prevents blistering in curing. The quality of the solvent used, and the temperature of the drying-room, determine how long this "hanging up" must last before curing. As indiarubber licks up, as it were, the vapours and odours which float about in the drying-room, it would be infinitely better to have a series of drying-rooms, so as not to hang up the more recently spread goods with those which have more or less completely lost their smell of naphtha. Goods which are cured by the cold process are hung up in the same way; but as they have always a more disagreeable smell, they should have a separate hanging-room to dry in.

Preparing Fabrics for Curing.—When spread cotton goods have become tolerably firm, or quite dry, they are wound upon hollow sheet-iron cylinders, for curing in open steam, or in a steam-jacketed heater. As the condensed steam spoils these goods, they are carefully wrapped up as air- and water-tight as possible. Since wool and silk are destroyed by the heat necessary to cure indiarubber in this way, the cold process is the only eligible method of vulcanizing. Very frequently, however, cotton goods are treated in the same manner.

In packing the goods for the steam-heater, care must be taken that the fabrics are wound without creases, and are not stretched, as the fibres of the cloth, after curing, will retain their distorted appearance. Double textures are simply wound up; but "surface" goods are first carefully brushed over with very fine French chalk, no excess or loose chalk being allowed to remain. They are then wound up; but, as this necessitates the rubber surface coming into contact with the cotton surface, whereby it is liable to be marked, it is more usual to run two pieces together, with the rubber surfaces against each other. This not only prevents marking, but secures an even surface; blisters, from dampness in the cotton, are also prevented.

Double textures are obtained by passing the proofed fabrics through a pair of rollers (the doubling-machine), whilst the surfaces are still sticky or adhesive; these are vulcanized, if required, by means of sulphur incorporated with the compounds, and steam-heat. The doubling-rollers are of solid cast-iron, with turned surfaces, 6 ft. long. One is fixed, while the other can be moved by a lever, so as to admit the fabrics to be doubled. As they revolve in opposite directions, they draw the fabric through, and, when tightened up, press the two coated surfaces together.

Indiarubber Felt.—Indiarubber-felt, felt-paper, or Clark's patent felt, is used for a variety of purposes, such as covering damp walls, protecting silk and other wares from dampness during water-transit, covering telegraph-wire, roofing, &c. Although indiarubber is now entirely used, guttapercha, alone, or mixed with resins and other matters, has been employed. A pair of ordinary mixing-rolls, running at equal speeds, receive over each a cotton fleece, which is delivered from the carding-machines stationed on opposite sides, so that the two fleeces enter together between the rolls, and passing down through an opening in the floor, are led away, or rolled up. A soft dough is carefully laid between the rolls, and as the fleeces pass through, the rubber is squeezed into them. The fabric is vulcanized by incorporating sulphur with the rubber mixtures, and curing in the same way as ordinary spread fabrics. If made with good rubber and naphtha, it should not feel clammy nor soft, but should be dry and tough. Paper can be similarly treated: and, for damp walls, &c., would in many cases be as useful as cotton, while much cheaper. A few years ago, coppered cloth made from this felt was recommended for roofing purposes; it was abandoned principally because the rubber decayed, thus leaving nothing to support the metal. By vulcanizing, the rubber could be preserved, but it is not certain that the sulphur, by acting on the copper, might not be a source of fresh trouble. Iodine or bromine incorporated with the rubber would not be liable to this action on the copper. It should form a very useful protection for iron plates on ships, and might be used for a variety of purposes, as it could be cemented on, and, if the cement contained sulphur, or other curative agent, it could be vulcanized by holding a heated body against it.

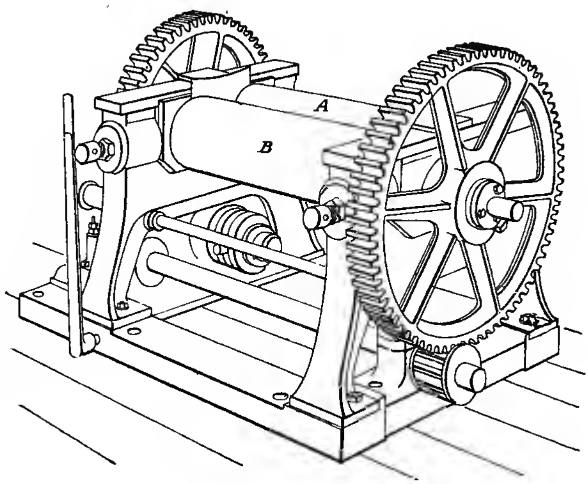
Grinding and Mixing.—The incorporation of pigments is effected between a pair of smooth rollers, running at unequal speeds (as 3 or 5 : 2). The rubber is first run through several times by itself, so as to soften it, and draw it out into sheet form; the pigments are dusted on as the rubber passes through, the process being continued until the whole is roughly blended. The rollers are then forced nearer together, by which the mixture is finely and more evenly ground, when it is ready for the calenders.

The grinders or mixers, consist of two very strong rollers A B (Fig. 850), 14–18 in. diameter, and 40 in. long, revolving inwards, so as to drag the rubber between them, and the rollers are hollow, so that steam or cold water can pass through them. They work in movable journals, as they require to be opened and closed. Equal-speed mixers are used for working the compounds into a more plastic and softer condition. They do not grind so well, and are consequently only used for special purposes. Grinders with shorter and stouter rollers are necessary for working up waste, and operating on more heavily-pigmented compounds. The less the compounds are worked or ground, the stronger will be the rubber when vulcanized or cured; on the other hand, if too hard, it cannot be so well calendered. Articles cured in moulds, as springs, washers, and valves, cannot easily get out of shape, or contract; but packing, and articles not cured in moulds, are shrunk well in boiling water before curing. As a rule the stronger the natural rubber is before mixing, the better and more elastic will be the manufactured article, if properly handled in grinding and mixing. An experienced calender-man can run out compounds into sheets with as little grinding as possible, whilst others require the rubber quite "killed."

Calendering.—Calenders are made with 2 or more rolls, according to requirement. Their object is to draw the compounds into sheets. Except in being more massive, and with the rollers arranged one above the other, and running at equal speeds, they are constructed in all respects the same as grinders. By bringing the rollers closer together, the sheets are made finer. A cloth is generally passed through the roll with the compound, and receives a coating on the side next the compound; it is passed through several times, until the desired thickness is obtained. All that is necessary is to raise the upper roll each time, and to bring the sheet from the front to the back of the calenders. For packing, the cloth is afterwards stripped off, therefore the first coating must not be run on too tightly; for sheeting, hose-cloths, &c., the reverse is aimed at.

Compounds for telegraph-wire are run out without cloth, and, on leaving the rolls, are received on a band or coated fabric, and wound up together. In some cases, the under side of the calendered compound is run over a roller, revolving in a trough of varnish made of shellac and methylated spirit, the object being to prevent sticking when wound on bobbins. Calendered strips or tapes are obtained by pressing down upon the roller, which carries the rubber round a series of cutters or dividers, the width of which can be varied. These strips are received in the same way, varnished, or otherwise. Care must be taken in these cases to keep the roller free from any soiling by the fingers, otherwise the compounds cannot be easily drawn off, but will be continually carried round. Highly worked mixtures cannot be so well managed as those worked for a shorter time, and moderately pigmented. As adhesion is essential between all the parts of a telegraph-wire, the compounds must not be calendered so hard as to prevent this.

850.



Calenders running at a slightly unequal speed are used for driving compounds into the meshes of fabrics; the grinding action opens the cloth by stretching, and forces the rubber completely through the fabric. Belting, hose, and packing-cloths, are thus treated. Sometimes a little naphtha or solvent is incorporated with the compounds, so as to make them more soft and sticky. Not unfrequently hose-linings, &c., are spread, instead of being calendered.

To avoid soiling the surfaces of a calendered sheet, it is usual to run a loose cloth, or, if both surfaces are calendered with rubber, two cloths with it, which also prevents sticking together. Finished sheets are brushed over with flour or French chalk: when the latter is used, the surfaces are permanently soiled; but when it is necessary to prepare these surfaces for cementing or joining, they are brushed over with flour, which can be removed when required by washing with water, taking care to allow all the moisture to dry off afterwards. Fig. 851 represents a set of 4-roll calenders, by Crossleys, Manchester: A B C D are 4 chilled-iron rollers, cast hollow, so as to admit steam or water. A D can be moved nearer to or further from B C, by screw-gearing, worked by a capstan or wheel W. It is general to drive the calenders by a special engine, so as to ensure a well regulated speed, which is not so easily attained from a main-shaft. S are spindles, for carrying drums, cutters, &c., necessary for the different calendering operations.

Valve-cutting.—Fig. 852 represents the most improved form of circular cutting-machine, manufactured by Crossley Bros., Manchester. It can be driven by hand, or by a belt from an overhead shaft. By means of the lever L, the cutting arrangement can be raised or lowered on the axis A; it is lowered gently by hand, while in operation. As it fits loosely on the axis, it is not carried around with it. Attached rigidly to the axis, are two square bars, each carrying a knife K, and a small can W for holding water; from these, pipes P deliver a stream of water in front of the knives, to keep them cool. When the knives, &c., are in position, they are prevented from shifting, by clamping to the bar. A screw enables them to be moved with accuracy. The sheet to be cut is placed quite flat under the machine; one screw is worked until the knife is in position for cutting out the central hole; the other knife is moved out for the required diameter; a belt working on the fast-pulley F sets the whole in motion, when the lever L being pressed down, the valve is gradually cut out. If no hole be wanted in the centre, one of the knives is removed, or drawn out so as to clear the sheet. A stop-cock, not shown, regulates the flow of liquid from W. The machine is bolted to a bench, so that a long sheet can be operated on. The knives should first be pressed down slightly, and the machine be driven slowly, preferably by hand, so as to just mark the dimensions before completing the cut. A circular knife is most expeditious for cutting up small articles, such as stationers' rubber. The article is first obtained in long strips, a gauge is

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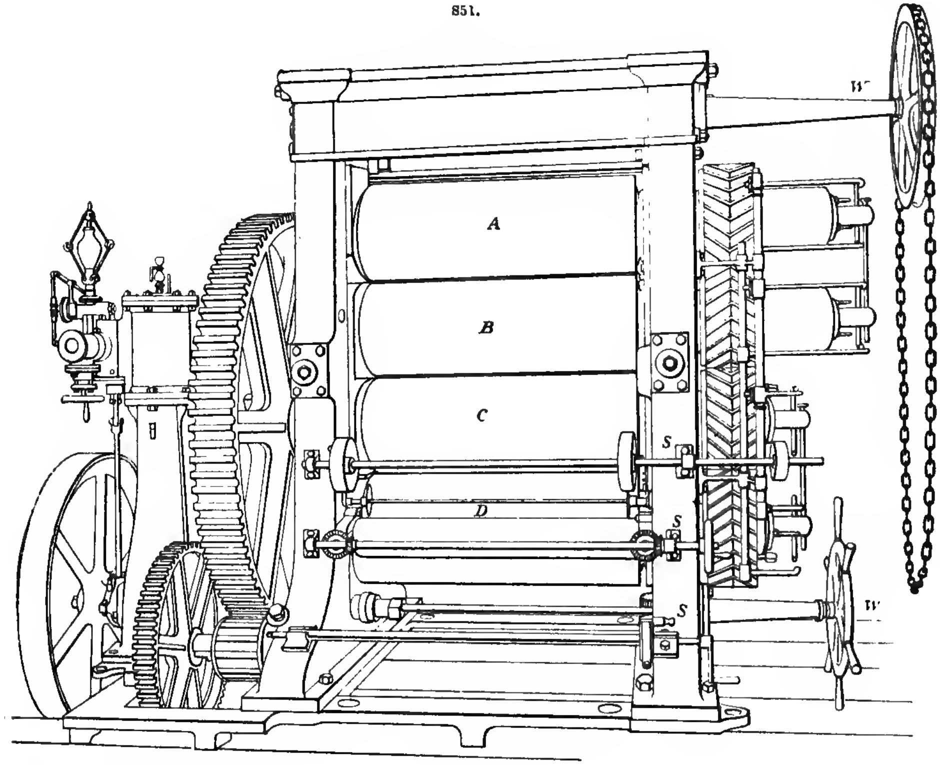

fixed for the length on the table in front of the knife, and the rubber, moistened with water, is simply pushed up to it.

Insulating Telegraph-Wires.—The methods of applying indiarubber to this purpose are:—(1) by lapping fillets on the conducting-wires, as they are led away; (2) by passing the wire and fillets between a pair of circular cutting-discs. More frequently, the two methods are used conjointly. When the core is to be vulcanized, especially if the coatings are applied longitudinally, it should be evenly, but not too tightly, bound round with a cotton or felt tape. Special care is required in preparing all the materials: imperfectly masticated rubber, or compounds not sufficiently worked in the mixing-machines, will invariably lead to failure. The selection and preparation of the pigments cannot be too carefully studied. The conducting-wire will not remain central, if the rubber is soft or overworked, nor if the pressure between the discs on the upper and lower fillets is unequal. A hard rubber will not easily unite at the edges when cut, nor will the adhesion with the previous or subsequent layers be reliable. This is the most important object to be attained. The pigments

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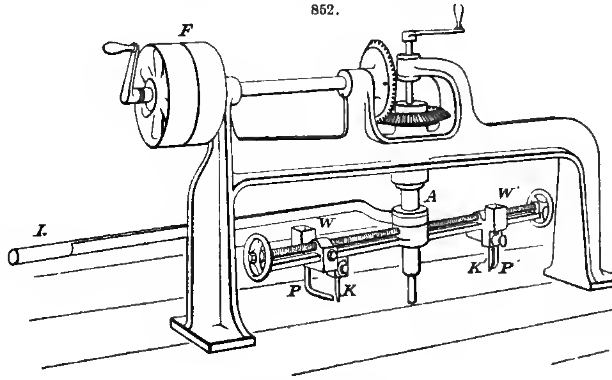
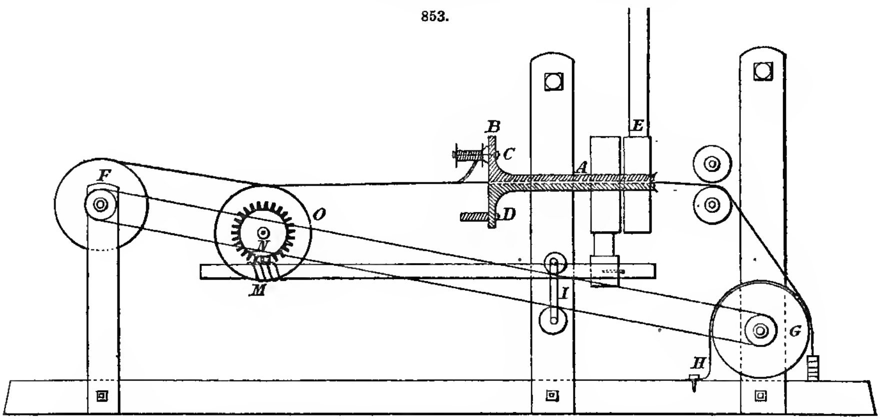


must be well sifted and dried, the grinding and mixing should be of uniform duration, and the temperature be kept as regular as possible.

Telegraph-core is cured, either on drums, when it should not be too tightly coiled on, or by being laid down loosely on long oval trays; in the latter case, several trays are superposed. Small wires may be laid in a mixture of French chalk and sulphur, or may be drawn through a tar and sulphur bath. Joints are cured generally in a mixture of beeswax and sulphur, at a high temperature; they should be tightly lapped in two or more coverings of tape. The great point being to ensure consolidation of the rubber coating, cleanliness, freedom from damp, and careful binding, must be attended to.

Indiarubber cores are largely used for torpedo and military telegraphs, from the fact that they are less easily injured than guttapercha by rough handling or heat. As an insulator, indiarubber possesses a superiority over guttapercha, in having a much higher resistance, with considerably lower capacity; in practice, however, whilst these superior merits are retained, its manufacture is not attended with that certainty of success met with in guttapercha. In the earlier days of insulating with the former, the masticated form in tape was used, the lappings were consolidated by heating, and were not vulcanized. The coating rapidly decayed on exposure to air and light. This led to the introduction of several methods of applying vulcanization to the rubber, either by mixing sulphur directly with it, or by allowing an inner coating of rubber to take up, under the action of heat, a certain proportion of sulphur from a superposed coating, so as to produce perfect vulcanization with a very small quantity of sulphur. Crystallization of sulphur takes place, when it is used in excess, and an efflorescence follows, which renders the coating porous and electrically defective. Only a few pigments are admissible in this manufacture; most metallic oxides, except the black oxide of manganese (manganic dioxide), and the puce oxide of lead, can be used, as well as their carbonates and sulphides. Soluble salts are inappropriate; earthy minerals, as French chalk, silica, &c., which are not hygroscopic, are not objectionable; asphalt, pitch, and a few resinous substances in small quantities do no harm.

853.



Indiarubber fillets are lapped around telegraph-wires by the "lapping-machine," Fig. 853. The frames are best made of wood, so as to avoid chilling the rubber in cold weather by contact with metal. In the construction, every precaution must be taken that no oil, dust, or grease can come into contact with the rubber or wire; consequently the driving-gear should all be placed under or below the machine. A hollow mandril A, carries a head-stock B, to the face of which are attached the spindle C, for carrying the bobbin of tape, and a balance-spindle D, as this machine is driven at very high speeds. To the mandril is fixed a pulley E, for driving the machine by a belt. The draw-off arrangement is worked off the same mandril by a worm-wheel M, working into a bevelled tooth-wheel N; to the axis of the same, is attached a small iron drum O, around which two or three turns of the wire are taken, and thence to the wooden drum F, where it is wound up. The wire is wound upon the drum G, which is worked by the draw-off gearing, a friction-plate or strap H preventing its going round too fast, so as to keep the wire rather tight. The drum F is turned round by a belt driven off G; this belt can be tightened or made slack by friction-wheels I, as its speed must be regulated, according to the diminishing diameter of the contents of G. The draw-off arrangement determines the length of lay; the friction on the bobbin regulates the tension on the tape, and consequently its thickness; a spring attached to the spindle can, by means of a small screw, give the necessary friction to the bobbin.

Indiarubber is applied longitudinally to telegraph-wires by means of circular cutting-discs,