SPONS' ENCYCLOPÆDIA

OF THE

INDUSTRIAL ARTS, MANUFACTURES,

AND

COMMERCIAL PRODUCTS.

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COMMERCIAL PRODUCTS.

DIVISION IV.

EDITED BY

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CONTENTS:

LONDON:
E. & F. N. SPON, 16, CHARING CROSS.
NEW YORK: 44, MURRAY STREET.
1882.

Fig. 854, grooved to the required size of the core. These cutters are movable, so as to admit of covering different sizes of wire. A stout iron frame A is firmly bolted to a wooden table. By means of the handle H, the upper disc can be lowered or raised for any final adjustment; it is essential that these discs be of exactly the same diameter, and driven at precisely the same speed. The discs D are made of Bessemer steel, about ½ in. thick and 8 in. in diameter, and are carefully turned, so that their cutting edges are just prevented from working on each other; a hole through their centres admits the spindles, which are supplied with nuts for screwing the plates P and discs D together. When more than one pair of these cutters is used, they are arranged so that the seams in the rubber coatings do not coincide; they are best at right angles to each other. Guides are placed in front of the cutters, so that the tapes entering with the wire are kept in their proper places; the portions sheared off are received in trays by the workmen. The tapes are wound up on flat circular plates, about 10 in. in diameter, which have fixed to them a circular piece of wood, corresponding in thickness to that of the tapes. The tapes must be carefully wound, so as to avoid sticking while being drawn off by the travelling of the wire, through the machine. To secure centrality, the pressure must be uniform, unequal tensions being avoided. The tapes must be of equal thickness, and, as near as possible, equally plastic; this is obtained by uniformity in grinding and calendering, and subsequent maintenance of equal temperatures. The condition of the compound must be such that a gentle pressure causes them permanently to unite at the recently cut edges. The surface of these tapes, forming the outside of the core, is varnished with shellac dissolved in methylated spirit, to prevent adhesion when wound on the bobbins.

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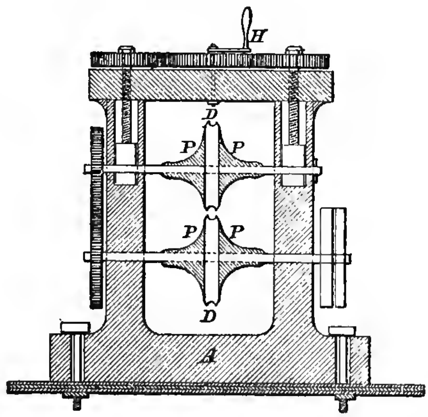

A form of cutting-disc used for making joints has the discs working outside the framework, and is moved by a handle. Similar appliances are convenient for making tubing, &c. The edges are well squeezed together, and the superfluous rubber is cut away by a rapidly revolving circular knife. Attempts have been made to use one tape only in covering wire; the air which is thus enclosed has been the barrier to its success, but it may be very conveniently adapted for making small tubing.

No material or compound is suited for an insulator unless it possesses a high resistance, and is impervious to moisture. A simple method of testing a sheet is shown in Fig. 855: E is an electrometer; W, a small weight of metal, resting on the sheet S, and occupying the central portion of its surface, so as to give a margin of 1 in. all round; the sheet is placed flat on a table or board. A dry glass rod, or ebonite tube, is rubbed with a silken cloth, and the knob of the electrometer is touched with it, when the instrument, if in good order, holds the charge thus communicated to it for several minutes, without an appreciable loss. It is now connected with the piece of metal resting on the sheet, and recharged. An idea of its insulating value is readily obtained by noting how long it takes for the pointer of the instrument to fall through any proportion of the arc to which it was originally deflected. Fig. 856 shows a simple method for testing the impermeability of a material to water. The material is made into a small bag B, which is filled with water, and closed with a metallic stopper, reaching down into the middle of the bag. It is placed in a tin box, filled with water. By pressing down the key A, the interior of the bag is charged by the battery, and on releasing A, and pressing down B, the charge thus communicated is sent through the galvanometer G. The deflection is noted. The bag is now recharged in the same way; on releasing A, the charge left in B is measured, after a few minutes, by pressing down D; the difference between these deflections will show what proportion of charge has leaked through. As sulphur rapidly destroys copper-wire, the latter should be well tinned, or coated with solder, when insulated with vulcanizable compounds.

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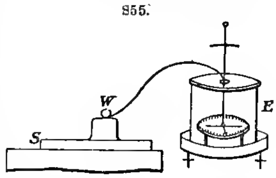

Ozokerit and paraffin-wax mixed with indiarubber have been recommended as insulating materials. Warren's "bromo-," "iodo-," and "chloro-" caoutchouc wires are made by imbedding rubber-covered wires in mixtures of French chalk and iodine, or bromine, or by immersion in solutions of these agents, or in an aqueous solution of chlorine. Rubber thus treated has all the properties of being vulcanized, and, according to the time of immersion, will be rendered soft and elastic, or hard and inelastic, like vulcanite.

Other Applications of Indiarubber.—In America, rubber incorporated with iodine or bromine, mixed with turpentine and a very small proportion of sulphur, has been used for dental purposes; it cures perfectly hard at 149° (300° F.), in short heats, and the incorporated pigments retain their bright or natural colours. Dental rubbers are supplied in the uncured state, and are vulcanized in a plaster mould. The pigments principally employed are the red sulphides of mercury and

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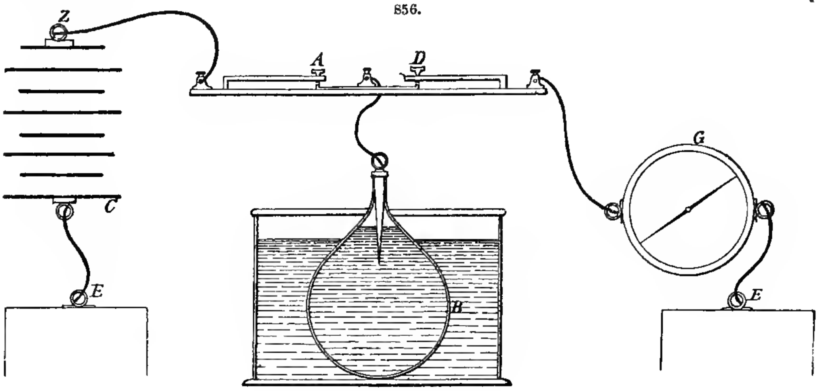

antimony, oxide and sulphide of zinc, with 40–50 per cent. of sulphur. It is important that no pigment used should be capable of being removed by weak organic acids; on this account, oxide of zinc is more often replaced by sulphide. Newborough employs a little iodine or bromine, mixed up with turpentine, which, in this form, does not act immediately on the rubber; this enables him to use a considerably smaller proportion of sulphur, to obtain a perfectly hard compound at 149° (300° F.) in a much shorter time, and in addition, the colours of the pigments are less damaged. It is very probable that the use of iodine and bromine, with or without sulphur, may lead to the introduction of less objectionable pigments than those now employed. Some of the earthy silicates are not seriously affected in colour by sulphur, when incorporated with rubber. Compounds containing red antimony are sometimes met with containing Spanish brown, rose-pink, &c. India-rubber mixed with phosphorus was patented by Parkes for producing moulds for electrotyping. Rubber is extensively used for giving a body to petroleum oils, when used for lubricating.

Curing or Vulcanizing.—When indiarubber is mixed with sulphur, and heated sufficiently, it acquires properties strikingly different from those of the original article. The tests which are now accepted as evidence of vulcanization may be contrasted with the behaviour of unvulcanized rubber under the same agents:—

Unvulcanized or Raw Rubber.	Vulcanized or Cured Rubber.
Heat.—Cannot be heated above 115° (240° F.) without decomposition setting in; if not at once visible, becomes very perceptible in a few days at most, especially on exposure to air or light. Heated to 118°–121° (245°–250° F.) for a little time, becomes soft and sticky, and finally is converted into a viscid liquid. Becomes quite hard at 4° (40° F.), and is readily softened by being held before a fire, or plunged into water heated to 21° (70° F.).	May be heated above 115° (240° F.) without any visible change, and does not become soft or sticky if heated for hours at 121° (250° F.). Higher temperatures, as 132° – 138° (270° – 280° F.), continued for a few hours, may render some goods soft and clammy, which is regarded as indicating imperfect manufacture. No change is perceptible when placed in a freezing-mixture, unless the rubber is imperfectly vulcanized. Water heated to 21° (70° F.) has no marked effect on its hardness. The effect of cold is more readily perceptible than that of heat on imperfectly cured rubber.
Stretching.—When stretched and kept drawn out for a little time, will retain more or less its elongated condition, and, if heated, will return almost to its original length.	Should be perfectly elastic or nearly so. Imperfect vulcanization is soon perceived by stretching, and measuring its increased elongation. Heat causes it to return slowly to its original length; if more thoroughly cured, it has scarcely any effect in this direction.

Unvulcanized or Raw Rubber—*continued.*	Vulcanized or Cured Rubber—*continued.*
Solvents.—Coal-tar naphtha dissolves it slowly, but soon renders its surface slimy and sticky. Other forms are more readily acted on by solvents, and yield in a few hours a gelatinous-looking mass. On evaporation, the rubber is left more or less sticky; by completely driving off the naphtha, the rubber is recovered either with its original properties unaltered, or perhaps a little soft. Inferior rubbers will remain sticky.	Unless highly cured, swells a little, but does not become sticky; if highly pigmented, it is rendered short and inelastic. It is not made sticky, unless under a very prolonged immersion, and heating. On evaporating off the solvent, the properties of the rubber are found unaltered, if of good quality.
Roasting.—Quickly passes into a tarry condition, and emits a peculiar odour, not garlicky, nor sulphuretted. The uncharred portions quickly pass into an unctuous mass, after a short exposure to the air.	Chars on the parts exposed to the heat, but does not so easily melt, and emits an offensive smell of garlic, which is modified by the proportion of sulphur. The uncharred portions remain unaltered if exposed to the air.
Sulphur.—Immersed in molten sulphur, it is converted into vulcanized rubber.	Thoroughly vulcanized, is not affected, but more or less effect will be produced as the rubber is imperfectly saturated with sulphur.
Uniting.—The freshly cut edges are easily joined by pressure with a little heat.	The freshly cut edges may show a slight tendency to unite, but a joint cannot be made without proper appliances, especially if well cured.

Vulcanized rubber is obtained either by heating indiarubber mixtures containing sulphur, or by immersing indiarubber in sulphur or mixtures containing sulphur. Chloride of sulphur, iodine, bromine, chlorine, hypochlorous acid, sulphurous acid, chloride of arsenic, and a few other chemical agents, have an action on indiarubber approaching vulcanizing. This "changing" of indiarubber was discovered by Parkes; it is now known as "cold curing" or "semi-curing." Chloride of sulphur is the only agent employed on a large scale. Warren's method of treating telegraph-wire has been already mentioned.

The present methods of vulcanizing, which will be considered here, are:—(1) when sulphur and a high degree of heat are employed—(*a*) the "water cure," where water heated by steam is the medium for heating; (*b*) the steam heater, where direct steam or a steam jacket is used; (*c*) hot air, or dry heat; (*d*) sand-bath; (*e*) high-boiling liquids; (*f*) sulphur, alone or in compounds, used in a molten state; (*g*) metals, either molten or heated surfaces. (2) Injecting hot air or gases, steam, water or other fluids, or metal, into the article to be vulcanized. (3) When little or no heat is employed, and chloride of sulphur and similar changing agents are used.

Circumstances arise where each of these methods is specially applicable; there is, however, a difference of opinion on the merits of some as compared with others where the same objects are to be attained. The different methods of heating are worthy the attention of the general manufacturer, because although he may not often require to use them, conditions requiring special treatment in vulcanizing frequently crop up. Some of these methods are applicable for heating any particular part of an article, when over-curing would result from re-heating the whole. Jointing telegraph-wire long lengths of hose-pipes, &c., requires contrivances not found in every factory, and which are useful in other ways, and for other purposes.

(1—*a*) The water-heater is simply a short boiler set on end in the ground, and is usually employed for curing sheet packing. It is most important that the articles should be well bound up, and immersed completely in the water. The heat is run with a thermometer dipping into the water, and the steam is injected into the centre of the heater. The degree and duration of the heating are the same as in steam-curing. The principal advantage of these heaters is that longer lengths of packing can be cured at one time, than would be possible with the steam-heater, without giving extra length, which, in many cases, would scarcely be convenient. To this must be added the fact that blistering is not so frequent if the sheets are well rolled upon the drum, and probably this capability of binding and wrapping, which would not be possible if the sheets were laid out flat, unless at great trouble and expense, gives an extra safeguard against damage by blisters. The packing is run taut upon a drum, with canvas, to prevent sticking, and is well wetted at the same time. When cured, it is, whilst hot, laid out flat on a smooth table, to cool. The allowance for shrinking and thickening by contraction is more easily made, and can be more depended upon, than when running in steam. The fabric used for binding is strong canvas.

(1—*b*) The ordinary steam-heater is similar to a steam-boiler; its opening is fitted with a strong iron cover, secured by bolts and nuts. The goods are packed in French chalk, on an iron carriage, running on a set of small rails. The carriage is drawn out by a rope and windlass.

Steam-heaters for curing telegraph-wire have been made to open at each end, the object being to pack the carriage at one end, whilst the heat is being run with core packed on a similar carriage at the other end; when one is drawn out, the other is ready to go in. Steam-heaters should be well covered with felt, brickwork, &c., to avoid loss of heat, draughts from open doors, &c. In curing goods by steam, much care must be exercised, as fabrics cannot be heated without having their strength more or less impaired. The compounds used should readily vulcanize at the lowest temperature, and the thickness of the goods should not be such as to retard the heating, and lead to some parts being over-vulcanized, and others only slightly cured. The only way to avoid this is to heat very gently for some time, so as to make sure of an equal distribution of heat, and to use pigments which will assist the vulcanizing, either chemically or mechanically, e. g. the better conductors of heat. There are several special kinds of steam-heater in use for curing belting, valves, hose, tubing, joints in telegraph-wire, and coated fabrics. Double or jacketed heaters are used where condensed steam would spoil the goods; and the extra precaution may be taken of wrapping the latter in waterproof cloths.

(1—*c*) The hot-air heater is made so as to revolve, or, if stationary, the goods themselves are turned on a drum. A series of gas-jets, burning in a close cupboard or chamber, makes a convenient heater; the only precaution needed is to place over the jets a sheet of metal, to avoid the direct scorching heat of the burners. A spindle, passing through the ends, carries a drum, on which the articles are packed; by means of a handle, continuous or intermittent motion is given.

A special form of heater is made for dentists who cure their own forms for gums, &c.; the heat is obtained either directly from a gas-burner, as in a stove, or through the medium of steam, generated from a small boiler attached to the stove.

(1—*d*) The goods are imbedded in sand, French chalk, &c., in a bath which is heated by gas.

(1—*e*) The goods are immersed in glycerine, covered up, and placed in a steam-heater, or direct heat may be applied by a sand-bath. Solutions of the alkaline and earthy polysulphides have recently been introduced for curing. Under heat, they yield part of their sulphur to the rubber.

(1—*f*) In curing with the sulphur-bath, the article to be vulcanized abstracts the requisite amount of sulphur; the same takes place, though not so well, with heated tar and sulphur, or beeswax and sulphur. In these methods of curing, the heat is applied much higher at the start than with steam —generally 127°–149° (260°–300° F.), consequently much less time is required. If the articles are bound up, the material should be capable of allowing the sulphur to pass through; they should also be kept gently moved during the whole time. Immersion in water immediately after the sulphur-bath, renders the adhering sulphur less troublesome to remove. Articles made from masticated rubber are more generally cured in this way, and are more durable than if ground with sulphur in the mixing-machines. A mixture of beeswax, sulphur, and rosin, is largely used for curing joints in telegraph-wire. The mixture is heated to about 138° (280° F.), when the joint, well bound with tape, is immersed in it; the heat is raised to 149°–160° (300°–320° F.), in about 20 minutes, and the joint is kept at the same temperature for 1–2 hours. It is essential that sulphur be in excess in this mixture, otherwise it will be partially abstracted from the article to be vulcanized.

(1—*g*) The press shown in Fig. 857 is now extensively adopted for curing large valves, belting, &c. It consists of two parts: the bottom A is stationary, whilst the upper B is movable; the whole is connected with a strong framework F, which supports the gearing for raising or lowering B. In the belt-press, A B are quite flat; for valves, A is cast with a rim or edge, so that B fits closely into it. The surfaces of A B must be quite smooth. The article to be cured is laid perfectly flat on the bed-plate A, and B is carefully lowered down upon it; the two parts are firmly clamped together by the screws and nuts S; steam is admitted into A B, so that the article is in reality cured by means of the heated metallic surfaces of the two steam-chambers. Loss of heat is avoided by coating the chambers with felt. The lower plate of the belt-press may be grooved to the width and depth of the belt; but more conveniently, shifting-plates are used, grooved to fit the belt, and having a flat iron bar, of exactly the same width, placed on them. The upper plate is lowered, steam is admitted as before until the portion in the press is cured; this is then drawn through, so as to admit of another section being cured, and so on. Belts thus cured have good square edges, and the pressure used causes the layers or plies to adhere more firmly together. Blowing or blistering, from dampness in the cotton, &c., is avoided by puncturing the uncured belt at a little distance from the press; the punctures disappear in the press. About 20 minutes is required for curing each length of belting. Red-lead and similar pigments which assist the curing are used in the compounds. Besides curing rapidly, it is equally essential to cure with as low heats as possible, so as not to weaken the fabrics forming the plies of the belt.

A press or heater for curing joints in telegraph-wire consists of a small upright boiler for generating steam. A jacketed tube longitudinally divided A B (Fig. 858), is attached to the boiler, in such a way that the parts can be brought together, and enclose, in their annular space, the joint to be cured or vulcanized. After clamping the whole together, steam is admitted into the concentric spaces through I, the condensed steam being led away by attaching rubber tubes at O.

Many small articles are cured in metallic moulds, under pressure in the press, or in open steam. For many kinds of goods, it is important that the metals forming the moulds should not be readily acted on by sulphur during the heating, as a portion of the sulphur would be abstracted, and leave a stain of the metallic sulphide on the goods; consequently, sheets of packing, if cured in the press, are prevented from coming into contact with the metal, by sheets of cloth or paper. Tin is the most convenient metal for resisting the action of sulphur; zinc sulphide, being white, indicates the suitability of zinc for coating moulds, &c. All new zinc surfaces should be well cleaned before use; a good plan is to dust them over with sulphur and French chalk, and heat them in the steam cure several times, or they give rise to very troublesome blistering. Boiling with caustic soda helps to prevent this, but is not certain in its action. Brass moulds should be well tinned. Ebonite, or hard-cured rubber, forms very convenient moulds, well adapted where metallic surfaces would be objectionable, from staining, &c. Stains from tin moulds or tinned surfaces are removed by leaving the cured articles in hydrochloric acid for some hours.

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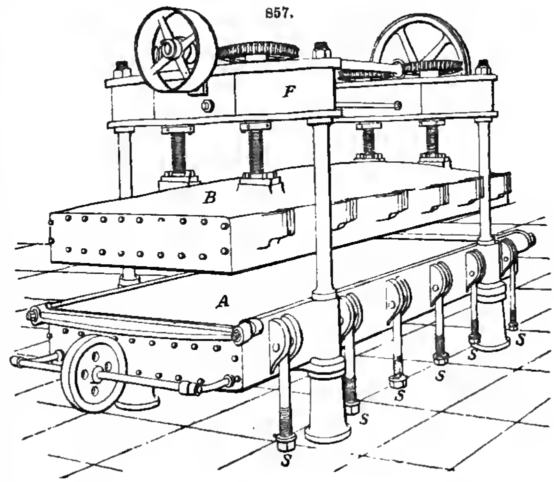

Fusible alloys, mixtures of tin, lead, antimony, and bismuth, melting at low temperatures, have been proposed as curing media.

(2) Canvas hose is sometimes cured by passing steam through it; the strength of the fibres is less affected, and the liability to loosen the coating by dampness through the fabric is entirely avoided, as the steam comes into contact with the rubber surfaces only.

In water and steam heating, the temperatures are now indicated by thermometers, pressure-gauges being found unreliable. It is usual to reach the maximum gradually, so as to allow the articles to get thoroughly warm and softened, without the vulcanizing action setting in. When the heater is closed up, ½ hour, or even much longer for thick masses of rubber, is usually required for reaching the first 66°–93° (150°–200° F.), which should be kept up for 30 minutes or so; during the next 30 minutes, the temperature may be allowed to rise to 115°–121° (240°–250° F.), which is maintained for 1–2 hours; the temperature is again gradually raised to 138°–144° (280°-290° F.), and kept constant for 1–2 hours. Very thick masses of rubber may require several hours for curing. Heats too rapidly changed cause blisters or sponginess, followed with bursting of the mass, even if enclosed in strong iron moulds. Vulcanite or ebonite is finished off at 149° (300° F.).

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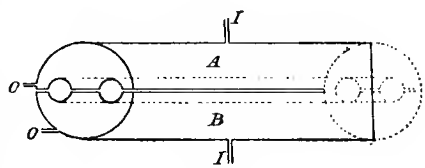

(3) Parkes' process of vulcanizing with chloride of sulphur is extensively used for surface curing, such as single textures for garments, and sundry small articles manufactured from masticated sheet rubber, as tobacco-pouches, tubing, rings, &c. The chloride is mixed with 30-40 times its bulk of carbon bisulphide for ordinary fabrics; but for solid rubber goods, much more dilute solutions must be used, and a longer immersion allowed, than with stronger solutions, since the surfaces would be overcured, and crack. Chloride of sulphur in vapour is preferable in many cases to the mixture in carbon bisulphide. The articles are then suspended in a lead-lined chamber, well varnished with shellac, and heated by steam-pipes; the chloride is gently evaporated, either by placing it in an open dish on the steam-pipes, or by using a small retort, the end of the tubulure of which passes into the chamber. The chloride is evaporated by a small gas-burner. Chlorine, bromine, hypochlorous acid, and several other vapours, can be used in the same way. Although Parkes uses these vapours with solvents of rubber, they act equally well, and in many cases more certainly, without them.

Several improvements for curing double textures have been recently introduced, the most important of which is the Silvertown process. This consists in passing the rubber surface of each piece to be united over a roller, revolving in a mixture of chloride of sulphur and bisulphide of carbon; the acid mixture does not come into contact with the fabrics, so that no injury can happen either to the colour or the fibres, and the most delicate tissues can be treated. Another process, patented by Anderson and Abbott, effects the curing by suspending the fabrics or completed garments in a chamber, which is afterwards charged with the vapours of chloride of sulphur; it is questionable how far this method can be depended upon, without injury to the fabrics. If the colours are discharged by the chloride of sulphur, they are brought back by placing a dish of liquid ammonia in the drying-room.

Single textures are cured by passing the coated surface over a roller, revolving in the curing-mixture, as above. The fabrics are run on to a large drum, and the cured surface, which is still sticky, is kept from coming into contact with the cloth surface, by making the drum pick up a roller whenever its arms pass the frame which supports them, so that between each two layers of material there is a space of about 2 in.; as soon as the bisulphide has nearly all evaporated, the fabrics are run on to a roller for hanging up.

Indiarubber Paints or Varnishes.—Indiarubber paints or varnishes can be made by mixing pigments with a little thin solution in some easily volatile solvent; after the solvent has evaporated, the film of rubber can be cured by the application of a little of the cold-curing liquid. The pigments easily retain their colours when applied in this way; but if mixed up with oil, they are not so elastic after a little exposure, and become harsh, and crack.

Varnishing Indiarubber Textures.—Single textures, when cured, are well wiped over, and varnished with shellac dissolved with liquid ammonia in water. Lamp-black is added for black goods; bleached shellac or seedlac is best suited for white or light-coloured goods. The varnishing is performed by passing the fabrics over a roller running in a trough of varnish, or better still, by letting the varnish fall on the rubber surface. It spreads of itself, the excess being removed by passing under a close-fitting scraper or pad. It is dried by running over a large drum or cylinder, heated by steam. Small articles are varnished by a soft sponge.

Joining Indiarubber Textures.—Cured or uncured fabrics are joined for garment-making and other articles by cementing together with thin solution. Camphene was largely used a few years ago for softening the edges of rubber for uniting. It leaves the rubber more sticky than any other solvent does. Its present price precludes its use on a large scale. Several coatings are applied, each being allowed to get nearly dry before the next is rubbed on; the two adhesive surfaces are then well rolled down by manual labour, and the excess of cement which oozes out is rubbed off, when nearly dry, by a piece of masticated block rubber. Double textures are stripped, so as to cement the rubber surfaces, by applying first a little solvent, which renders the stripping-off easier. In spreading, it is necessary to coat one of the fabrics with less pressure, so as not to drive the rubber into the meshes of the cloth. Such coatings are specially designated "stripping-coats." Without such arrangement, double textures could not be made with watertight seams.

Testing Cured Goods.—Well-cured rubber should swell but slightly in cold tar-naphtha, and leave no imprint of the finger-nail when pressed into it. On stretching, it should draw out evenly; sudden or gradual extension should produce but little, if any, permanent elongation. Defects in curing are air-cavities and blisters due to insufficient sulphur, heat, or moisture, when the articles may be spongy and soft, though tolerably well cured. Over-curing imparts a harshness to the surface. Under-cured rubber is clammy, more or less adhesive when the freshly cut edges are pressed together, swells readily in naphtha, and retains a considerable elongation on stretching. Buffers, springs, &c., are tried in a screw-press for two or three days. Diving-dresses, fishing-boots, powder-bags, &c., are filled with water, and allowed to stand for several hours. Steam is used for those articles made of solid rubber; any defect is rendered visible in a few minutes by damp spots appearing on the surface. Fire-hose and other strong tubes are tested by forcing water in until the required pressure is shown on a gauge. Defective proofing is shown by taking a piece of the fabric, with the rubber surface upwards if a single texture, and placing it over a sieve or deep hoop, so as to hold water; after some hours, water will have leaked through to the under side, if the proofing is imperfect. A test used by the Admiralty for vulcanized rubber and sheeting is as follows. The sample is placed in a hot-air oven B (Fig. 859); through the cover C passes a thermometer T, reaching down to within a very short distance of the surface of the sample, which should rest on a flat clay-tile, reaching about half-way up, as shown by the dotted line. The temperature is first raised to 132° (270° F.), the sample is placed in the oven, and the dampers are carefully adjusted, so that this temperature can be kept constant for one hour. A Bunsen's burner is a convenient method of heating. No stickiness should be perceptible with a perfectly cured sample, when, after heating, it has cooled down to the temperature of the air.

As petroleum acts energetically on vulcanized rubber, steam-valves for marine and other engines have become specialties with the leading indiarubber manufacturers. The distention produced by these mineral oils at 100° (212° F.) affords a ready test for the suitability of a compound for steam-valves; a good valve should remain firm, and swell slightly, after several hours.

Efflorescent sulphur is removed from the surface of vulcanized goods by boiling for some time in a strong aqueous solution of caustic soda. Fabrics are washed over with the same solution, and well dried. Carbon bisulphide can be used for this same purpose. The boiling process is called "devulcanizing," but more correctly is desulphurizing. Deodorizing is effected by exposing the goods to air and charcoal; bleaching is rapidly performed by exposure to sunlight in the open air.

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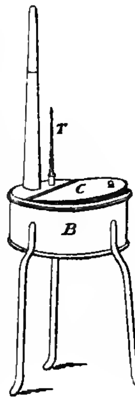


Pigments.—A manufacturer should know whether his pigments are what they are represented to be. The following simple tests will answer generally for the more important:—

Sublimed or flowers of sulphur, stirred into distilled water, should only slightly redden litmus-paper, as sulphurous acid modifies the action in curing. It should entirely disappear when heated, and should readily yield about 60–70 per cent. of its weight to bisulphide of carbon. Ground sulphur has been lately introduced as a substitute for the above. It agrees with it, except in that it entirely dissolves in a little bisulphide of carbon. It should be a more acceptable agent for curing than the preceding. Milk of sulphur should entirely dissolve in bisulphide of carbon, and disappear when heated in a porcelain dish.

Sulphide of antimony is readily soluble in sulphide of ammonium. A solution of tartaric acid should take up only a small proportion of soluble salts or oxides, which are precipitable by sulphuretted hydrogen from this solution for estimation. Bisulphide of carbon should remove 25–40 per cent. of sulphur, and leave a perfectly bright-red residue.

Oxide of zinc, shaken up in a test-tube with sulphide of ammonium, should be only slightly darkened by traces of lead and iron. A slight insoluble residue (silica, sulphate of lead, &c.) should remain after treatment with dilute sulphuric acid. The filtered solution, neutralized with ammonia, and the same added in excess, and left in a warm room for some time, should show only a slight deposit of hydrated sesquioxide of iron. The filtered solution, strongly acidified with nitric acid, treated with solution of molybdate of ammonia, and allowed to remain in a warm place for 24 hours, should yield only a very slight yellow precipitate, due to arsenic.

White-lead and litharge, if pure, dissolve readily in nitric acid. Commercial litharge yields an insoluble residue (fine sand, &c.) of 17–18 per cent. Insoluble matters in white-lead ought to be insignificant. It is sometimes adulterated with sulphates of lime and baryta. The nitric acid solution, submitted to the action of sulphuretted hydrogen for a long time, and the clear portion evaporated, should show but a very slight residue, principally iron.

Red-lead, digested for a short time with fuming nitric acid, and then largely diluted with water, should dissolve easily. The solution, treated as above, should give little or no residue when the liquid filtered off is evaporated. It is not so largely adulterated as has been stated.

Caustic lime should effervesce but slightly with hydrochloric acid, and should leave a small quantity of undissolved matter (silica and small pieces of flint). Hydrated carbonate of magnesia is entirely soluble in dilute sulphuric acid; lime, if present, should not exceed 1–2 per cent. The loss due to carbonic acid is about 33 per cent., and to water, 30 per cent. (see Acid—Carbonic).

To test for moisture, a weighed quantity of the substance is placed in a desiccator for about 24 hours. The sulphuric acid in the dish absorbs the moisture, and the sample is reweighed. Moisture in pigments is a source of serious trouble, consequently everything should be well dried, and kept free from damp. As sulphur oxidizes on exposure to the air, especially in a warm place, it should be kept well covered up when sifted.

The pigments which are incorporated with rubber and sulphur have different effects, as they may retard or assist the vulcanizing. Red-lead and white-lead assist the curing, probably by forming sulphurous acid when heated with the sulphur, or by giving up their oxygen to the rubber. They are converted into sulphides by curing. Caustic lime and magnesia (hydrates) have an accelerating influence, when used in small quantities; in larger quantities, lime will yield hard compounds at much lower temperatures, and in shorter time for curing, than if sulphur alone had been used; these substances are probably converted into sulphides, for when a piece of this rubber is broken, and slightly moistened with an acid, distinct traces of sulphuretted hydrogen are perceptible. Carbonates of lime (whiting) and magnesia (hydrated carbonate) do not behave in this way. Magnesia hardens the rubber, by its absorptive properties; and the same may be said of French chalk, baryta, and similar pigments. Oxide of zinc retards the curing; it is not certain whether it is converted into sulphide, although rubbers containing much oxide of zinc require more sulphur

If the oxygen were liberated in the same way as with lead oxides, or caustic lime, a similar result might be expected; this not being the case, it is possible that if a sulphur acid be formed, it is taken up by the zinc.

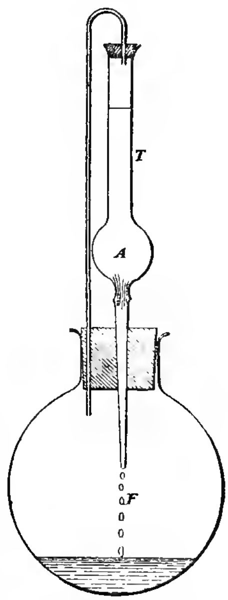
It is said that metallic sulphides will cure in the same way as sulphur. This admits of easy contradiction, for if the sulphides of antimony, arsenic, lead, and zinc, be deprived of their free sulphur, no curative action is visible. The presence of chloride of arsenic in sulphide of arsenic containing no free sulphur will explain the curing action of this pigment. Sulphide of zinc does not retard the vulcanizing action, like the oxide does; and goods containing this pigment retain a purer white colour.

For the purpose of colouring, only those metallic compounds can be used whose metals yield sulphides of suitable colour, or which are not easily converted into sulphides from the combination which is employed. Oxide of chromium yields green; sulphide of antimony, red; of mercury, crimson; of arsenic, yellow; of cadmium, yellow; of zinc, white; of lead, black. Spanish brown, and other mineral silicates which are not easily decomposed by strong acids, can likewise be used as colouring matters. Blacks are also obtained with lamp-black, vegetable-black, and graphite. The sulphides of tin have not been used, although they are very permanent.

The amount of sulphur absolutely necessary to vulcanize any particular class of goods depends upon the uses to which they are to be applied. From 1½ to 2 per cent. of sulphur will, with a heat of 138° (280° F.) for 2 hours, and ½ hour for getting up the heat, cure Pará rubber perfectly, provided that the mixture is not overworked or ground too much. Vulcanized rubber used for mechanical work contains 5–7 per cent. of sulphur; ebonite, and hard goods, 30–50 per cent. Where small quantities of sulphur are required, it is better to use precipitated or milk of sulphur; it is more easily soluble in the naphtha for spreading, and thus becomes more evenly distributed. The sulphides of antimony and lead contain their free sulphur in this form. The proportions used are equivalent to adding 2–5 per cent. of sulphur to the rubber.

The quantity of free sulphur in these compounds is readily ascertained by percolation in a filter-tube with carbon bisulphide. A filter-tube T, Fig. 860, is plugged with a little asbestos A in long fibres; any loose particles are removed by pouring in some bisulphide; a weighed quantity of the sulphide is placed in the tube, sufficient bisulphide is poured over it to moisten it, and after a few drops have passed through into the flask F, the filter should be filled up, and the tubes connected as shown. The flask is fitted with a cork containing two perforations, one for the filter-tube, the other for a bent glass tube, which passes into a cork at the top of the filter; in this way, the exhaustion goes on out of contact with the air. The flask should be carefully dried and tared. After the sulphur has all passed into the flask, the latter is fitted with a bent tube, and placed in a beaker of hot water, so as to drive off the carbon bisulphide into a cool receiver, connected with a suitable condenser. The weight of sulphur is determined by reweighing the flask. Carbon bisulphide should always be evaporated by means of warm water, and out of contact with flame.

860.



Moulding, &c.—Few shaped articles can be cured with certainty without some support. Compounds which are sufficiently firm to retain their shape tolerably well, when heated, are simply imbedded in French chalk; most articles, however, are cured in moulds, either of iron or of brass, having the exact size and form of the required article. For solid goods, the rubber is forced into the moulds under pressure, which is kept up until they are cured. Hollow goods are placed in the moulds in segments, which are joined together, and before being closed up, a little water or carbonate of ammonia is introduced; the article is then placed in its proper mould, clamped, &c., ready for curing. The water or ammonia expands during the heating, and causes the rubber to completely fill up the mould. Buffers, springs, and washers, are moulded in long cylindrical iron moulds, accurately turned inside; a spindle passing through the centre forms the required hole, and serves to clamp the ends of the moulds tightly together; when cured, the springs are removed from the moulds, and cut up in a lathe into washers, or any desired thickness of buffers. An unsoiled thin calendered sheet is sometimes rolled up on a spindle or mandril, taking care to exclude all air from the folds, and rolling evenly on a hard surface; a binding of cloth is applied as tightly as possible, which serves as a mould in curing. Small washers or rings are cut from these in the same way as buffers, a wooden mandril or spindle being passed through the central hole formed by the wire or rod on which the sheet has been rolled. Small articles are conveniently formed by repeatedly dipping moulds or forms into a solution of indiarubber, and drying after each immersion, until the required thickness has been given to the article.

Mats are formed by perforating the calendered sheet by punches, so as to give the required device; the design is first stencilled in chalk or whiting on the sheet, the parts are removed so as to leave the design or pattern, when it is cured in French chalk.

Compressed paper-pulp, plaster of Paris, and vulcanized rubber itself are frequently employed for moulds in curing. Vulcanite sheets are cured between sheets of pure tin-foil, smeared over with lard-oil, or, to avoid soiling with metal, sometimes between sheets of hard cured rubber.

The plies of belting, hose, hemp or rope packing, &c., are put together by manual labour; each ply is well rolled down by pressure. Corrugated rollers are sometimes used to give rough surfaces to washed or calendered sheets of rubber. Rubber compounds are frequently calendered on fabrics which are cured with the goods, and stripped off afterwards. This stripping is facilitated by well damping the cloth with water; if this is ineffectual, a little naphtha should be applied after thoroughly drying off the water. In such cases, the fabric itself forms the mould by keeping the article in shape. Telegraph-wire is kept cylindrical by a lapping of felt or other fabric.

A very convenient metal or alloy for moulds or shapes is a mixture of tin and lead, which can be recast with trifling loss for any altered design. The stain left by iron moulds can be removed by dilute sulphuric acid.

Dipping forms or moulds into solutions of rubber, and allowing the solvent to evaporate, is a very convenient way of obtaining many small articles, which are required to be seamless and smooth; the mould is removed either before or after the article is vulcanized.

Vulcanite is stamped into various forms or devices by cutting-dies; the hard cured material is made warm before being placed in the press; the dies are made of well tempered steel. Combs and similar articles are stamped out by cutting-dies in the same way. Tubing or sheet can be readily bent to any required form, when heated over a gas-jet, until it becomes soft. In a lathe, vulcanite admits of being turned or worked like wood or metal. It is polished by means of a cloth buff, running at about 800 rev. a minute, with brick-dust and oil. Vulcanite is used for insulators for aërial lines of telegraph, cells for galvanic batteries, photographic baths, &c. Battery cells and insulators are tested electrically by being filled with water, slightly acidulated with sulphuric acid. Vulcanite has almost entirely replaced glass for frictional electric machines. With the ordinary silk rubber, it yields negative electricity.

The principal articles made from soft rubber are valves, springs, buffers, washers, tubing, packing, and telegraph-wire; spread on cloth, it is largely used for pontoons, garments, balloons, diving-dresses, sheeting, garden-hose, canvas packing, belting, invalid mattresses, &c. From hard rubber or ebonite, acid-pumps, battery cells, insulators, tubing, rod, sheet, photographic, surgical and sundry vessels for holding chemical liquids. Kamptulicon is manufactured by incorporating cork-dust with waste rubber (see Floorcloth—Kamptulicon).

Reworking Rubber Compounds.—For some years past, indiarubber manufacturers have endeavoured to utilize the parings of vulcanized rubber, old valves, packing, &c. So inferior is the product, that it is only suitable for very low-class goods; hence it is that old vulcanized rubber realizes such a small price compared with the new article. Numerous patents have been devoted to the object, such as grinding with water, naphtha, caustic alkalies, acids, &c. Generally the rubber is ground dry between a strong pair of grinding-rolls. Ground waste being liable to spontaneous combustion, it should be carefully watched, and kept in a cool place. A short time ago, it was much used for stuffing chairs, &c. Numerous cheap articles are now made from ground waste, by agglutinating with dough or solution, compressing, and curing. Compounds containing ground waste cure more readily than fresh rubber. In purchasing rubber for reworking, it is difficult to give any very definite tests as to its value. Most manufacturers mark their goods, which is of great use in selecting old valves, buffers, &c. Hose-cuttings and belting, before being cured, are ground up together, and are very useful for packing, to withstand attrition or other rough treatment. As woollen cuttings cause blisters and sponginess, care must be taken to separate them from cotton cuttings, by sorting, or by boiling in caustic alkalies when the fabrics are mixtures of wool and cotton, or silk and cotton. Forster and Heartfield proposed the use of wool for indiarubber sponge. By heating, the wool is easily charred, and the moisture or gases generated give the rubber a honeycombed structure.

When vulcanized rubber is strongly heated in a closed vessel under pressure for some hours, and the liquids produced by its decomposition are distilled off by superheated steam, or removed by compression, a soft mass is obtained suitable for incorporating with fresh rubber. Vulcanite waste is reworked by being finely ground, when it can be incorporated with fresh uncured material. When thoroughly cured, it cannot be jointed nor repaired; but if slightly cured, adhesion between it and new material can be successfully secured. Hence large masses should never be cured thoroughly in the first heating.

Rubber Substitutes.— Under the name of "artificial rubber," several compounds have been introduced with more or less success. The basis of the most important are oxidized and vulcanized oils (see Floorcloth; Oils). Lake's "improved artificial indiarubber compound" consists of saponified resins and vulcanized oils, which are incorporated with indiarubber or guttapercha, and vulcanized in the usual way. In Day's "improved substitute for indiarubber," the oils are partially saponified by acids, and are then heated with sulphur, &c. These acid compounds cannot be used in the manufacture of fabrics, as the heating would destroy the fibre. Bruce Warren's "thionoline" or vulcanized oil consists of linseed-oil, or other drying oils, vulcanized by adding sulphur at high temperatures. Oils vulcanized by chloride of sulphur are obtained by treating similar oils with chlorinated sulphur, or sulphur chlorides; the principal objection to these compounds is their acid qualities, which prevent their being used with fabrics, or certain pigments. Leather parings and wool have been proposed as substitutes, when previously treated with chloride of sulphur, or heated in molten sulphur. Oxidized oils have also been proposed, but have not been so successfully employed. A material called "vulcanized fibre" has lately been introduced. It consists of animal or vegetable fibre, paper-pulp, &c., mixed with vulcanized oil and glycerine, and calendered or spread by some such arrangement as Clark's machine, shown in Fig. 849, p. 1148.

Guttapercha in many of its properties agrees with indiarubber, and is manufactured for some of the same purposes. At 100° (212° F.), it is soft and plastic, but regains its firmness on cooling. By destructive distillation, it yields oily hydrocarbons. It is soluble in the same menstrua as indiarubber. It is cleansed or freed from its impurities first by slicing into very thin laminæ, being forced against a revolving wheel or disc, furnished with radial knives or blades. These parings are thrown into cold water, when the heavier impurities sink; the floating portions are passed on to another tank, containing boiling water; in this, it is softened by boiling, so as to allow sand, particles of wood, &c., to separate out; it is then collected in a machine called a "ticker" or "teazer," in which it is still further torn up in warm water. According to the class of goods required, this operation is carried to a greater or less extent. It is then worked in a closed masticator for some hours with hot water, kept warm by injected steam; and is finished off in another masticator, first heated by steam, to expel all traces of moisture. Whilst plastic, it is strained through very fine wire gauze, by means of hydraulic pressure. The portion of the press holding the guttapercha is jacketed, so as to admit of being kept quite hot by steam or hot water. For stowing away, it is not kept in blocks or masses, like indiarubber, but is calendered into sheets about $\frac{3}{8}$ in. thick. Calendered into very thin sheet, it is largely used for surgical purposes, and for protecting goods against damp. Machine-bands, cord, tubing, buckets, and tanks for electro-plating, are the principal articles manufactured, except cores for telegraph purposes, for which it is eminently adapted. For this purpose, however, the raw article is carefully selected.

Articles are moulded from guttapercha, by working it by hand, whilst in a soft and plastic state, into the required form; it needs very careful, though not skilful, labour; to prevent it sticking to the hands or fingers, they should be wetted with water containing a little soap, taking care to remove all traces of moisture when jointing is required. It is kept soft in water heated by steam. Picture-frames and similar articles are made in metallic moulds. Cord, tubing, and telegraph-wire, are made by forcing the plastic material through dies of special construction, from which the articles traverse a long tank of cool water. To increase the cooling action, telegraph-wire is passed backwards and forwards several times. The moisture must be removed before another coating can be applied. Telegraph-wire is carefully overhauled after each coating, and any defect is cut out or repaired by an operation called "tooling." A heated iron is applied to the guttapercha, and is carefully moved about, so as to work it well together over the defective part. The wire, or as it is now called, "the core," is passed first through a heated mixture of guttapercha, rosin, and Stockholm tar, and then through the dies, to receive a second coating of guttapercha. When cooled, the overhauling, and coating with compound and guttapercha, are repeated, according to the number of coatings required. This series of coatings secures the centrality of the conducting-wires, a greater freedom from faults, and rapidity of cooling. Although the application of the required guttapercha at one operation would save great cost of labour, it is not adopted. The copper wires are first coated with the compound, immediately before applying the guttapercha; or, if stranded wires are used, the central one is drawn through the compound, when the other wires squeeze the compound into the interstices of the strand, and fill them up completely. This compound serves to unite all the coatings together, and to the conducting-wires. At one time it was proposed to place the completed core in an iron tank, and after exhausting the air as far as practicable, to force in this compound, or Stockholm tar alone, under great pressure, so as to fill up any cavities or pores. This has led to the present improved condition of telegraph-wire.

Specifications for guttapercha telegraph-wire stipulate that certain electrical and mechanical data shall be carried out. The copper, whether solid or stranded wires, must weigh so much per statute mile for land work, or so much per nautical mile for cable or submarine work; and the specific conductivity of the copper must be equal to (within a small percentage) that of pure copper. The guttapercha must be applied in several coatings, alternating with a coating of compound.

The wire or strands are to be filled up or coated with the same compound. The completed core is tested electrically after being kept in water at a temperature of 24° (75° F.) for 24 hours. As these wires are electrically better after a short time than when newly made, it is necessary to keep the core, if possible, for a fortnight or longer before testing.

Telegraph-cores are made into cables, coated with lead, and sometimes taped and tarred for street or tunnel work, when they are afterwards drawn through sand. For military purposes they are braided, and saturated with a mixture of beeswax, rosin, &c. Joints in telegraph-wire are made in the following manner. The conductor, well cleaned, is first soldered up, and the guttapercha is softened by the flame from a spirit-lamp, and worked uniformly backwards from the joint. The exposed wire is coated with compound, and the guttapercha is carefully worked from both sides of the joint towards the middle, where the blending should be perfect. A coating of warm compound is applied over this, and one or more layers of specially prepared guttapercha sheet are worked over with alternate coatings of compound.

Sabine gives the following method for making joints in guttapercha cores. The two ends to be joined together are first cut "flush," so that each end presents a clear section. The guttapercha is next warmed for a distance of 3 in. by a spirit-lamp (in which wood-naphtha is burned), and when softened, is worked or rolled back into a knob; the conductor is joined, and smeared with a coating of Chatterton's compound (described below); one knob is warmed, and worked gradually towards the other, so as to form a tubular covering; this is smeared with another coating of compound; the other knob is softened, and worked down over it towards the other end, so that two tubes are formed, one from each end, and overlapping each other. Another coating of compound is applied, and, over this, a piece of softened joint-sheet is evenly and carefully worked. The whole is "tooled" up with a heated iron, so as to make a perfectly homogeneous covering. Sometimes the two knobs are worked simultaneously towards the middle, the excess of guttapercha is removed, so as to ensure only a thin but perfect covering, and the full diameter of the core is made up with new sheet and compound alternately.

A rough kind of joint is made by enclosing the two ends in a tube of glass or metal, which is moved on one side so as to join the conductor; this is smeared with compound, or a mixture of ozokerit, &c.; the tube is drawn over the joint, and filled in with similar compound. Willoughby Smith places the completed joint in a grooved piece of wood, and secures on it a similar grooved piece so as to compress the joint. Warren recommends a longitudinal strip of canvas, wrapped with a spiral covering of cotton tape. For temporary joints in indiarubber wires, Warren proposes a vulcanized indiarubber tube, drawn over the wire, and secured at the ends with twine. Cotton-tape soaked in paraffin, or strips of vulcanized rubber, lapped tightly on with alternate smearings of compound, make very useful temporary joints.

Joints in telegraph-cores are tested electrically. After immersion in water for some hours, they should be quite firm and hard, smooth and regular, and only a trifle larger than the core itself. Rapid cooling is dangerous, as unequal contraction might lead to "stripping" or non-adhesion in the coatings.

Jointing-sheet is a specially prepared guttapercha, having a dark colour, about $\frac{1}{8}$ in. thick; it is a little more highly worked than for ordinary purposes, and becomes more adhesive when heated. It should be kept in air-tight cases in a cool place; it should be rejected when the surface has a brittle or resinous appearance, cracking slightly when bent or folded.

Chatterton and Smith propose to immerse guttapercha cores in Stockholm tar, with a view to render them more repellent. The cores are placed in a closed tank, and the air is pumped out, so as to obtain a vacuum. The tar, heated to 21°–27° (70°–80° F.), is run in by opening a stopcock communicating with the reservoir; a pressure of 500 lb. a sq. in. is then put on for 10 minutes. Reid's pressure-tanks were much used for testing cores under pressure and vacuum. The cores, if air were enclosed between the coatings, showed a rough and irregular surface by the vacuum test; and holes, imperfect jointing, and impurities, were rendered more evident by the injection of water, which was afterwards pressed to 500–1000 lb. a sq. in., according to the depth for which the cable was required. Small hydraulic pumps, on the same principle, were used for testing guttapercha joints.

Willougby Smith's improved guttapercha has of late been very extensively employed for telegraph cable-cores. It possesses remarkable electrical advantages. Anthracene is said to reduce the inductive capacity of guttapercha; its use as an insulator has been patented by Perkins and Tandy.

Vulcanized Guttapercha.—Some years ago it was proposed to cure guttapercha by adding sulphur to it in the masticating-machine. Large quantities of telegraph-wire were made with this mixture; but as the sulphur was not combined, it so corroded the copper wire, that in a few years it became entirely converted into sulphide. This fact gave rise to the discovery of Statham's fuzes. If guttapercha be mixed with indiarubber, and sulphur be added to the mixture, it can be readily vulcanized, either to a soft or hard state. Guttapercha can be vulcanized by the cold-curing process. The cleansed guttapercha is cut up into shreds, and dissolved in carbon bisulphide, so as to form a stiff solution; to this solution, 2–15 per cent. of chloride of sulphur is added, according to the required extent of vulcanizing: 10 per cent. renders the guttapercha hard and horny, and not softened at 100° (212° F.). Sheets are vulcanized by repeated dipping. Parkes adopted the use of curing agents in vapour and solution. Guttapercha thus treated has not received much attention, although it possesses many remarkable qualities, and may be moulded, whilst liquid or plastic, into any form; being colourless, or nearly so, it might replace ivory in many of its applications. It might also be used for chemical-tanks, pipes, &c., as it is not softened by heat, nor acted upon by cold acids or alkalies. Bromine, chlorine, and phosphorus, and their sulphur compounds, have also been proposed for this purpose; the chlorides of sulphur are the best and cheapest.

Cattell's bleached guttapercha is made by dissolving cleansed guttapercha in solvents requiring heat, as coal-tar naphtha, and its rectified products, turpentine, and rosin-spirit; or solvents requiring no heating, as chloroform, and carbon bisulphide. In using the first class of solvents, 1 oz. of alcohol, holding in solution 30 drops of glycerine to the gallon (soap, wood-naphtha, or commercial nitrate of ethyl, may be used in the same proportions), is agitated in a closed vessel, together with the solvent and guttapercha, for an hour or more, until sufficiently defecated or decolorized, when it is decanted, and mixed with a little alcohol and glycerine, to precipitate the guttapercha. The solvent is recovered by distillation. The alcohol or similar agent removes the oxidized portions of the guttapercha, resins, &c., and leaves the pure guttapercha colourless.

Articles manufactured of guttapercha rapidly become brown on exposure to the air, from oxidation, and are ultimately converted into a brittle resinous matter. This is prevented to a great extent by varnishing with shellac dissolved in wood-spirit. In manipulating guttapercha, manufacturers avoid bringing into contact with it, any liquid or substance having a solvent action, such as coal-tar naphtha. The incorporation of Stockholm tar tends to preserve guttapercha, and there is no doubt that many resinous substances can be blended with it in presence of this tar, which could scarcely be safe without it, from their setting up some kind of decomposition, which is not easily explained.

Cattell's purified guttapercha can be mixed with colouring pigments, for the production of useful or ornamental objects. Oxide of zinc, vermilion, and similar compounds, can be used; but not oxides or compounds which represent a saturated or high degree of oxidation. Guttapercha, by strong oxidation, gives rise to formic acid. As guttapercha resists the action of fluoric acid, it is made into bottles, jars, &c., for holding this corrosive liquid. Silver salts and cyanides generally are decomposed in contact with guttapercha, consequently this substance is not suited for tanks to contain these liquids; but if the surface be well brushed over with graphite, the action of these bodies may be retarded.

Chatterton's Compound.—This compound is employed for uniting the different coatings of guttapercha cores, and for cementing guttapercha to wood, &c. It is sold in rolls about 1 in. thick, and 7–8 in. long. It should soften readily at 38° (100° F.), and become firm again when cooled for a few minutes. Its freshly cut surface should be smooth and compact; it should not break, but bend easily with slight elasticity; its sp. gr. is about 1·020, it should not become hard or brittle on exposure to the air. The following process is adopted for its manufacture—$\frac{1}{5}$ by weight Stockholm tar, and about the same weight of rosin, are put into a jacketed vessel, heated by steam, strained when melted, and intimately mixed with $\frac{3}{5}$ by weight of cleansed guttapercha in shreds or thin pieces. The whole is worked together by horizontal stirrers, fixed on a vertical shaft.

There are a few other substances having intermediate properties between indiarubber and guttapercha, such as "balata," a product obtained from the "bullet-tree" of British Guiana, "susu-poco," and "chapapote." Balata closely approaches guttapercha, and is used in many of its manufactures. The inspissated juice of the "cow-tree" (*Massaranduba*) has been for the last few years exported from Pará as indiarubber. Warren has shown that it is quite equal to the finest descriptions of Pará rubber, when vulcanized.

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(See Resinous Substances.)

INK (Fr., *Encre*; Ger., *Tinte, Dinte*).

The term "ink" is used to denominate a great variety of fluid or semi-fluid compounds employed in the permanent delineation of objects upon paper, stone and other grounds. The chief desiderata in most inks are a capacity of flowing readily from the writing instrument, while possessing sufficient body to prevent spreading and blotching, combined with a depth and permanency of colour. The latter naturally depends in a great measure upon the physical and chemical characters of the article written upon, and especially upon the presence or absence of bleaching agents. The composition of inks varies as widely as do the purposes to which they are applied; hence they may be classified as follows:—Black writing-ink, copying-ink, coloured writing-ink, invisible or sympathetic ink, marking-ink, Indian-ink, printing-ink, engraving-ink, ink for stone or marble-writing, and gold and silver inks.

Black Writing-ink.—The following are among the most approved recipes:—

A. With Galls and Sulphate of Iron.—(*a*) 1 lb. bruised galls, 1 gal. boiling water, 5⅓ oz. sulphate of iron (copperas) in solution, 3 oz. gum arabic previously dissolved, and a few drops of an antiseptic, such as carbolic acid. Macerate the galls for 24 hours, strain the infusion, and add the other ingredients. (*b*) 12 oz. bruised galls macerated for a week in 1 gal. cold water, 6 oz. sulphate of iron in solution, 6 oz. mucilage of gum arabic, and a few drops of antiseptic. (*c*) 12 lb. bruised galls, boiled for an hour in 6 gal. soft water, adding water to replace that evaporated; strain, and reboil the galls in 4 gal. more water for ½ hour; strain, and boil with 2½ gal. more water; strain, and mix the liquors. Add 4⅓ lb. coarsely powdered sulphate of iron, and 4 lb. gum arabic in small pieces; agitate till the ingredients are dissolved, and filter through a hair sieve. This will make about 12 gal. of good ink. (*d*) 2 lb. bruised galls, digested in 2 qt. alcohol at a temperature of 40°–60° (104°–140° F.); when about half the alcohol has evaporated, add 3 qt. water; stir well, and strain through a linen cloth. To clarify the solution, add 8 oz. glycerine, 8 oz. gum arabic, and 1 lb. sulphate of iron dissolved in water. Stir thoroughly from time to time for a few days, allow to settle, and put up in well-stoppered bottles for preservation. The addition of too much sulphate of iron is to be avoided, as causing the ink soon to turn yellow. Ink thus prepared is said to resist the action of light and air for at least 12 months, without suffering any change of colour. (*e*) Digest in an open vessel 42 oz. coarsely powdered galls, 15 oz. gum senegal, 18 oz. sulphate of iron, 3 dr. aqua ammonia, 24 oz. alcohol, and 18 qt. distilled or rain water. Continue the digestion till the fluid has assumed a deep black colour. (*f*) To good gall ink, add a strong solution of fine Prussian blue in distilled water; the ink writes greenish-blue, but afterwards turns black; it is said that it cannot be erased either by acids or alkalies, without the destruction of the paper. In all the inks described in this section, nut-galls are introduced for the sake of their tannic acid. For this purpose, they are not equalled by any other tannin-yielding substance; and a Commission lately appointed by the Prussian Government, to decide what was the best ink to be employed for official purposes, selected that made from galls as being the foremost of all for durability. For cheaper inks, the galls may be replaced by catechu, sumach, and the host of other astringent substances described in the article on Tannin. The antiseptic (carbolic acid, &c.) is added to prevent the formation of mould.

B. With Logwood.—(*a*) A decoction of logwood is first made by boiling 10 lb. logwood in enough water to produce 80 lb. of the decoction. To 1000 parts of this logwood extract, when cold, is added 1 part of yellow (neutral) chromate of potash (K_2CrO_4), stirring rapidly. It is ready for use at once, without any addition; but it possesses the great fault of soon becoming thick. This may be corrected by (*b*) adding corrosive sublimate, or any other antiseptic. (*c*) Boil 10 oz. logwood in 20 oz. water; then boil again in 20 oz. more water, and mix the two decoctions; add 2 oz. chrome alum, and boil again for ¼ hour; add 1 oz. gum arabic. The product is 25 oz. deep black ink. (*d*) Dissolve 15 parts extract of logwood in 1000 parts distilled water, to which 4 parts carbonate of soda have been added at boiling heat; and add 1 part neutral chromate of potash dissolved in a little water. This ink will not gelatinize. (*e*) 10 lb. best logwood is repeatedly boiled in 10 gal. water, straining each time. The liquid is evaporated down till it weighs 100 lb., and is then allowed to boil in a pan of stoneware or enamel. To the boiling liquid, nitrate of oxide of chrome is added in small quantities, until the bronze-coloured precipitate formed at first is redissolved with a deep blue coloration. This solution is then evaporated in a water-bath down to a syrup, with which is mixed well-kneaded clay in the proportion of 1 part of clay to 3½ of extract. A little gum tragacanth is also added to obtain a proper consistence. It is absolutely necessary to use the chrome salt in the right proportion. An excess gives a disagreeable appearance to the writing; while, if too little is used, the black matter is not sufficiently soluble. The other chrome salts cannot be used in this preparation, as they would crystallize, and the writing would scale off as it dried. The nitrate of oxide of chrome is prepared by precipitating a hot solution of chrome alum with carbonate of soda. The precipitate is washed till the filtrate is free from sulphuric acid. The precipitate thus obtained is dissolved in pure nitric acid, so as to leave a little still undissolved. Hence the solution contains no free acid, which would give the ink a dirty-red colour.

Oxalic acid and caustic alkalies do not attack the writing. Dilute nitric acid reddens, but does not obliterate the characters. This ink is manufactured into ink-pencils, which give a very black writing, capable of reproduction in the copying-press, and not fading on exposure to light. (*f*) 20 parts by weight extract of logwood are dissolved in 200 parts water, and the solution is clarified by subsidence and decantation. A yellowish-brown liquid is thus obtained. In another vessel, 10 parts ammonia alum are dissolved in 20 parts boiling water; the two solutions are mixed, there being also added $\frac{1}{5}$ part sulphuric acid, and finally $1\frac{1}{2}$ part sulphate of copper. The ink should be exposed to the air for a few days to give it good colour, after which, it should be stored in well-corked bottles. (*g*) 30 parts extract of logwood are dissolved in 250 parts water; 8 parts crystallized carbonate of soda, and 30 parts glycerine (sp. gr. 1·25), are added; lastly, 1 part neutral chromate of potash and 8 parts gum arabic, reduced to a powder, and dissolved in water. This ink does not attack pens, does not turn mouldy, and is very black.

C. Miscellaneous.—(*a*) The juice or sap of the ink-plant of New Granada, to which is given the name of *chanhi*, is at first of a reddish tint, but in a few hours becomes intensely black. It may be used without any preparation. The *chanhi* corrodes steel pens less than ordinary ink, and better resists the action of time and chemical agents. It is said that, during the Spanish rule, all public documents were required to be written with this ink: written otherwise, they were liable to damage by sea-water. (*b*) 20 gr. sugar is dissolved in 30 gr. water, and a few drops concentrated sulphuric acid are added; the mixture is heated, when the sugar is carbonized by the acid.

Copying-ink.—The quality required of a copying-ink is that it shall afford one or more copies of the written matter by applying dry or damped paper to its surface, and subjecting it to more or less pressure. The best kinds of copying-ink are usually prepared by adding a little alum to an extract of logwood of 10° B. (1·075 sp. gr.), or to a decoction of the same, and then, to improve its copying power, some sugar and glycerine, or table-salt is added. Such inks have a violet tint, are purple when first written, and gradually darken on the paper. The copies taken from them are at first very pale, and only slowly darken. The chief recipes for copying-inks are the following:—(*a*) Mix about 3 pints of jet-black writing-ink and 1 pint glycerine. This, if used on glazed paper, will not dry for hours, and will yield one or two fair, neat, dry copies, by simple pressure of the hand, in any good letter copy-book. The writing should not be excessively fine, nor the strokes uneven or heavy. To prevent "setting-off," the leaves after copying should be removed by blotting-paper. The copies and the originals are neater than when water is used. (*b*) A good copying-ink may be made from common violet writing-ink, by the addition of 6 parts glycerine to 8 parts of the ink. Using only 5 parts of glycerine to 8 of the ink, the ink will copy well 15 minutes after it has been used. With fine white copying-paper, it will copy well without the use of a press. (*c*) $\frac{1}{2}$ lb. extract of logwood, 2 oz. alum, 4 dr. blue vitriol (sulphate of copper), 4 dr. green vitriol (sulphate of iron), 1 oz. sugar; boil these ingredients with 4 pints water, filter the decoction through flannel; add a solution of 4 dr. neutral chromate of potash in 4 oz. water, and a solution of 2 oz. "chemick blue" in 2 oz. glycerine. The "chemick blue" is the solution of indigo in sulphuric acid, or sulphindigotic acid. (*d*) A black coyping-ink, which flows easily from the pen, and will give very sharp copies without the aid of a press, can be prepared thus:—1 oz. coarsely broken extract of logwood, and 2 dr. crystallized carbonate of soda, are placed in a porcelain capsule with 8 oz. distilled water, and heated until the solution is of a deep-red colour, and all the extract is dissolved. The capsule is then taken from the fire. Stir well into the mixture 1 oz. glycerine, (sp. gr. 1·25), 15 gr. neutral chromate of potash, dissolved in a little water, and 2 dr. finely pulverized gum arabic, which may be previously dissolved in a little hot water so as to produce a mucilaginous solution. The ink is now complete and ready for use. In well-closed bottles, it may be kept for a long time without getting mouldy, and, however old it may be, will allow copies of writing to be taken without the aid of a press. It does not attack steel pens. This ink cannot be used with a copying-press. Its impression is taken on thin, moistened copying-paper, at the back of which is placed a sheet of writing-paper. (*e*) A new kind of Parisian copying-ink has been recently introduced into Germany, which differs from those previously in use in having, while liquid, a more or less yellowish-red colour; but on paper, it rapidly turns blue, and immediately produces a distinct blue-black copying-ink. Moreover, it remains liquid a long time, while ordinary violet copying-ink soon gets thick; this kind copies easily and perfectly. The following is the method of its manufacture:—A logwood extract of 10° B. (sp. gr., 1·075) has added to it 1 per cent. of alum, and then enough lime-water to form a permanent precipitate. This mass is then treated with a few drops of a dilute solution of chloride of lime (bleaching powder), just enough being added to impart to it a distinct blue-black colour, after which, dilute hydrochloric acid is added drop by drop, until a distinctly red-coloured solution is produced. To this solution is added a little gum, and $\frac{1}{2}$–$1\frac{1}{2}$ per cent. of glycerine. It is evident that the small quantity of chloride of calcium, formed by this process, greatly increases the copying power of the ink; while the exceedingly slight excess of free hydrochloric acid causes the ink to remain liquid, by holding in solution the lime and alumina lakes of logwood. When the writing dries, the acid gradually escapes, or is neutralized by the trace of alkali in the paper, so that the blue-black lake is left. It is evident that any considerable excess of hydrochloric acid must be avoided, as also the use of too much chloride of lime solution. (*f*) Add 1 oz. lump-sugar or sugar-candy to 1½ pint good black ink; dissolve. (*g*) A decoction of Brazil wood and glycerine used as an ink requires neither press nor copying-paper for multiplying the impressions; it is only necessary to lay tissue-paper upon the writing, and to rub with the finger. (*h*) 5½ oz. best galls, 1 dr. bruised cloves, 40 oz. cold water, 1½ oz. pure sulphate of iron, 35 minims pure sulphuric acid, ½ oz. sulphate of indigo in thin paste, and neutral or nearly so. Place the galls, when bruised, with the cloves, in a 50-oz. bottle, pour in the water, and digest, shaking daily, for a fortnight. Filter through paper into another 50-oz. bottle. From the refuse of the galls, wring out the remaining liquor through a strong clean linen or cotton cloth into the filter, to avoid waste. Put in the iron, dissolve completely, and filter through paper. Add the acid, and agitate briskly; add the indigo, and shake up thoroughly; pass the whole through filter-paper. Filter from one bottle to another till the operation is complete. The same ingredients may be used for common writing-ink, reducing the proportion of galls to 4½ oz.

Coloured Writing-ink.—Coloured inks may be divided into two classes, those in which the colouring matter is derived from coal-tar, and those in which it is not.

A. Without Coal-tar Colours.—*Red:* (*a*) 4 oz. ground Brazil wood, and 3 pints vinegar, boiled till reduced to 1½ pint, and 3 oz. powdered rock alum added. (*b*) ¼ lb. raspings of Brazil wood, infused in vinegar for 2–3 days; boil the infusion for 1 hour over a gentle fire, and filter while hot; put it again on the fire, and dissolve in it, first, ½ oz. gum arabic, then ½ oz. alum and white sugar. (*c*) Boil 2 oz. Brazil wood in 32 oz. water; strain the decoction; add ½ oz. chloride of tin, and 1 dr. powdered gum arabic; then evaporate to 16 fl. oz. (*d*) Dissolve 1 dr. carmine in ½ dr. liquid ammonia, sp. gr. 0·880; dissolve 20 gr. powdered gum arabic in 3 oz. water; mix the two solutions. (*e*) Mix 2000 parts Brazil wood, 3 salt of tin, 6 gum, and 3200 water; boil till reduced to one-half, and filter. (*f*) 2 parts Brazil wood, ½ alum, ½ cream of tartar, 16 water; boil down to one-half, and filter; add ½ part gum. (*g*) To an ammoniacal solution of cochineal, add a mixture of alum and cream of tartar, till the required tint is obtained. (*h*) Digest 1 oz. powdered cochineal in ½ pint hot water; when quite cold, add ½ pint spirit of hartshorn; macerate for a few days, then decant the clear portion. (*i*) Dissolve 20 gr. pure carmine in 3 fl. oz. liquid ammonia; add 18 gr. powdered gum.

Purple: (*a*) To a decoction of 12 parts Campeachy wood in 120 parts water, add 1 part sub-acetate of copper, 14 parts alum, and 4 parts gum arabic; let stand for 4–5 days. (*b*) To a strong decoction of logwood, add a little alum, or chloride of tin.

Violet: (*a*) Boil 8 oz. logwood in 3 pints water, till reduced to 1½ pint; strain, and add 1½ oz. gum, and 2½ oz. alum. (*b*) Mix 1 oz. cudbear, 1½ oz. pearlash, and 1 pint hot water; allow to stand for 12 hours; strain, and add about 2 oz. gum. If required to keep, add 1 oz. spirit of wine.

Blue: (*a*) Dissolve 2–3 oz. sulphate of indigo in 1 gal. water. (*b*) Rub together 1 oz. oxalic acid and 2 oz. fine Prussian blue, and add 1 qt. boiling water; the excess of iron in the Prussian blue must first be removed by a strong mineral acid; then wash in rain water. (*c*) 2 oz. Chinese blue, 1 qt. boiling water, 1 oz. oxalic acid; dissolve the blue in the water, and add the acid; it is ready for use at once.

Green: (*a*) Calcine acetonitrate of chrome; dissolve the green powder in sufficient water. (*b*) Dissolve sap green in very weak alum water. (*c*) 2 oz. verdigris, 1 oz. cream of tartar, ½ pint water; boil till reduced to one-half, and filter.

Green-black: Boil 15 parts bruised galls in 200 parts water for about 1 hour; strain; to the liquor, add 5 parts sulphate of iron, 4 fine iron shavings, and a solution of ½ pint powdered indigo in 3 pints sulphuric acid. This ink flows readily; it writes green, but turns black after a few days.

B. With Coal-tar Colours.—The colouring matters derived from coal-tar may all be employed for writing purposes. These inks possess bright colours, do not precipitate their colour, and dry quickly. When dried up or thickened, they can be put right by simple dilution with water. On the other hand, they are readily destroyed by chemical reagents. They must not be used with pens which have been employed in writing with other inks. They do not require any addition of gum; but if desired, 1 part dextrine may be added to every 100 parts ink. Almost all tints may be produced by mixtures, in varying proportions, of the following principal colours:—

Red: (*a*) 1 part magenta in 150–200 parts hot water. (*b*) Dissolve 25 parts (by weight) safranine in 500 parts warm glycerine; then stir in carefully 500 parts alcohol, and 500 parts acetic acid; dilute in 9000 parts water, containing a little gum arabic in solution.

Blue: 1 part soluble blue (night blue) in 200–250 parts hot water.

Violet: 1 part violet-blue in 200 parts hot water.

Green: 1 part iodine-green in 200 parts hot water. Gives a bluish-green writing; for a lighter tint, add a little picric acid.

Yellow: 1 part picric acid in 120–140 parts water. This is not very successful.

Invisible or Sympathetic Ink.—The terms "invisible" and "sympathetic" are applied to any writing fluid which leaves no visible trace of the writing on the paper, until developed by the application of heat or chemical reagents. They have been suggested (somewhat impractically it must be owned) for use on post-cards. They are principally as follows:—(*a*) Solution of sugar of lead in pure water leaves no trace of writing when dry; the written characters held over a jet of sulphuretted hydrogen are developed of an intense black colour. (*b*) Nitrate of the deutoxide of copper in weak solution gives an invisible writing, which becomes red by heating. (*c*) Chloride of copper in very dilute solution, is invisible till heated. To make it, dissolve equal parts of blue vitriol and sal ammoniac in water. (*d*) Nitrate of nickel and chloride of nickel in weak solution form an invisible ink, which becomes green by heating, when the salt contains traces of cobalt, which usually is the case; when pure, it becomes yellow. (*e*) Chloride of cobalt in properly-diluted solution will produce a pink writing, which will disappear when thoroughly dry, become green when heated, disappear when cold, and pink again when damp. When often or strongly heated, it will at last become brown-red. (*f*) When the solution of acetate of protoxide of cobalt contains nickel or iron, the writing made by it will become green when heated; when it is pure and free from these metals, it becomes blue. (*g*) Bromide of copper gives a perfectly invisible writing, which appears very promptly by a slight heating, and disappears perfectly by cooling. To prepare it, take 1 part bromide of potassium, 1 part blue vitriol, 8 parts water. It is better also to discolour the blue vitriol with 1 part alcohol. (*h*) A drawing or writing made with a strong solution of acetate of lead becomes dark-brown by exposure to sulphide of hydrogen gas. (*i*) Writing with iodide of potash and starch becomes blue by the least trace of acid vapours in the atmosphere, or by the presence of ozone. To make it, boil starch, and add a small quantity of iodide of potassium in solution. (*j*) Sulphate of copper in very dilute solution will produce an invisible writing, which will turn light-blue by vapours of ammonia. (*k*) Soluble compounds of antimony will become red by sulphide of hydrogen vapour. (*l*) Soluble compounds of arsenic and of peroxide of tin will become yellow by the same vapour. (*m*) An acid solution of chloride of iron is diluted till the writing is invisible when dry. This writing has the remarkable property of becoming red by sulpho-cyanide vapours, and it disappears by ammonia, and may alternately be made to appear and disappear by these two vapours. (*n*) Writing executed with rice-water is invisible when dry, but the characters become blue by the application of iodine. This ink was much employed during the Indian Mutiny. (*o*) Characters written with an aqueous solution of iodide of starch disappear in about 4 weeks. (*p*) Dissolve 1 fl. oz. common oil of vitriol (sulphuric acid) in 1 pint soft water; stir well, and allow to cool. Write with a clean steel pen; when dry, the writing is invisible; held to the fire, it becomes indelibly black. (*q*) Writing executed with a clean quill pen dipped in onion or turnip juice is invisible when dry; when the paper is heated, the characters assume a brown colour.

Marking-ink.—The use of marking-ink is for writing on textile fabrics; it must therefore be proof against the action of hot water, soap, alkalies, &c. The chief recipes are:—(*a*) 20 parts potash are dissolved in boiling water, 10 parts finely cut leather-chips, and 5 parts flowers of sulphur are added, and the whole is heated in an iron kettle until it is evaporated to dryness. Then the heat is continued until the mass becomes soft, care being taken that it does not ignite. The pot is now removed from the fire, and water is added; the solution is strained, and preserved in bottles. This ink flows easily from the pen. (*b*) Triturate 1·75 grm. aniline black with 60 drops strong hydrochloric acid and 42 grm. strong alcohol. The mixture is diluted with a hot solution of 2·5 grm. gum arabic in 170 grm. water. This ink does not attack steel pens, and is destroyed neither by mineral acids nor by caustic alkalies. (*c*) Neutralize 75 gr. carbonate of ammonia with pure nitric acid, and triturate 45–60 gr. carmine with the solution. Mordant the fabric with a mixed solution of acetate of alumina and tin salt, and write upon it, when it is perfectly dry, with the ink. The characters will be of a Tyrian purple colour. (*d*) Dissolve in 60 grm. water, 8·25 grm. crystalline chloride of copper, 10·65 grm. chlorate of soda, and 5·35 grm. chloride of ammonium: dissolve 20 grm. hydrochlorate of aniline in 30 grm. distilled water, and add 20 grm. solution of gum arabic (1 part gum to 2 water), and 10 grm. glycerine; 4 parts of the aniline liquid mixed in the cold with 1 part of the copper solution produce a greenish liquid, which may be used at once for marking linen; but as it decomposes in a few days, it is better to preserve the two solutions separately. The writing is at first greenish, but is blackened by exposure to steam (for example, by being held over the spout of a boiling kettle). A dry heat renders the tissue brittle. (*e*) First mix 1 lb. extract of logwood with 1 gal. water; then dissolve 4 oz. sulphate of protoxide of iron in 4 oz. water; and $\frac{1}{4}$ oz. sulphide of potassium in 2 oz. water. Dissolve the logwood extract by boiling; add the potassium solution to the iron solution, until the latter assumes a black colour; then add this to the logwood solution, and boil for a few minutes. Add $\frac{1}{2}$ oz. cyanide of potassium, to fix the colour; then gum and alcohol. (*f*) An excellent marking-ink is made from the resinous juice of "marking-nuts," the fruit of an

E. Indian tree (*Semecarpus Anacardium*). The "nuts" are coarsely crushed, then digested for some time in petroleum ether; the solvent is finally allowed to evaporate spontaneously. The syrupy residue when used for marking gives a brown mark, which changes to black on applying ammonia or calcic hydrate. The marks resist chloride of lime, acids, and potassium cyanide. (*g*) First, moisten the place where the letters are to be written with a solution of 1 dr. carbonate of soda and 1 dr. gum arabic in ½ oz. water, and smooth the spot with a warm iron. Next, with a quill pen, write with a solution of 1 dr. bichloride platinum in 2 oz. water. Lastly, when the writing is dry, write over the letters only with a solution of 1 dr. protochloride of tin in 2 oz. water. The marks immediately acquire a bright-purple colour. (*h*) A quicker but more expensive method is to write with a solution of chloride of gold on the linen, previously starched and pressed; on exposure to sunlight, the letters assume a bright rose-pink colour. (*i*) When a stencil-plate is used, apply with the brush a mixture of Chinese vermilion with thin copal varnish. The letters will appear red. (*j*) 22 parts carbonate of soda are dissolved in 25 parts distilled water; also 17 parts nitrate of silver in 24 parts ammonia; 20 parts gum are then macerated in 60 parts water, and mixed with the soda solution; the nitrate of silver solution is then added, together with 33 parts sulphate of copper. The ink writes a rich blue. (*k*) Dissolve 1 dr. nitrate of silver in ¾ oz. water; add to solution as much liquid ammonia as will redissolve the precipitated oxide, with some sap green to colour it, and sufficient gum water to raise the volume to 1 oz. Letters written with this ink should be first fire-heated, and then exposed to the sun to blacken. The fabric requires no previous preparation. (*l*) Write with a solution of nitrate of silver, thickened with gum, and tinted with sap green, on fabrics previously damped with solution of carbonate of soda. (*m*) Dissolve separately 1 oz. nitrate of silver, and 1½ oz. carbonate of soda; mix the solutions, and collect the precipitate on a filter; wash well; introduce the moist precipitate into a mortar, and add 8 scr. tartaric acid; triturate till effervescence ceases; add sufficient strong liquor ammonia to dissolve the tartrate of silver; add 4 fl. dr. orchil, 4 dr. powdered white sugar, and 12 dr. powdered gum arabic; make up to 6 fl. oz. with distilled water. (*n*) Crimson marking-ink may be made by adding 6 gr. carmine to the liquor ammonia of (*m*); but it soon loses its crimson tint, and becomes black. (*o*) Dissolve 25 gr. powdered gum copal in 200 gr. lavender oil, by the aid of gentle heat; then add 2½ gr. lamp-black, and ½ gr. powdered indigo. (*p*) In 18 oz. water, boil 2 oz. shellac, and 1 oz. borax; when cold, filter; add 1 oz. gum arabic, dissolved in 2 oz. water, with the requisite quantity of indigo and lamp-black. (*q*) First, dissolve together 8·5 parts chloride of copper, 10·6 parts salt, and 5·3 parts sal ammoniac, in 60 parts distilled water; then dissolve 20 parts hydrochloride of aniline in 30 parts water, to which has been added 20 parts of a gum solution (made by dissolving 1 part gum in 2 parts water), and lastly, add ten parts glycerine. These solutions are kept in separate bottles. For use, mix 1 part by bulk of the first solution with 4 parts by bulk of the second. Apply with a quill pen or small brush. The writing appears green at first, but blackens on exposure to a higher temperature.

Indian-ink.—The peculiar ink employed by draughtsmen is termed "Indian," because the best qualities have always come to us from India and China. In the latter country, the manufacture of drawing-inks is a large industry, and several factories are to be found in Shanghae and other parts of the empire.

A. The Chinese mode of manufacture is as follows:—In some parts of N. China, the lamp-black, which forms the foundation of the ink, is prepared much in the same manner as in Europe (see Blacks—Lamp-black). In other districts, the following method prevails:—The furnaces are built upon the ground, with a length varying from 8 ft. to 40 ft., or even 50 ft., and with a mouth about 2 ft. in diameter. The material generally used is pine, or other resinous wood, or the resin itself, which is burned at the mouth of the furnace. Only the black deposited at the extreme end of the furnace is used for the finest ink, all the remainder being proportionately coarser. The fineness of the grain depends also upon the slowness of the combustion. The very finest black is said to be derived from pork-fat; the next from oils and other kinds of grease. The smoothness of the ink is likewise largely dependent upon the careful sifting of the black through silken bags or sieves. The first operation in compounding the ink is to soak a quantity of the excellent glue made from buffalo-hide; when thoroughly swollen, it is set aside, and will keep in this state for several days. For use, the glue is melted in an iron pot, and as much lamp-black is added as will produce a soft paste. This paste is very carefully kneaded by hand. A small quantity of pea-oil is then added, and the whole is maintained at a temperature of 54°–60° (130°–140° F.), until the paste is found to be perfectly homogeneous. It is then poured out in the form of flat cakes, weighing 1–2 lb. each, and is left in that condition for many days, to "ripen." It often happens, when the weather is hot and damp, that the cakes become covered with mould; but this does not seem to produce any ill effect. While one set of workmen manufacture the paste, another set fashion it into the familiar forms met with in commerce. The latter sit at a bench, with a small brazier beneath; the workman warms a piece of the paste, kneads it vigorously in his hands, presses it into a mould, and places the latter under a long lever, on the end of which he sits, so as to compress the ink forcibly, for some seconds; he fills another mould in the meantime, and so the operation progresses. The moulds are made of wood, the characters to be impressed upon the cakes being engraved also on wooden dies. One of these dies is dropped into a cavity in the bottom of the mould, while another is laid on the top of the paste in the mould. Common qualities are often pressed into large moulds with several partitions, so that the cakes, when dry, can easily be broken off from each other. For wholesale manufacturing purposes, the best is simply rolled, and the sticks, perforated at one end, are strung together in bunches of ½–1 doz. The drying of the cakes occupies 5–6 days, according to the temperature. Their high polish is due to brushing over with a hard brush impregnated with tree-wax (probably that secreted by *Coccus Pe-la*, on the branches of *Fraxinus chinensis*), which has the additional effect of preventing the ink soiling the hands when they are moist. The peculiar odour possessed by the finest ink is produced by mixing a small quantity of musk, or of Borneo camphor, with the paste while hot. The common qualities are unscented. The Japanese make ink in the same way, but it is inferior to the Chinese product, as, though the glue and gelatine are equally good, less care is taken in the preparation of the lamp-black. The finest ink should be slightly brown in tint; when quite black, bluish, or grey, it is inferior. A stick of fine ink gives a clear, sharp sound, when struck; if the tone be dull, the ink is not homogeneous. The heaviest ink is the best; it improves in colour and brilliancy by age. The chief test of good ink is that it will produce a tint of any depth, without the slightest appearance of irregularity. Some cakes are worth 5–6*s*. each.

B. There are several cheaper home-made imitations of the Chinese ink, besides some recipes for improving the qualities of the latter. They are chiefly as follows:—(*a*) To improve Indian-ink for drawing, so that even the thickest lines will quickly dry, add 1 part of carbolic acid to 80 of the ink. If, by mistake, too much has been added, it may be rectified by putting in more Indian ink. If the mixture is properly performed, the ink is as easy to draw with as it is without carbolic acid, but dries quickly, and may even be varnished without discharging. (*b*) For making a deep-black Indian-ink, which will also give neutral tints in its half shades, rub thoroughly together 8 parts lamp-black, 64 parts water, and 4 parts finely pulverized indigo. Boil the mixture until most of the water has evaporated; then add 5 parts gum arabic, 2 parts glue, and 1 part extract of chicory. Boil the mixture again till it has thickened to a paste; then shape it in wooden moulds, which have been rubbed with olive or almond oil. (*c*) Most of the black Indian-ink met with in commerce possesses the disadvantage that it blots when a damp brush is passed over it; or, as draughtsmen say, "it does not stand." The addition of alum does but little good; but bichromate of potash accomplishes the object, by rendering insoluble the glue which the ink contains, and thus making the ink permanent. The bichromate of potash possesses a deep-yellow (almost red) colour, but does not at all injure the shade of the ink, as 1 per cent. of it in a very fine powder, intimately mixed with the ink, is sufficient. The bichromate must always be mixed with the ink in a dry state, otherwise the latter might lose its friability in water. A drawing which has been made with this ink in the dark, or by artificial light, must be exposed to sunlight for a few minutes, which renders the bichromated glue insoluble in water. Draughtsmen who cannot provide themselves with such ink, make use of a dilute solution of bichromate of potash in rubbing up the ink. There is no danger of the yellow penetrating the paper, if the ink is thick enough. (*d*) A substance much of the same nature and applicable to the same purpose as Indian-ink may be formed in the following manner:—Convert 3 oz. isinglass into size by dissolving it over a fire in 6 oz. soft water; dissolve 1 oz. Spanish liquorice in 2 oz. soft water, in another vessel over a fire; grind up, on a slab with a heavy muller, 1 oz. ivory-black with the liquorice mixture; add this compound to the isinglass size while hot, and stir well together, till thoroughly incorporated. Evaporate away the water, and then cast the remaining composition into a leaden mould slightly oiled, or make it up in any other convenient way. (*e*) Dissolve horn shavings with caustic alkali; boil the brown liquid in an iron kettle till it is thick; pour on double its weight of boiling water, and precipitate by dissolved alum; dry, grind, mix it with gum-water, and pour it into a mould; add perfume, if desired. (*f*) Horse-beans, perfectly calcined, are ground to a fine powder, made into a paste with solution of gum arabic, and then formed into cakes. (*g*) Mix finest lamp-black with a solution of 100 gr. lac and 20 gr. borax in 4 oz. water.

Printing-ink.—The ink used by printers is compounded mainly of two ingredients, colouring matter and varnish. The former varies according to the quality and tint of the ink; the latter may be obtained by natural resinous substances, or by mixing oil, rosin, and soap.

A. Black.—(*a*) The chief colouring matter in black printing-ink is vegetable lamp-black. The price of the best qualities precludes their use, except for specially fine ink; nevertheless, good ink cannot be made with inferior samples. An undue proportion of lamp-black in the ink will cause it to smear, however long it may have been printed, and to "set-off" during book-binding operations. Thus the thickest inks are not the best, if the lamp-black is more than the varnish can bind. Ivory-black is too heavy to be used alone; but a proportion ground up with the other ingredients makes a valuable ink for producing the best possible effect with wood-engravings.

Only the best and blackest is admissible. Prussian blue, ground exceedingly fine, and used sparingly, deepens the colour of ink; in excess, it gives a cold appearance. Indigo may replace Prussian blue. Perhaps the blackest tint is produced by equal quantities of each. To give a rich tone, and remove the coldness caused by indigo and Prussian blue, the addition of a little Indian red is strongly recommended.

The natural resinous substances employed as a source of varnish are balsam of copaiba and Canada balsam. The former is superior, and, when old and pure, may be used without any preparation. The latter is much thicker, and dries more quickly, and cannot therefore be used alone; but for a strong ink, a small proportion may with advantage be added either to the balsam of copaiba or to the artificial varnish now to be described.

The basis of the artificial varnish is linseed-oil, which should be as old as possible. Of all other oils, the only one recommended as a substitute is nut-oil. The rosin used may be either black or amber. It melts in the boiling oil, and combines with it, preventing its separation from the colouring matter and staining of the paper, and binding the ink to prevent its smearing. The properties possessed by soap, which render it such an indispensable ingredient of printing-ink, are that it causes the ink (1) to adhere uniformly to the face of the type, (2) to coat it completely with the smallest quantity, (3) to leave the face of the type clean, and attach itself to the surface of the damp paper by the action of pressure, and that repeatedly, (4) to wash easily off the type, and (5) to never skin over, however long it may be kept. For all dark inks, well dried yellow or turpentine soap may be employed; for light-tinted inks, curd-soap is preferable. Used in excess, soap tends (1) to render the colour unequal, where a large surface is printed, (2) to spread over the edges of the types, so as to give them a rough appearance, and (3) to prevent the ink drying quickly, and cause it to "set off" when pressed. It is thus opposed to the binding quality of the rosin. Its due proportion is when the ink works clean, without clogging.

The combination of these several ingredients is effected in the following manner:—Into an iron vessel having 2–3 times the capacity of the materials it is to receive, put 6 qt. linseed-oil, and make a fire under it. After a time, the oil simmers and bubbles up, but as the temperature increases, the surface resumes placidity; next it commences to smoke, and then to boil, emitting a very strong odour; as the boiling continues, a scum arises. At this stage, repeated tests should be made to ascertain whether the escaping vapours will ignite. At the moment when they will do so, the pot is removed from the fire, and placed on the ground, and the contents are stirred with an iron spatula, and kept burning. The pot is covered occasionally to extinguish the flame, while samples are withdrawn to test the consistence. When drops of the oil let fall upon a porcelain surface will draw out into strings about ½ in. long, the oil is suited for ink for ordinary book-work. The flame is then extinguished by firmly replacing the cover. On removing it, there is a great escape of strong-smelling smoke, and much froth; the latter is made to subside by thorough stirring, and when this is accomplished, but not before, 6 lb. of amber or black rosin is gradually introduced and stirred in. When the rosin is dissolved, 1¾ lb. of dry brown or turpentine soap, in slices, is stirred in gradually, and cautiously, as it froths copiously. When all the soap is in, and the frothing has ceased, the pot is returned to the fire till its contents boil, constant stirring being maintained. This completes the varnish. Into an earthenware pot, or a tub, of sufficient capacity, is put 5 oz. of Prussian blue, or indigo, or the two combined; then 4 lb. of the best "mineral lamp-black," and 3½ lb. of good lamp-black; next add the varnish by degrees, while warm, stirring meantime and until all the ingredients are thoroughly mixed; finally pass it through a levigating mill, or between the stone and muller, and reduce it to impalpable fineness.

(*b*) A fine, intensely black, strong ink, without the use of oil and rosin, may be made in the following manner:—9 oz. balsam of copaiba, 3 oz. lamp-black, 1¼ oz. indigo, or Prussian blue, or equal proportions of each, ¾ oz. Indian red, 3 oz. dry turpentine soap, ground between a muller and a stone to impalpable fineness. This is an excellent ink for giving good effect to highly finished wood-engravings.

B. Coloured.—Printing-inks may be made in a number of colours besides black. The principal are the following:—

Red: (*a*) Carmine may be readily ground into a fine ink of brilliant colour by admixture with black ink varnish made with balsam of copaiba. It is expensive, but valuable for special purposes. (*b*) Crimson lake is easily reduced by the muller; it works clean, and does not require more soap than is contained in the varnish, but it does not possess much depth. (*c*) A deeper tone than can be obtained from commercial lake may be produced in the following manner:—1 oz. best cochineal, powdered, and boiled in 1 qt. water, till the colouring matter is extracted; let the cochineal subside, and pour the liquid into another vessel; when cold, gradually add some chlorate of tin, with constant stirring, till the supernatant liquid, on standing, becomes nearly colourless; then add a little powdered alum. Assist the solution by stirring; allow to subside; pour off the excess liquid; wash the coloured residue with 3 or 4 waters, to remove the acid; and dry carefully and slowly. The addition of cream of tartar during the process will give a purple tint. (*d*) Vermilion may be used for red ink where neatness is required, as for title lines of books. The quantity varies much, and necessitates care in its proportions. It requires much soap to make it work clean. (*e*) For cheap work, such as posting-bills, red-lead may be used; it requires additional soap to make it work clean, and its colour soon changes to black. (*f*) An excellent, permanent red, of rich tone, may be produced from Indian red. (*g*) Venetian red is easily ground into a smooth ink, and requires but little more soap than the varnish usually contains; it is not very intense.

Yellow: (*a*) The highest yellow is obtained from chromate of lead, which is easily ground into a fine ink, works freely and well, and requires but little soap beyond what the varnish contains. (*b*) Yellow ochre is easily ground into a fine ink; it gives a useful colour, dull but permanent.

Green: Various shades of green may be produced by suitable admixture of blues and yellows. Prussian blue and chromate of lead make a good rich green; indigo and the same yellow, a deeper, duller colour; Antwerp blue and the same yellow, a brilliant rich green. The chromate must be quite pure to ensure bright colours.

Blue: (*a*) Indigo gives a deep but dull blue; it is cold, but permanent. (*b*) Prussian blue needs much grinding, and extra soap; it affords a deep, bright colour, and is useful for making greens. (*c*) Antwerp blue is easily ground to the proper degree of fineness, makes a good ink, and works clean and well; its tint is bright and light, with a slight green tendency.

Purple: Different shades of purple may be made by grinding together carmine, or purple lake, with Prussian blue.

Engraving-inks.—Under the term "engraving-inks," will be included all inks employed for engravers' purposes, whether on stone, wood, or metal.

Black.—(*a*) Coal-tar, 100 parts; lamp-black, 36; Prussian blue, 10; glycerine, 10. This ink may be used for lithography, chromolithography, autography, &c. (*b*) To the varnish obtained by boiling linseed-oil, as for printing-ink, is added as much best calcined Paris black as can be ground up with it. This is a litho printing-ink. For copper-plate printing, the Paris black is replaced by lamp-black. (*c*) 8 oz. mastic in tears, 12 oz. shellac, 1 oz. Venice turpentine; melt together; add 1 lb. wax, 6 oz. tallow; when they are dissolved, add 6 oz. hard tallow soap-shavings, and mix; then add 4 oz. lamp-black. Mix all well together, let cool slightly, pour into moulds, and cut into cakes of convenient size. This ink is suited for writing on stones. (*d*) To render (*c*) liquid, for writing and drawing on transfer-paper, it is warmed in a pot, and then rubbed down with soft water (rain, or distilled water). The pen should be dipped into oil, and wiped, before use.

Coloured.—Coloured inks are made by adding to the varnish already described, certain pigments, of which the principal are as follows:—

Red: 5 oz. mineral orange-red, 2 oz. Chinese red.

Blue: 2 oz. celestial blue, 3 oz. marine blue.

Green: 2 oz. mineral green, 3 oz. chrome-green.

Brown: 2 oz. burnt umber, 1 oz. rose-pink.

Lilac: 1 oz. Prussian blue, 2 oz. Chinese red.

Pink: 2 oz. mineral pink, 1 oz. satin-white.

Orange: 2 oz. orange-red, 1 oz. flake-white, ground up with Canada balsam, and omitting the linseed-oil varnish.

Miscellaneous Inks.—Inks for writing on metallic surfaces may be made as follows:—(*a*) 1 part verdigris (acetate of copper), 1 part sal ammoniac, ½ part soot, 10 parts water; stir well write with a quill. (*b*) 1 grm. sulphate of copper, dissolved in 20 grm. water; add 2 drops hydrochloric acid, and enough solution of gum arabic to make the ink adhesive. To make the writing appear at once, add a little pyrogallic acid. Write with a copper pen. (*c*) Dissolve 2 oz. shellac in 1 pint alcohol, filter through chalk, and mix with finest lamp-black; forms a jet-black, lustreless ink, insoluble in water. A violet ink for rubber stamps is made by mixing 2–4 dr. aniline violet in 15 oz. alcohol and 15 oz. glycerine. Gold inks are made as follows:—(*a*) 24 leaves gold, ½ oz. bronze gold, 30 drops spirit of wine, 30 grm. honey, 4 dr. gum arabic, 4 oz. rain-water; rub the gold with the honey and gum, and having mixed it with the water, add the spirit. (*b*) 1 part gold, 3 parts aqua regia; mix, and evaporate till all the chlorine is given off; cool, and mix well with ether; thicken with naphtha or essential oils. An improved method of making gold and silver inks is to triturate the purified metallic powder with a solution of 1 part white gum arabic in 4 parts distilled water, and 1 part potash water-glass.

Imports of Inks.—The value of the inks imported into the United Kingdom from all countries in 1879 was 8273*l.*

Bibliography.—W. Savage, 'Printing Ink' (London: 1832).

(See Blacks; Camphor; Coal-tar Products; Dyestuffs; Pigments; Printing and Engraving; Resinous Substances; Tannin.)

IVORY (Fr., *Ivoire*, *Éburne*; Ger., *Elfenbein*).

The term "ivory" is properly restricted to that substance which forms the main body of the long, projecting, horn-like teeth, called "tusks," of the elephant, and the other proboscidian quadrupeds belonging to the two genera, *Elephas* and *Mastodon*. It is the only form of dentine, or tooth-substance, which, in transverse sections or fractures, shows lines of different colours, or striæ, proceeding in the arc of a circle, and forming, by their decussations, minute curvilinear lozenge-shaped spaces. This peculiarity extends to the smallest fragment of true ivory, whether recent or fossil, and serves to distinguish it from all other kinds of tooth-substance, from bone, and from artificial compounds such as celluloid. The large size, and the density of the principal substance, of the teeth of many other species of animal, however, favour their application to many purposes analogous to those for which true ivory is used; these will find a place in the present article.

The economic value of teeth is dependent chiefly upon the laws of their growth. Those of limited growth, and which are incapable of renewing the waste that they suffer by wear, as in the case of man and most animals, are practically valueless; but those which continue to grow as long as the animal lives, as the tusks of the boar, hippopotamus, walrus, narwhal, elephant, and mastodon, are important objects of commerce. In teeth of unlimited growth, tooth-substance is formed at the base as fast as it is worn away from the apex, and thus the growth is uninterrupted. At first, the ratio of addition is greater than that of abrasion, and the tooth not only grows but increases in size; when the animal has attained its full size, however, the tooth is reproduced without increase of size, or augments only in length, and that solely where its surface is not abraded by an opposite tooth. The shape of the tooth or tusk, and the impressions on its surface, are due to the shape of its socket; malformations of the latter produce various abnormal forms of tusk. The tusk of the elephant is slightly movable in its socket, and may be readily made to grow in any particular direction by habitual pressure.

Having thus discussed the subject in its general bearings, it will be convenient to devote some separate consideration to each of the ivory-yielding animals—the elephant, mammoth, hippopotamus, walrus, narwhal, and dugong.

Elephant-ivory.—Existing elephants are divided into two distinct species—*Elephas indicus*, found, in several varieties, in both continental and insular Asia; and *E. africanus*, widely distributed in Africa. The most important characteristic of the Asiatic elephant, in connection with this article, is that tusks of a size to possess any commercial value are confined to the males. In the African species, the tusks of both sexes are of marketable growth, though the male is considerably the larger.

The two large permanent tusks of the elephant are preceded by two small deciduous ones, which make their appearance beyond the gum between the 5th and 7th months. They measure about 2 in. in length, and $\frac{1}{3}$ in. in diameter where they protrude; they are shed between the 1st and 2nd years. The permanent tusks cut the gum when about 1 in. long, and at 1–2 months after the "milk-tusks" are shed. At this period, the permanent tusks are black and rugged at the ends; as they grow beyond the lip, they are worn smooth by the motion and friction of the trunk. The microscopic structure of the peculiar modification of dentine called ivory is characterized partly by the minute size of the tubes, which, at their origin from the pulp-cavity, do not exceed $\frac{1}{15000}$ in. in diameter; in their close arrangement, at intervals but little greater than the breadth of a single tube; and, above all, in their strong and almost angular gyrations, which are much greater than the secondary curvatures of the tubes of ordinary dentine. By the minuteness and close arrangement of the tubes, and especially by their strongly undulating secondary curves, is produced a tougher and more elastic tissue than results from their disposition in ordinary dentine. Hence the superior value of ivory. Domestication of the elephant is usually attended by depreciation in quality, and decrease in size, of its ivory; and scientific observation has not resulted in the discovery of any means for increasing the growth, nor improving the quality, beyond the straightening process alluded to.

The tusks of the variety of Indian elephant called *Dauntelah* project nearly horizontally, and are sometimes almost straight. They are the largest of all Indian ivory, and rarely exceed 72 lb. in Bengal, and 50 lb. in Tipperah. In the *Mooknah* breed of India, the tusks are much smaller, are straight, and point directly downwards. Indian ivory has an opaque dead-white colour, and manifests a tendency to become discoloured. The exports of unmanufactured ivory from British India in recent years have been:—5936 lb. in 1874, 8288 lb. in 1875, 12,300 lb. in 1876, 10,731 lb. in 1877, 11,211 lb. in 1878. Their respective values were:—2295*l.*, 3918*l.*, 5947*l.*, 5256*l.*, 5665*l.*; and the values of the manufactured ivory exported in the same years were:—155*l.*, 212*l.*, 885*l.*, 302*l.*, 42*l.* Very large numbers of elephants are still found in Ceylon; their ivory is distinguished by fine grain, small size, and pearly bluish tint. Siam produces considerable quantities of ivory, which is considered much superior to Indian in appearance and density. The search for fossil ivory, probably of the same species as now exists, is said to be very profitable all along the W. side of the Gulf of Siam. The Singapore ivory most resembles that from Ceylon. Pegu and Cochin China afford larger tusks, up to 150 lb.

The ivory of the African elephant is much larger than that of the Indian. The animal itself is also much larger, especially to the south of 20° S. lat. Curiously enough, the nearer the equator is approached from that line, the smaller are the animals, but the larger the tusks. The latter feature may be accounted for by the greater age of the animals in less disturbed districts. The finest transparent ivory is collected principally along the W. coast of Africa, between lats. 10° N. and 10° S., and is believed to deteriorate in quality, and to be more liable to damage, with increase of latitude in either direction. The best white ivory is chiefly the produce of the E. coast of Africa generally. African ivory is considered to be in best condition when, recently cut, it has a mellow, warm, transparent tint, almost as if soaked in oil, and with little appearance of grain or fibre. In this state, it is termed "green" or "transparent." By exposure, the transparency is reduced, and the remaining delicate white line should be permanent. The quality of W. African ivory varies much. That best suited to the English market comes from the Camarone coast; Gaboon, Loando, Congo, and Ambriz rank next; these are followed by Gold Coast ivory, and that shipped at Sierra Leone and Cape Coast Castle. The Gold Coast may generally be known by having a roughly hewn hole near the end of the hollow; Gambia tusks are usually very bad, always broken, crooked, cracked in the hollows, and more or less damaged. On the E. coast of Africa, Zanzibar is the principal mart for perhaps the finest and largest ivory in the world. It collects the produce of the lands lying between the parallels of 2° N. lat., and 10° S. lat., and the area extending from the coast to Lake Tanganyika. The merchants at Zanzibar recognize three distinct qualities:—(1) The best, a white, soft and large variety, with small "bamboo," is from the Banadir, Brava, Makdishu and Marka. A somewhat inferior, harder sort is brought from the countries of Chaga, Umasac and Nguru. The Wamasai often spoil their tusks by cutting them, for facility of transport; and, like the people of Nguru, and other tribes, they stain the exterior with smoke, as a supposed preventive against their cracking or splitting in the sun. (2) The second quality is imported from the regions about Lake Nyassa, and carried to Kilwa by the Wabisa, Wahido, Wangindo, Wamakua, and other clans. The "Bisha" ivory formerly found its way to Mozambique. (3) The third and least valued quality is the western variety, the gendai, and others imported from Usagara, Ujiji, Urori, Unyamwezi, and its neighbourhood—Mgunda Mkhali, Usukuona, Umanda, Usagozi, &c. The ivory of Ujiji is collected from the provinces lying around the northern end of the lake, especially from Urundi and Uvira; these tusks have one great defect: though white and smooth, when freshly taken from the animal, they put forth, after a time, a sepia-coloured or dark-brown spot, extending like a ring over the surface, and gradually injuring the texture. It is apt to flake off outside, and is little prized on account of its lightness. Burton instances a lot of 47 tusks at Zanzibar averaging 95 lb. each, 80 lb. being considered moderate, and 70–75 lb. poor. Specimens weighing 175 lb. are not uncommon, and even 227–280 lb. is spoken of. At a London sale, Zanzibar tusks averaged 122 lb., Lagos 114 lb., Cape and Natal 106 lb., Gaboon 91 lb., and Angola 69 lb.; but these figures are not an absolute guide. Large quantities of ivory find an outlet at the Cape and Natal. The former exported 143,682 lb., value 60,402*l.*, in 1875; 161,234 lb., 58,626*l.*, in 1876; 137,660 lb., 50,711*l.*, in 1877; and 149,701 lb., 50,155*l.*, in 1878. The latter shipped 27,792 lb., 9430*l.*, in 1875; 29,172 lb., 11,048*l.*, in 1876; 43,119 lb., 15,014*l.*, in 1877; 37,136 lb., 12,054*l.*, in 1878. Of late years, a considerable quantity of ivory is brought by caravan across the desert to the various ports of N. Africa. Thus, the value of the export from Tripoli was 30,800*l.* in 1878, and 21,000*l.* in 1879; that from Bengazi, in 1878, was 5000*l.* (all to England); while those from all Egyptian ports, in 1879, were: to Great Britain, 4400*l.*; France, 1500*l.*; Italy, 1330*l.*; Austria, 530*l.*; Turkey, 260*l.*

Fine ivory is known by having no cracks nor flaws, whether in the solid or in the hollow; their presence is a serious detriment. Tusks that taper very gradually are preferred, and those which have a small hollow, i. e. are as straight as possible. Sharply-tapering and much-bent tusks cause great waste in cutting up. Tusks damaged at the point are inferior, and depreciated internally. The coat should be fine, thin, clear, and transparent. The applications of ivory include almost all ornamental articles of turnery, as well as knife-handles, brush-backs, combs, piano-keys, &c. "Scrivelloes," or tusks weighing less than 20 lb., are principally converted into billiard-balls. The ivory for piano-keys, combs, and other square articles, is cut into shape by means of very fine circular saws. The goods are polished and bleached. The latter operation is performed either by exposure to sunlight for periods varying from 4 weeks to 6 months, or by immersion in turpentine (kept near the surface), accompanied by exposure to sunlight for 3–4 days. When bleached, the ivory may be dyed. For ordinary dyestuffs, it will need to be first mordanted by soaking for 6–8 hours in vinegar, or alum solution. Red may be produced by a decoction of peach-wood; yellow, by saffron; green, by a solution of 3 parts verdigris and 1 part ammonia in vinegar; blue, by following the green bath with potash lye; black, by logwood decoction and acetate of iron. Coal-tar colours may also be used. Ivory is silvered usually by immersion for a few minutes in a nitrate of silver bath, and then in clean water exposed to the sun; or by exposure to the fumes of phosphoretted hydrogen after the silver bath. It may be made flexible by immersion in pure phosphoric acid, of sp. gr. 1·13; it hardens again on exposure to the air, but resumes pliancy when put into hot water.

Mammoth- or Fossil Ivory.—The tusks of the extinct *Elephas primigenius*, or mammoth, have a bolder and more extensive curvature than those of *E. indicus*. The numerous specimens which have been discovered may be ranged under two averages of size—the larger at 9½ ft. long, the smaller at 5½ ft. Prof. Owen assigns the smaller to the female animal, and thus makes the mammoth more nearly allied to the African than the Indian elephant of the present. This extinct elephant roamed in countless herds over the temperate and northern parts of Europe, Asia, and America, and its remains are now found in great abundance in Siberia and Alaska, preserved in the frozen soil. The erosion of the soil along the banks of the great rivers feeding the Arctic Ocean discloses every year very large quantities of this fossil ivory, the chief centres for its barter being Yakutsk, on the Lena, Turuchansk, on the Jenesei, and Obidorsk, on the Obi. Numbers of tusks are also found scattered about on the Tundras; while the richest harvest of all is gathered from the New Siberia Islands. Probably the total annual production of fossil ivory in Asiatic Russia amounts to 20,000–30,000 lb., the average weight of a pair of tusks being placed at 200 lb. The largest rarely leave the country, being either too rotten for industrial purposes, or so heavy that the natives are obliged to saw them up for removal. This latter fact causes great waste of the material. The tusks were an article of export to China at least 7 centuries ago, and no signs are yet visible of any diminution in the supply. Some were sold in London in 1876 at prices varying from 22*l.* to 43*l.* a cwt. Recent explorations on the Yukon river, in Alaska, are said to indicate the existence of even larger quantities of fossil ivory than have been yielded in Siberia.

Hippopotamus-ivory.—The hippopotamus, or "sea-cow" (*Hippopotamus amphibius*), is a native of Africa, in some parts of which, it is found in great abundance. The teeth of this animal which possess commercial value are of two kinds—the "canines," and the "incisors." The former are 4 in number, 2 in each jaw; those of the lower jaw are the larger; both are much curved. They are composed principally of an extremely dense, compact kind of dentine, protected on the most exposed portions of the surface by a thick layer of enamel, so hard as to strike fire with steel. The incisors number 8, are various in size, but all smaller than the canines, and are of less value. Usually only the two lower, lateral, projecting incisors are imported. The larger proportion of mineral matter in the dentine of the canines, as compared with elephant- or walrus-ivory, and its great density of formation, render it harder, and less liable to receive stains, than other similar substances, whilst the smaller amount of organic matter, and the almost complete absence of oily particles, account for its superior and delicate whiteness. These latter qualities, on the other hand, induce a certain brittleness, and render it easily acted upon by organic acids. The enamel is still whiter and harder than the dentine. Formerly, the canines were largely used by dentists, for making artificial teeth; but they have latterly been replaced by substitutes less liable to destruction by the acids met with in the act of eating. They are much employed in France, for the production of delicate intaglios; they are also superior to ivory for handles of surgical instruments, &c. For all but dental purposes, the enamel is first removed by an acid bath. The incisors are too soft to be of any value to dentists; the two long lower ones are made into knitting- and netting-needles, and similar articles. The smaller and curved upper incisors are fit only for common turnery. At one time, we imported 7–10 tons annually, worth up to 30*s.* a lb; the quantity now is small, and the value only 1*s.* 6*d.*–2*s.* 6*d.* a lb.

Walrus-ivory.—The walrus, or "sea-horse" (*Trichecus Rosmarus* [*Rosmarus obesus*]) is a native of the Arctic regions, being found abundantly on the coasts and islands of Alaska, where some 50,000 are obtained every year by the American whalers. The tusks of the animal are limited to a single pair, growing from the upper jaw, and descending outside the lower jaw. Their substance is less dense and coarser than the dentine of the hippopotamus tusk, and is of proportionately less value in commerce. They weigh about 4 lb. a pair, and sometimes attain a length of 2 ft. They were formerly in demand for dental purposes, and are much used in Chinese turnery. The quantity annually produced in Alaska amounts to about 100,000 lb.; and the Hudson's Bay Co. sometimes import 100–200 lb. in a year.

Narwhal-ivory.—The narwhal or "sea-unicorn" (*Monodon monoceros*) is also an inhabitant of the Arctic seas. The tusks are reduced to a single tooth, restricted to the male. It grows from the upper jaw, in a straight line; its exterior is marked by spiral ridges, which wind from within, forwards, upwards, and to the left. About 14 in. is implanted in the socket, and this is the most solid and weighty portion; it tapers gradually from base to apex, and attains a length of 9–10 ft., and a diameter of 4 in. at the base. It is, in fact, the left tusk of a pair, the right one being abortive, but always to be found in a rudimentary state, and occasionally protruding for a few inches. Denmark has sometimes imported 100 tons of these tusks (miscalled "sword-fish horns") from the Arctic seas in one year. The Greenland Co. collected 457 lb., valued at 175*l.*, in the year ending March 1875. The substance of the tusk is comparatively coarse, and of little value.

Dugong-ivory.—The Australian "dugong" (*Halicore australis*) is best known as affording a valuable animal oil, and is therefore described at length under Oils; but it also yields a kind of ivory. According to some accounts, the intermaxillary bones of the animal possess a fineness and hardness of grain, specific gravity, and appearance closely resembling ivory, and may be generally used as a substitute for elephant-ivory. Other accounts speak only of the two large incisor teeth or tusks, which adorn the head of the male, as being suitable for such purposes. Some cwt. have formerly been shipped from Moreton Bay, and valued at 60*s.* a cwt.

Imports and Values of Ivory.—Our imports of ivory—designated, in the Custom-House Returns, as elephants', sea-cows' and sea-horses' "teeth" (the commercial term being, in this case, scientifically correct)—in 1879 were as follows:—From Holland, 580 cwt., 23,876*l.*; Malta, 648 cwt., 26,203*l.*; Egypt, 685 cwt., 37,530*l.*; Aden, 440 cwt., 21,505*l.*; E. coast Africa, native states, 650 cwt., 32,511*l.*; British S. Africa, 1367 cwt., 62,772*l.*; British W. Africa, 85 cwt., 3337*l.*; W. coast Africa, Portuguese possessions, 275 cwt., 11,613*l.*; W. coast Africa, not particularly designated, 1801 cwt., 69,798*l.*; Bombay and Scinde, 1737 cwt., 79,065*l.*; Bengal and Burmah, 55 cwt., 2625*l.*; other countries, 1091 cwt., 36,092*l.*; total, 9414 cwt., 406,927*l.*

The approximate relative values are:—Elephant-ivory: 70 lb. each, and upwards, 50–70*l.* a cwt.; 50–70 lb., or "seconds," 45–65*l.*; 35–50 lb., or "thirds," 40–60*l.*; 20–35 lb., or "fourths," 30–50*l.*; "scrivelloes," 12–34*l.*; solid scrivelloes for billiard-balls, 45–65*l.*; cut pieces for billiard-balls, 50–75*l.* Sea-horse (walrus) teeth, 6*d.*–8*s.* a lb.

The chief substitutes for ivory are an artificial compound termed "celluloid," and the hard vegetable kernels called "corozo-nuts."

Bibliography.—R. Owen, 'Ivory and Teeth of Commerce' (Jour. Soc. Arts, Vol. v., No. 213, London: 1856); P. L. Simmonds, 'Animal Products' (London: 1877).

(See Bones; Celluloid; Horn; Nuts—Corozo-nuts).

JUTE MANUFACTURES.

The use of jute as a textile fibre, though known ages since in India, is only of recent introduction into this country. After the manufactures of India had been made familiar to the English public, attention was turned to the raw products of the country, amongst which the numerous indigenous fibrous plants engaged a great share. The use of jute for the manufacture of gunny-bags, canvas, carpets, and various other purposes, by the Hindoos, suggested its adaptability for similar textures at home. Towards the close of the last century, small lots of the fibre were imported into this country, and also to Hamburg and America, with the view of introducing it to manufacturers. But it was not favourably regarded, and, though for several years afterwards the E. India Co. repeated the experiment, the fibre continued in neglect, and remained comparatively unknown. Abingdon, in Oxfordshire, noted for its manufactures of woollen carpets, canvas, tunics, and similar fabrics, received some of these first importations; and here the first serious attempts were made to test its utility. Some of the fibre having been spun by hand, the yarn produced was discovered to possess some resemblance to woollen yarn, which led to its being dyed, and manufactured into carpets. This was probably between the years 1820–5. Tentative efforts continued to be made throughout the following 10–15 years. These took place chiefly at Dundee, at that time one of the principal seats of the linen manufacture. The fibre was tried in hand spinning, shed-spinning, and upon power flax machinery, which last was then beginning to be introduced into the trade. There was, however, much prejudice against it, and great reluctance to devote either money or effort to the experiments. The unsatisfactory results of previous trials of unknown Indian fibres engendered considerable distrust concerning all similar articles from that country. But it was not manufacturers alone who looked askance at the fibre: merchants, dealing in the classes of goods into which it was proposed to introduce it, refused to have anything to do with it, and required guarantees that the fabrics they purchased should contain none of it. Yet notwithstanding these obstacles, experiments were repeated in various directions, though on the smallest scale; and here and there, such results were obtained as encouraged persistence in the efforts to obtain something useful from it. From 1832, may be dated the practical success of these endeavours. At that time, Mr. Watt, a linen merchant, more far-seeing than most of his competitors, perceived its adaptability for several of the fabrics manufactured in the locality, particularly cotton-bagging, then rising into great demand. The length of the fibre, however, as compared with others in use, was a great drawback. Watt therefore got an old breaker card erected, and passing the jute through this, reduced it to a manageable length. The results of attempts to spin it in this form must have been more satisfactory, as Watt's difficulties diminished rapidly, several of the leading spinners becoming free purchasers of the raw material. From that time, its progress has been one of steady growth in public favour, until it has attained the important position it now holds amongst the textile industries of this country.

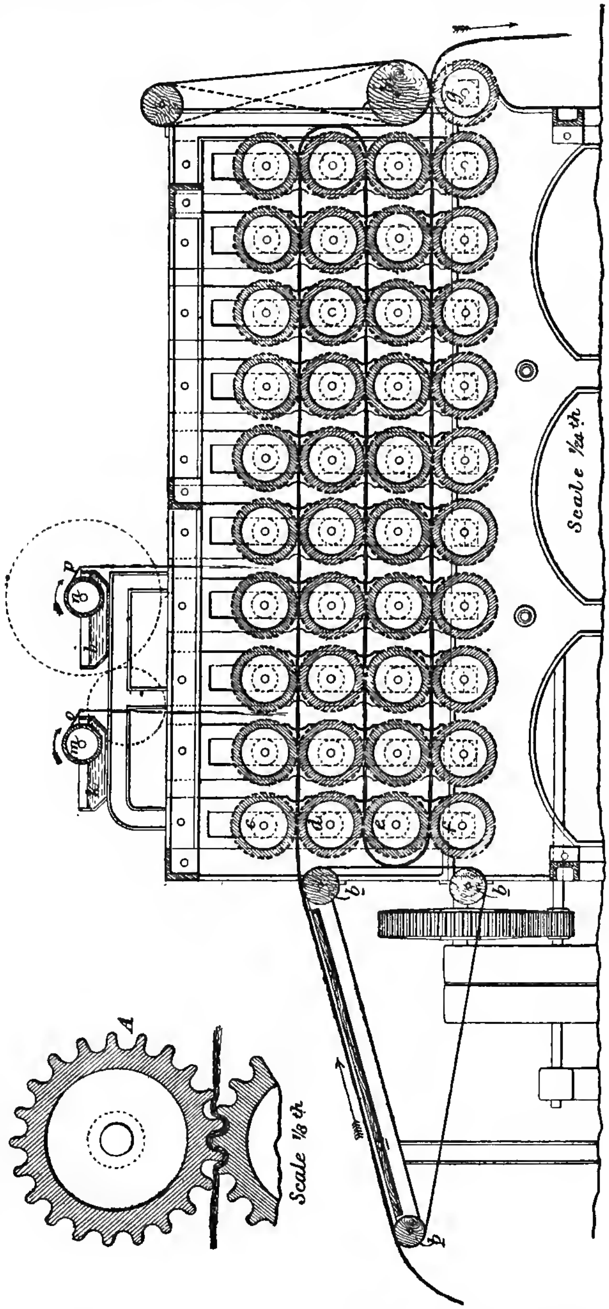
The jute consumed in our manufactures is chiefly imported from Bengal, where it is largely grown. After being assorted into different qualities, it is packed in bales containing about 400 lb.

each, and exported to the principal centres of consumption, the seaports nearest thereto, and often to other places, such as London and Liverpool, being a convenient return cargo.

The processes of manufacture which jute undergoes in the first division, are :—Softening, carding, drawing, roving, and spinning. These leave it in the form of yarn.

Softening.—Owing to the harsh character of the fibre, which renders it ill adapted for spinning, and which was one of the greatest difficulties encountered in the first experiments with it, the raw material requires to be subjected to the process of "softening." After being taken from the bale, the fibre is passed between a series of heavy fluted rollers, which crush and crimp it so that it becomes much more amenable to torsion than before.

861.



862.

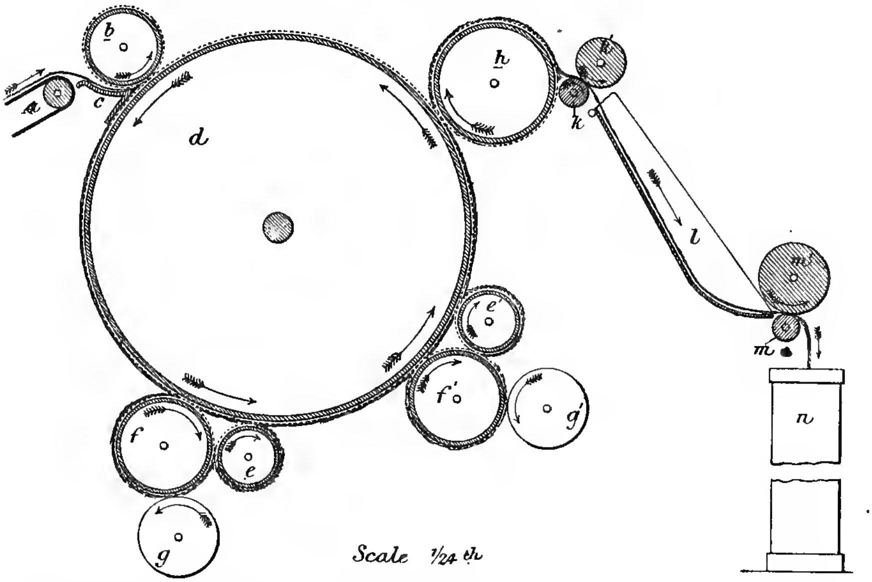
Fig. 861 exhibits a longitudinal section of the softening-machine, by means of which this is accomplished. It consists of four rows of rollers, 10 in each row, which are superimposed on each other. These rollers are 9 in. in diameter, and 2 ft. 6 in. in length. They are deeply fluted, as may be seen in Fig. 862, which is upon a scale of $\frac{1}{8}$th the size of the object; they are held in position by their axles being inserted in vertical slots in the side of the frame. The top roller rests upon the second, these two upon the third, and the whole three upon the bottom one. A feed-apron *a* is attached to the front of the machine. Over the top, are placed two cisterns *k l*, the first of which is a reservoir of water, and the second of oil. Each of these contains a revolving roller *m n*, which dips half its circumference into the fluids. Impinging against the upper surface, is a "doctor" or scraper *o p*, extending across the length of the roller, and the outer edge of which passes beyond the cistern. This is arranged to form an inclined plane, the lower edge being that away from the roller. At the extremity of the machine, are a pair of delivery-rollers, the bottom one of which is fluted, the superincumbent one being plain.

The process is as follows :—The "stricks," or handfuls of jute, are evenly fed upon the travelling apron *a*, which is actuated by the three rollers *b*, and travels in the direction of the arrow, the layer of fibre passing between the rollers *c d*, thence along the series, around the last of which it descends to retrace its course to the front of the machine, coming out between the rollers *d e*, down the front of which it again descends, and passes between the third and the bottom series, emerging from between the delivery-rollers *g h*. It will be observed that, when the fibre passes between the rollers *a b*, it is subjected only to the weight of the upper row of rollers; on its return, this weight is doubled, as the fibre is then passing under the two upper rows, after doubling from which, it is subjected to the weight of the three uppermost rows of rollers. The action of the corrugated surfaces of the rollers is also assisted by a slight lateral traverse, which is imparted to them to increase their effect.

Formerly jute was subjected to a process called "batching," in which the fibre was spread in layers, and sprinkled with oil and water, afterwards being left for several days, so that the mass might become uniformly permeated by the moisture, and thereby softened for the card. This is now more efficiently performed by means of this machine, with its attachment, as mentioned above, consisting of the water-cistern *k*, and the oil-cistern *l*, which, by means of the revolution of their respective rollers, discharge their contents upon the jute, as it is passing between the first rows of rollers. The even distribution of the oil and water, which is thus secured, and to which is added the further distributive effect of the lateral motion of the rollers, so uniformly moistens the mass of the fibre, that the necessity of allowing it to lie in heaps for several days is obviated. The softening process having been completed, the fibre is weighed into bundles, and conveyed to the card.

Carding.—In the first or breaker card, the length of the fibre, naturally 6–7 feet, is broken down to 14–18 in., which length it retains until it reaches the spinning process. The essential parts of the breaker card are shown in section in Fig. 863, and consist of a revolving feed-lattice or apron *a*;

863.

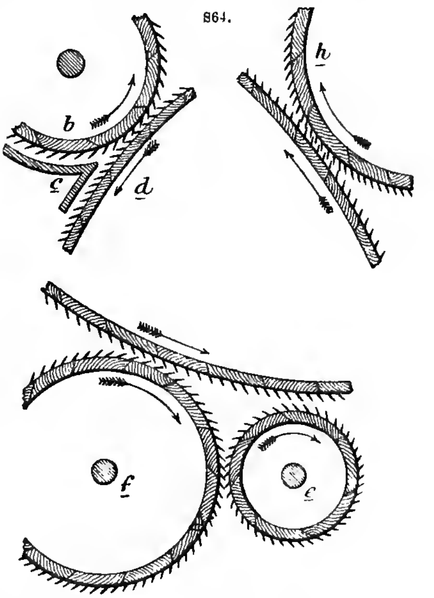


a feed-roller *b*, which possesses a concentric plate or shell *c*, placed on its lower side; the main carding-cylinder *d*, of about 4 ft. diameter and 6 ft. wide on the working surface, which is covered with strong steel cards or pins, arranged so as to incline slightly in the direction in which the cylinder revolves (Fig. 864); two pairs of workers and stripper-rollers *e f*, each pair having a tin roller *g*, for pressing the fibre into the card of the stripper to prevent its falling, and ensure its being carried around its periphery until delivered to the main-cylinder again; a doffer-cylinder *h*; doffing-rollers *k*; conductor *l*; delivery-rollers *m*; and sliver-can *n*.

In the operation of this card, the stricks of jute are evenly laid by the attendant upon the endless feed-apron *a*, with their foot- or root-end foremost, all joints being carefully broken. The movement of the apron conveys it to the feeder *b*, whose surface speed being only about 10 ft. a minute, the fibre is drawn slowly forward, and pressed into the teeth of the roller by the concentric plate *c*. As the feed-roller revolves, the fibre is presented to the action of the main carding-cylinder *d*, the surface revolution of which, being at the rate of 2000 ft. a minute, strikes the fibre with great force in a downward direction, thereby combing and dividing it very efficiently before the feeder and the concentric plate relinquish their hold. It is also obvious that a large quantity of the fibre will be broken or torn away by the great rapidity and severe action of the main cylinder. These portions, being carried on the card-points of the cylinder, are caught by the workers and strippers, and are opened and combed by their action.

The fibre is carried by the main cylinder down to the first worker *e*, which is the foremost to act after the cylinder has taken the jute from the feed-roller. The worker is about 9 in. in diameter, and has a surface speed of 50 ft. a minute. Its carding-pins or points are inclined at a more acute angle than those of the main cylinder, and in a direction opposite to that of its revolution, which is the same as the contiguous surface of the main cylinder (Fig. 864). As a consequence, the fibres, being partially thrown off the surface of the main cylinder by centrifugal force, are caught upon the pins of the more slowly-revolving worker, the points of which are inclined for their reception, the worker *e* being adjusted so that its pin-points shall be $\frac{1}{16}$–$\frac{1}{8}$ in. from those of the cylinder. The action of the main cylinder is therefore to pull the fibres upon the pins of the worker, and to carry them well towards their base, by which means, the latter roller succeeds in retaining a great portion of that which has not been sufficiently opened in the first stage of its passage through the machine. The worker, having thus secured possession of, and assisted to comb out more perfectly, the unopened fibre, is cleared in turn by the stripper *f*, a roller about 13 in. in diameter, and having its card-points inclined in the direction of its revolution (Fig. 864), and a surface speed of 450 ft. a minute, by which means, it is enabled to strip the worker *e*, whose cards are inclined to deliver them to its action. The latter in turn is similarly inclined to, and is stripped by, the main cylinder, revolving at a much quicker rate. The second worker and stripper perform a similar function, but they are adjusted a little closer than the above to the main cylinder, so that they will operate on any portion of the fibre that may have escaped the action of the preceding parts.

864.



All the jute having been thus delivered again to the main cylinder, and, in its progress to this point, having been combed and carded until it is clean, and its fibres are laid parallel, it is carried along by the revolution of the cylinder, until the doffer *h* is reached. This is a roller of about 16 in. in diameter, covered with rather finer cards than the preceding, and which are inclined away from the direction of its revolution. It is set still nearer than any of the preceding, its points almost touching those of the cylinder. This arrangement, combined with its relatively slow pace, enables it to strip all the carded fibres from the cylinder, whence it is carried to the small pair of doffing-rollers *k*, which receive it in a thin sheet or fleece, and pass it into the conductor *l*, which, from being the width of the rollers at the top, narrows until it is not more than 4 in. across. The fleece, in its transit along this way, is condensed into a sliver, and passes through the delivery-rollers *m*, falling into the sliver-can *n*, when the work of the breaker-card is completed.

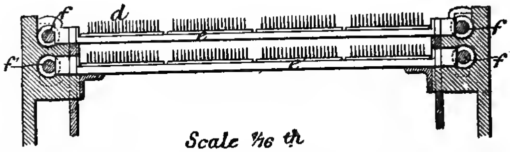
The surface speeds of the doffing-rollers *k* and delivery-rollers *m* are usually about 14 times the rate of the feed-roller *b*, hence, when the lap of jute is fed to the machine at about 2 lb. to 1 yd., it will be delivered at the opposite side in the sliver, attenuated 14 times = 7 yd. to 1 lb.

Jute being, like flax, capable of minute subdivision in its fibres, is usually submitted a second time to the process of carding. The machine used in this case is called the finisher-card, and, in its essentials, is exactly similar to the breaker-card. The differences consist in the cards upon all the rollers being finer than in the preceding case, and in each roller being set closer to its work. According to the comparatively rough or fine quality of work required, the pairs of working- and stripping-rollers are less or more in number, varying from three to five pairs, the latter being employed when the best work is wanted.

Twelve cans containing the carded jute from the breaker-card are placed behind the finisher, and the sliver from each, laid upon the endless apron, forms a lap, which passes into the machine, and is further combed and subdivided to the required state. The irregularities which will obviously occur in the sliver from the breaker-card, are, by this means, almost eliminated; and, as the speeds of the feed-roller and doffing-rollers are, in this case, 16 to 1, further attenuation takes place, the sliver delivered being of about 9½ yd. a lb., and, as compared with that from the breaker, much more level.

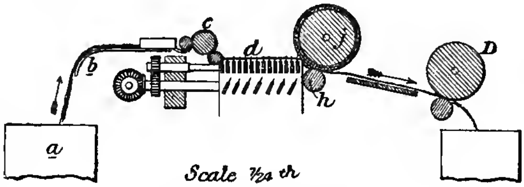
Drawing.—The sliver from the finisher-card is next required to undergo further attenuation, and to have its fibres placed in more perfectly parallel order. This is accomplished by the spiral gill drawing-frame, whose essential parts are shown in Figs. 865, 866, 867, 868. There are other kinds of these frames, but that illustrated is in most general use. Fig. 865 is a transverse section, showing the traveller-bars with the gills mounted upon them. Fig. 866 is a longitudinal section while the process is in operation. Fig. 867 gives an enlarged representation of the travelling-bars and the gills or hackles, which are seen in section in the preceding Fig., 866. In Fig. 868, is illustrated an enlarged section of the travelling-bar carriage.

865.

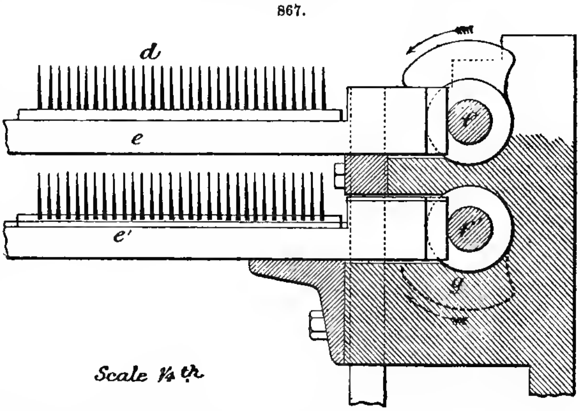


In operation, the cans *a*, containing the slivers from the finisher-card, are placed behind the machine. The slivers are then passed over the guide-plate *b*, and conducted to the retaining-rollers *c*, passing under the first, over the second, and under the third. These constitute the feed-rollers, their function being to supply the fibre to the gills *d*, upon the travelling-bars *e*, best seen in Figs. 867, 868. These bars are arranged just in front of the delivery side of the rollers, and each bar carries four "gills" or "hackles"—brass stocks filled with a row of vertical steel pins. On each side of the bars, are two shafts extending longitudinally across the machine, and one placed above the other. These have a large thread turned upon them in the middle portion of their length (*f*, Fig. 868), and are called the top and bottom screws. The top screws are cut at a pitch varying from 1½ to 2 threads an inch. The ends of the travelling or gill-bars are bevilled, so as to fit into the angle formed by the thread of the screws, the body of the bars and the gills they are carrying being thus maintained in a vertical position. In working, by the revolution of the shafts, the bars are made to travel forward from the retaining-rollers, carrying with them the gills, whose pins, having penetrated the sliver, draw the jute along with them, their speed slightly exceeding that of the rollers delivering the sliver, which secures the latter being held tightly, so that it is prevented rising from the pins. The bars move upon steel slides, which keep them at an uniform elevation, and secure them in their proper position. The threaded part of the shafts is proportioned to the length of the fibre, being 10–11 in. for carded jute.

866.



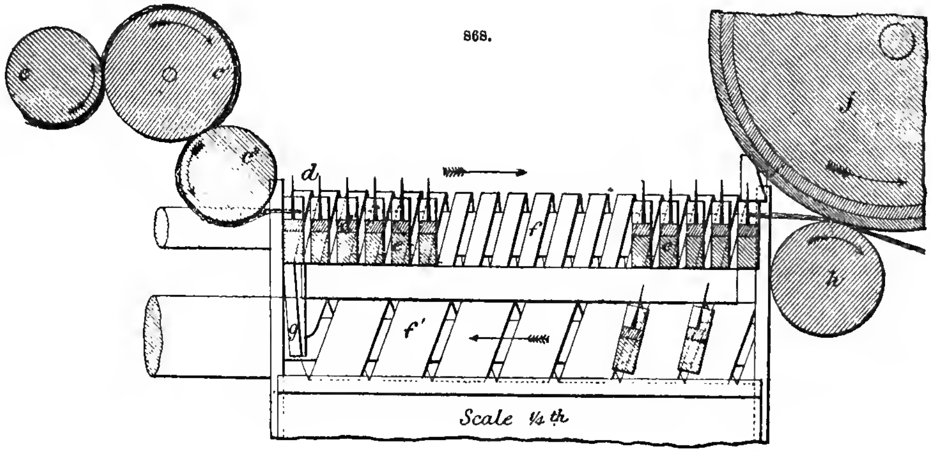
867.



On the arrival of each bar at the end of the top screw *f*, it drops from its position, the slides being purposely cut short to allow of this, upon the two bottom screws *f'*, into the threads of which, its bevilled extremities enter, as in the top screws. These screws are adjusted accurately, so as to receive the bars correctly. They are cut to the same hand as the top ones, but with a much quicker thread. They revolve in a direction opposite to those of the top, by which action, they carry back the bar to the position whence it started at the opposite end of the frame. The thread of the bottom shafts terminates in a projecting cam *g*, by which the bar is lifted again into the top shafts, the gill-pins in its elevation penetrating the sliver in process of delivery by the retaining rollers: thus commencing its journey anew.

At the front of the machine, where the sliver is delivered by the gills, are two rollers, the lower one *h* being composed of steel, about 2½ in. in diameter, and called the drawing-roller. The superincumbent one *j* is of cast iron, covered with leather, about 8 in. in diameter, and is called the pressing-roller. These rollers are pressed together by weighted levers, and revolve at a speed 6 or 7 times greater than that of the retaining-rollers *c*, or the movement of the travelling bars. The effect of this is that the sliver is seized by these rollers as the travelling bars drop from the top to the bottom screws, and drawn away from the pins of the gills, and that it is greatly attenuated, the gills which have not fallen retaining a sufficient hold of the sliver, and acting as a comb, holding the fibres back, and preventing them entering the rollers in a tangled state. After passing these, the sliver goes over a guide-plate between the delivery-rollers, and is again received into a can.

868.



The above parts constitute one division of a drawing-frame. The travelling bar is 3 ft. long, and fixed upon it are 4 gills, which are 6 in. wide at the pins. Each set of bars and gills, with their complement of retaining-, drawing-, and delivery-rollers, form a carriage; and frames are usually composed of two, three, or four of these carriages. In a drawing-frame of two carriages, containing four gills per carriage, there are eight sets of gills. Two slivers from the finisher-card are put up to each gill, the number of slivers required to supply such a frame therefore being 16. The card-sliver being about 9½ yd. to the lb., and the draught of the rollers as 6 to 1, with two slivers for each gill, the drawing-sliver as delivered from the rollers will be about 28½ yd. to the lb. But as there are still inequalities in the sliver, it is usual to double them after leaving the gills, by passing two of them together over one guide-plate, and through the above-mentioned delivery-rollers into one sliver-can, as, in that form, they are more convenient for the second drawing, to which they are next conveyed. The sliver, having thus been doubled, is, at this stage, about 14 yd. to the lb.

The second drawing-frame is of similar construction to the first, the only differences being that the gill-pins are finer and more closely set, and that the slivers are delivered singly from the drawing- to the delivery-rollers, and thence to the cans. Two slivers having again been put up to each gill, and the draught being 6 to 1, the strand is here attenuated to a length of 42 yd. to the lb.

As in the case of almost every other textile fibre, the object of these preparatory processes is to clean, comb, and attenuate the fibres, so as to fit them for the last operation of spinning into a thread, of dimensions suitable for the purpose to which it is intended to be applied. The roving-frame is the next to receive the sliver, and its function is to further attenuate it, and deliver it in a form convenient for the next stage of treatment.

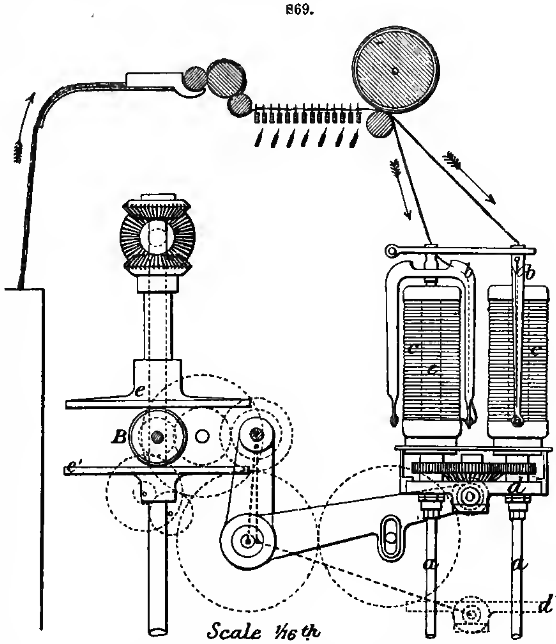
Roving.—In its chief parts, the roving-frame resembles the drawing-frame, the sliver-cans delivering their contents over a guide-plate to a set of three retaining-rollers, thence to the gills on the travelling bars, which carry it to the drawing-roller, between which and the presser, it passes to a flier-spindle, carrying a large bobbin, upon which the rove is wound, instead of, as in the preceding operations, being deposited in a can. Owing to the attenuation which the sliver has undergone, all the preceding parts of the machine are reduced in dimensions. One sliver only being put up to each gill, in this instance, the latter are made much smaller, the gill-pins being finer and more closely set than in the preceding machines, which enables eight gills to be mounted on one travelling bar, in place of four, as previously. . The draught in this case is usually as 7 to 1, so that the roving is greatly reduced in dimensions, measuring about 294 yd. to the lb. This necessitates the introduction of the flier-spindle, and the use of the bobbin as a receptacle for the roving.

The spindle and flier of the jute roving-frame are, with the exception of their dimensions, exactly the same as those employed in the cotton trade. Here, however, the parts are larger and stronger, as befits the heavier fibre to be treated. The number of spindles in a frame may be either few or many, ranging between 24 and 64 to each frame. A common size contains 56 spindles ; and as there is required a gill to each spindle, and eight gills form the complement of each carriage, there are consequently 7 carriages in a frame of 56 spindles.

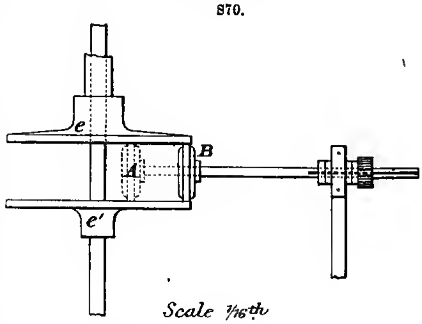
The spindles *a*, with their fliers *b* on the summit, are arranged in two rows in a vertical position in front of the frame, as shown in section in Fig. 869. The spindles are actuated by gearing at the foot, and make about 600 rev. a minute. The arms of the flier are tubular, the rove, after leaving the drawing-rollers, being conducted downwards through them to the extremity of the arm, whence, passiug through an eye or curl, it is wound upon the bobbin.

The bobbin is driven by gearing similar to that which turns the spindles, but of which it is quite independent. The course of its revolution is in the same direction as the flier, and either flier or bobbin may be arranged to lead. As a rule, it is the former that takes precedence, with the bobbin following. The twist imparted to the rove should not be more than is necessary to secure its coherence when being drawn from the bobbin in the subsequent process. Assuming a case in which the frame is arranged for the flier to lead, and supposing that one turn a minute is sufficient for the roving being produced, with the spindles making 600 rev. a minute, the followiug conditions require to be observed. The drawing-roller must be arranged to deliver 1 in. for each rev. of the flier, and the speed of the bobbin must be retarded, as compared with the spindle, to a degree sufficient to enable it to wind up the quantity of roving delivered by the drawing-rollers. In this case, the roller delivers 600 in. a minute, the spindle and flier make 600 rev. a minute, and the shank of the bobbin *c*, which is shown by the dotted vertical lines, is 5 in. in circumference. Dividing the number of in. (600) delivered by the roller by the winding surface (5 in.) = 120, then 600 − 120 = 480, is the speed at which the bobbin is required to run to wind up the 600 in. But this is not a constant rate: every layer of roving wound upon the bobbin enlarges the circumference of the winding surface. If the bobbin were to remain constant, the roving would be rapidly attenuated, or so over-run as to be broken in every case long before the bobbin could be filled. These results are obviated by means of differential driving-gear, the essential parts of which are seen in Figs. 869, 870. The roving is first wound upon the bare shank of the bobbin in an even layer, and each succeeding one upon that which has gone before, until the bobbin is filled. This is accomplished by mounting the bobbins on a lifting-rail *d*, whose traverse extends downwards to *d′*, by which means, the bobbins *c* are moved upwards and downwards through the same space, and the rove is placed in even layers by the flier. The deposit of each layer of rove upon the bobbin increases the circumference of the winding surface of the bobbin, but the drag which this would cause is prevented, by the speed of the bobbin being accelerated in exact proportion to its increased winding surface, so that it still continues to take up only the 1 in. delivered for each rev. of the flier. This acceleration of the speed is caused by a projection attached to the lifting-rail, which is so arranged as to release a catch each time the rail arrives at the top and bottom of its traverse. The regulating motion is obtained from a bowl or pulley B, Figs. 869, 870, having a leather face, which is made to revolve by frictional contact between two flat, circular, iron discs *e*, rotating in opposite directions.

869.



870.

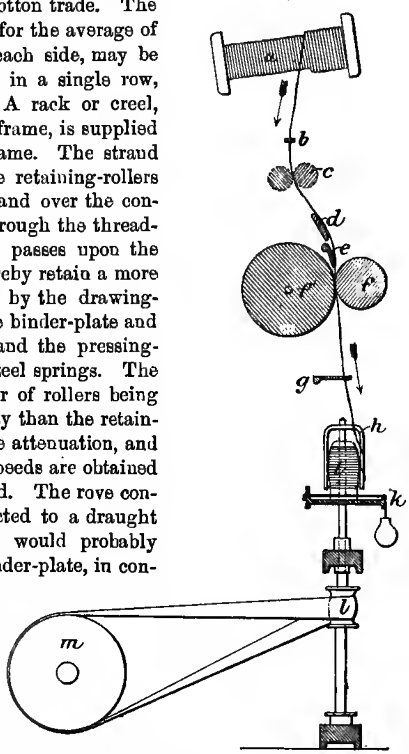


In commencing to fill a set of bobbins, the friction-bowl B occupies the position shown by the dotted lines at A (Fig. 870), which is its starting-point. Each time that a catch is released, either at top or bottom of the traverse, the bowl, with the shaft on which it is fixed, is allowed to slide outwards a little from the centre of the two discs *e*, whereby its speed is increased, and that of the bobbin correspondingly accelerated, for each additional layer of rove that the bobbin receives; and when the bowl has arrived at the position B (Fig. 870), the bobbin has attained its maximum speed, is filled, and is then ready for doffing. When the frame is arranged so that the bobbin leads, these movements are reversed.

Ordinarily, the product of this frame is rove only; but it is customary, when the yarns required do not exceed 400 yd. to the lb., to finish the operation in this frame, by giving the material the amount of twist that is necessary to impart the requisite strength, and constitute it yarn. By this means, one process is dispensed with.

Spinning.—The bobbins containing the rove are next carried to the spinning-frame, in which the latter is attenuated for the last time to any required degree, and receives the complement of twist which renders it yarn. Fig. 871 shows a section of this machine, which, in its essential parts, is the "throstle-frame" of the cotton trade. The details of size, &c., depend upon requirements; but, for the average of jute yarns, a frame providing 128 spindles, 64 on each side, may be considered of full dimensions. These are arranged in a single row, the pitch or distance between them being 3¾ in. A rack or creel, possessing as many pins as there are spindles in the frame, is supplied with the bobbins *a*, containing rove from the last frame. The strand of rove is conducted through an eyelet-guide *b*, to the retaining-rollers *c*, between which it passes to the binding-plate *d*, and over the conductor *e*, to the drawing- and pressing-rollers *f f′*, through the thread-plate *g*, and around the leg of the flier, whence it passes upon the bobbin *i*. The retaining-rollers *c* are fluted, and thereby retain a more firm grip of the rove. As the latter is attenuated by the drawing-rollers, it is slightly condensed by its passage over the binder-plate and conductor. The drawing-roller *f* is made of iron, and the pressing-roller of wood, the latter being held in position by steel springs. The attenuation of the rove is accomplished by this pair of rollers being made to run at a considerably greater surface velocity than the retaining-rollers: the higher the velocity, the greater is the attenuation, and the finer the yarn. The differences in the relative speeds are obtained by change-wheels, to suit the size of the yarn required. The rove containing only one turn of twist per inch, when subjected to a draught of seven, almost loses its power of coherence, and would probably break, were it not for the service rendered by the binder-plate, in consolidating the somewhat loose form of the fibres, and the assistance of a similar kind derived from the conductor, whilst the rove is on its passage to and through the drawing-rollers. Immediately on emerging from the nip of these, it is twisted strongly by the rapidly-revolving spindle, which fixes it in the form it has to retain as a thread, and so completes the first stage of the manufacture. Maintaining the assumption that the rove was 294 yd. to the lb., a draught of 7 would yield a yarn of 2058 yd. to the lb., loss the small proportion that would be taken up by the twist which is imparted to the strand.

871.



For the foregoing illustrations, and much valuable information, indebtedness is acknowledged to W. Fleming, of the Barrow Flax and Jute Works, and to the Institute of Mechanical Engineers.

Jute yarns receive their denomination from the weight of the "spyndle," which contains 14,400 yd.; such a yarn as has been assumed to be passing through the series of machines described above would give 7 lb. to the spyndle, and hence would be known as "7-lb. yarn." The range of weights of yarn extends from 1¾ to 30 lb. a spyndle.

Jute yarns, as such, are used for many purposes: twines, cords, ropes, covering telegraph-cables, wire-ropes, &c.

Manufacturing.—Having traced the raw material through the processes necessary to form it into yarn, it only remains to describe the weaving department, or the operations necessary to convert it into a textile fabric. As compared with the preceding, these are comparatively unimportant, and vary but little from the processes followed in other branches of weaving.

Jute differs from most other textile fibres in being capable of use in the "green" or unsized condition for most of its purposes, though the finer Nos. of its warp yarns are usually sized.

The calculations for the manufacture of jute in the weaving department are based on the following table:—

90 in.	=	1 thread	=	2½ yd.	
120 threads	=	1 cut	=	300	„
2 cuts	=	1 heer	=	600	„
6 heers	=	1 hasp	=	3,600	„
4 hasps	=	1 spyndle	=	14,400	„

This means that jute yarn is reeled on a reel of 90 in. circumference, and 1 rev. forms a thread; 120 threads are tied together, and make a cut; and so on throughout the table. As observed above, the fineness of the yarn is determined by the weight of the spyndle, and is spoken of as 6-, 7-, and 8-lb. yarn, or otherwise, as the case may be.

Jute fabrics are described by the number of "porters" and width in inches, the length being according to requirement. As an illustration, take say a "16-porter 40-in. Hessian, of 18 "shots" or picks per inch and 100 yd. in length. The porter is the standard in jute manufacture by which the fineness of the "camb" (or set of heddles) and the reed are determined, and consequently the number of threads in the warp to make any given description of cloth. The porter is composed of 40 heddles, each heddle containing one thread, and 20 splits or dents of the reed, two threads going between each two dents. When one thread alone is used, the reed is as fine again. The number of porters in 37 in. of the reed indicates the fineness of the cloth. In the case supposed, it occurs 16 times, and so gives its denomination to the web. The texture of a jute fabric is, however, considerably modified in the finishing process to which it is subjected. This consists of heavy calendering, by which the length of the piece is increased at the expense of its width, and by means of which it may happen that the latter is so much contracted that, though woven as a "16-porter," it could only be accurately described by calling it an 18-porter fabric.

When the particulars of a cloth which it is intended to make are found, the necessary instructions are given to the warper. On 37 in., 2 in. are allowed for shrinkage in width, and 10 per cent. for what is taken up in the length owing to the warp threads being deflected from a straight line by the insertion of the weft threads. This amount is not invariable, being larger when the weft is coarse or heavy, and less when very fine.

Warping.—In establishments in which both spinning and weaving are carried on, the bobbins from the spinning-frame are often taken directly to the warper, and the cost of winding is thereby avoided. The bobbins are placed in a "bank" or creel, and sometimes, when the fabric is very narrow, and the creel will contain a sufficient number of threads, these are run direct upon the weavers' beam, if it is intended to be used in the green state. When the warp requires a large number of threads, it is divided into four parts, one quarter being warped at a time, the four parts next being run upon the weavers' beam. This process is generally regarded as the most expeditious and economical in making wide warps, as the small number of threads enables the warper to give them perfect attention, and, at the same time, permits the speed to be considerably increased. The warping-mill employed in the jute trade is the common vertical reel mill, composed of an upright beam revolving upon two iron pivots, one at each end. Into this beam are inserted three rows of arms: one each at the top, centre, and bottom. Vertical bars of wood are fixed upon the extremities of these arms, and the whole composes the reel. At the bottom of the central beam, is a pulley, around which passes the driving-band from a larger pulley outside the reel, whereby it is driven. Owing to the comparatively short length of jute warps, and the frequent stoppages that occur in making them, it is customary to use manual power instead of steam, though the latter may be at hand. The warping-mill is therefore worked by means of the hand and foot of the attendant. The yarn from the banks or creel, being passed through two reeds, is attached to and wound spirally upon the reel, the length of the warp depending upon the number of turns of the reel before its action is reversed. The breadth is decided by the number of threads in the bank, and the number of "bouts," as a complete traverse of the winding process over the reel is termed. When the warp is completed, before it is "doffed," or removed from the mill, a "lease" is taken, which means that the threads have to be alternately elevated and depressed, to admit of the insertion of a transverse thread, to facilitate a subsequent process. In order to permit this to be done with facility, the two small reeds employed to conduct the threads from the bank of bobbins to the reel are utilized. The reed nearest the bank is constructed in the usual open way, but the second has every alternate split stopped with solder at about 1 in. from its rim, by which means the threads are instantly separated as desired. The doffing constitutes a chain, warp, or section of a warp, as the case may be.

Beaming.—The next process is "beaming," or winding the warp upon the loom-beam. The sections of the warp are placed side by side, and the threads from each are passed in a larger or smaller number through the dents or splits of a coarse reed, termed an "evener" or "wraithe," by means of which, when the machine is started, the yarn is wound evenly upon the beam, as guided. This evener contains 72 pins in 37 in., and sometimes has a loose top which is removed in order to insert the threads between the pins, and replaced to retain them in position for the winding process. The number of threads put into the spaces between the pins are termed "pinfuls."

Drawing-in.—After beaming, the next process is to draw the warp threads into the camb and the reed. The eyelets of the heddles are composed of wire rings. The "drawing-in" of the warp is a very simple process, accomplished by means of a hook being put through the reed and heddle-rings, which, having the warp threads put over it by a child assistant of the drawer-in, is with-drawn, bringing each thread with it. When all have been thus drawn in, the warp is ready for the loom. This process only takes place when a camb is new and has to be used for the first time. After the first warp has been woven to near the end, it is cut so as to leave a sufficient length behind the heddles, to which the succeeding warp can be tied.

Sizing.—In the case of fine yarns, the processes differ somewhat from these. The bobbins from the spinning-frame are taken to the winder, who winds the yarn upon large bobbins which go to the sizing-frame. This frame is a very simple machine, being almost like the beaming-frame just described, but instead of taking the yarn in the form of a chain, it is fitted with a creel, large enough to contain a sufficient number of bobbins for a complete warp. The threads are passed through a reed, as before, after which they are conducted through a trough of thin size made from farina, on emerging from which, the "sheet" of threads is exposed to the action of several drying-fans, and then passes upon the beam. There is no sizing for weight in the jute-trade.

Weaving.—Jute looms possess no feature to distinguish them from looms employed to weave other fibrous materials, beyond being of increased strength. They are adapted to weave plain fabrics, twills, and sometimes figured goods, as in the case of jute carpets. They are usually on the overpick principle, and of various widths. When contrasted with looms used in other branches of the textile industries, they appear crude and roughly finished, and, generally speaking, it might be advantageous to bestow upon their construction a little more care than is apparently given at present. Owing to the character of the fibre, and the heavy yarns usually spun from it, the looms for weaving jute have necessarily large projections at the end of the lathe for shuttle-boxes to receive the great heavy shuttles employed.

Formerly pirns were used, on which the weft yarns were wound. These were of wood, but were of necessity so large that very little yarn could be put upon them, and the frequent stoppages caused by its exhaustion greatly restricted the production from a loom. A few years ago, however, a machine for forming cops for weft purposes was invented, and has now to a great extent superseded the use of pirns. The yarns intended for weft are brought upon the bobbins from the spinning-frame to the copping-machine. Being placed in the frame, the thread is drawn from the bobbin, and passed through a conical cap fixed upon the extremity of an oscillating lever. The thread is attached to the winding-spindle, and the oscillating cap, which is a hollow cone, traverses the thread in the winding so as to form a cop, which, when doffed, is ready for the loom. The peculiarity of this cop is in its construction, which enables it to be used from the base, the yarn being drawn from its interior. This necessitates a peculiar form of shuttle also, which has no peg, as ordinarily, but is prepared to receive the cop without, and has the open top closed with a metallic plate, fastened down with a spring. By the adoption of this plan, the production has been increased, the quality improved, and the cost lessened.

In jute-weaving, similar qualities are required as in other sections of the trade, to constitute the best results. An even distribution of both longitudinal and transverse threads must be secured; irregularities in the picking must be avoided, and the fabric must not be "reed-raked." "Putting a skin on the cloth," as it is technically called, is an important matter in making a marketable article. This is what is known in the cotton trade as "cover," or throwing upon the surface all the loose fibres of the yarn composing both warp and weft, whereby the fabric appears full and closely woven, or more so than it would otherwise do were this matter neglected. These are points of detail occurring in practice which do not require further reference here.

When the cloth leaves the weaver, in a well-conducted establishment, it is usually examined, and all blemishes are repaired, absent threads through breakages being inserted by the needle. The women to whom this task is confided execute it with great dexterity and swiftness. After examination, the cloth is ready for finishing.

Finishing.—The finishing of jute fabrics consists of little more than calendering. The material has, long before arriving at this point, lost most of the moisture it received in the batching process, and has become dry and rough. In order to render it pliable, and more amenable to the influence of the calendering process, each web is passed through a damping machine; in the body of this is fixed a brush, which, dipping into a trough of water, and rapidly revolving throws a shower of fine spray against the cloth. As the cloth is thus rolled damp, every portion is soon penetrated by the moisture, and it is then ready for the calender.

Calendering-machines are of different forms and sizes to suit requirement. The largest and most powerful are capable of putting a pressure of 100 tons upon the article subjected to their operation. The price of machines of this capacity is 4000*l*.–5000*l*. An ordinary calender consists of four rollers, two being hollow metallic cylinders, highly polished, and heated by steam. These are placed alternately with the other two, which are composed of compressed paper-material, and are extremely solid and heavy. The web being passed through this machine, and thus subjected to great pressure and heat, receives a glazed finish, which considerably alters its appearance. The length is increased at the expense of the width, sometimes to the extent of a porter or two, as indicated above, which consequently alters its denomination as a matter of fact, though the change may not always be made.

There are different kinds of finishes, but, as they chiefly depend upon the amount of pressure given in the calender, they do not require further description. In one or two cases, for special purposes, the fabrics are passed through a shearing-machine, and subjected to the action of a revolving knife-roller, which clears off all the loose fibre of the yarns.

After passing the finishing processes, the pieces are rolled, folded, or plaited, according to requirement, and made up in the most convenient forms for the different markets.

Sometimes the manufacturing processes are carried beyond this point, and coffee-, sugar-, grain-, and other descriptions of, bags and sacks are made upon the establishment where the raw material has been spun and woven. In this case, the fabrics are cut up into appropriate lengths by machinery, stitched by powerful sewing-machines driven by steam-power, piled in bundles, subjected to hydraulic pressure, and packed for sale.

Jute is one of those textile fibres which is capable of very minute subdivision. But for a long time, it proved comparatively intractable in the hands even of the most skilful operators. This confined its use to the most humble domain of the textile industries; the manufacture of sacking, canvas, carpet-backing, and coarse carpeting. A few years ago, however, it began to yield to the efforts made to accomplish the more perfect disintegration of its fibre, which has led to its use in more pretentious fabrics, such as crumb-cloths, table-cloths, towellings, &c. Further success has also been more recently attained, not only in the more minute subdivision of its fibre, but also in bleaching and dyeing it. All attempts to accomplish the former object rendered it weak and brittle, and almost unfit for textile uses; whilst efforts to dye it succeeded merely to the extent of depositing a thin film of colouring matter upon its surface, which slight friction would rub off. In all these points, considerable advances have been made. The fibre can now be divided so finely that it is capable of being mixed with silk, for association with which its natural lustre eminently fits it. The improvements effected in the methods of dyeing have led to the production on it of the most bright, fine, and permanent colours, of lustrous beauty. These results, though practically successful, have hardly yet been commercially so; but it may be hoped that no long period will intervene before even this is achieved.

The progress made in manufacturing jute in this country since its introduction is very remarkable, as will be seen from the following figures extracted from the latest official Returns (1879):—

Jute Factories in the United Kingdom.

	No. of Factories.	Total No. of Spinning-Spindles.	Total No. of Doubling-Spindles.	Total No. of Power-Looms.	No. of Children working Half-time.		Total No. of Persons employed.		
					Males.	Females.	Males.	Females.	Total.
England and Wales ..	12	23,762	1,407	1,057	325	298	1,382	3,579	4,961
Scotland ..	99	183,056	5,855	10,009	1,203	1,674	8,920	21,481	30,401
Ireland ..	6	5,858	230	222	14	8	272	720	992
Total ..	117	212,676	7,492	11,288	1,542	1,980	10,574	25,780	36,354

The numbers of persons employed, the capital invested, and the value of the manufactured product, fully demonstrate that, though one of the youngest of the textile industries, it bids fair to attain considerable importance.

R. M.

KNITTED FABRICS—HOSIERY (Fr. *Bonneterie;* Ger. *Strumpfwaaren, Wirkwaaren.*)

The adoption of coverings for the nether limbs was undoubtedly one of the latest developments of the clothier's art. By what people the custom was first introduced, is not known; and it is equally uncertain what material was first employed for the purpose. As various causes compelled some tribes of the human race to wander into temperate and cold regions, they must have found that the partial covering, which had previously sufficed for their requirements, no longer served to shield them. Hence those parts of the body which had hitherto been left uncovered, such as the arms and legs, would receive equal attention with the other portions. It is a probable conjecture, therefore, that "hose" originated with some of the nations residing in the northerly temperate latitudes.

The material first used would most likely be the skins of the smaller quadrupeds, including those of kids and lambs, to be succeeded in time by cloth of different materials, when the art of weaving had made some progress. Hose made from woven fabrics remained in general use until comparatively recent times. Woollen cloths being common, and possessing other merits to recommend them, were most naturally adopted for this purpose. Plenty of evidence exists to show that hose of this description was in general use down to the close of the 16th century, when it began to be superseded by the knitted article, which, from its superior adaptability, after its introduction, soon won universal favour.

When or by whom knitting was invented, is not known, but in manuscripts of the early part of the 16th century, are occasional references to knitted hose, whose prices indicate that the art was then a rare accomplishment.

Of the origin of machine knitting, we have more definite particulars. The hosiery industry, as we know it now, is indebted for its existence, and probably for its remarkable development, to the inventive genius of a clergyman, William Lee, of Calverton, near Nottingham. His struggles in perfecting his invention appear to have almost exhausted his means before the idea received practical embodiment. Even after this was accomplished, success was far from complete. His unsuccessful endeavour to obtain the patronage of Queen Elizabeth is well known. Encouraged by promises from the King of France, he subsequently emigrated to that country, and settled at Rouen, where he endeavoured to plant the new industry. Here misfortune still followed him: his patron, Henry IV., being murdered, all his hopes of protection and favour were destroyed, and, under increasing difficulties, he died in Paris in 1610, in a state of indigence. Subsequently, his brother James brought the machines back to England, and settled in London, where the new art soon made considerable progress. The industry grew to such an extent that, about 1650, its members had become so numerous, wealthy, and influential, as to make efforts to establish a chartered company. Another motive inducing them to take this step, was the difficulty the unchartered company experienced in enforcing regulations, devised to prevent unfair competition amongst its members. These objects were realized in 1657, by the grant of a charter from Cromwell. A second charter, confirming the first, was afterwards obtained from Charles II.

It is not necessary here to trace the steps by which Lee perfected his machine, nor to detail its subsequent development in the hands of later inventors, in more than brief outline. Few were of much importance, until Jedediah Strutt added the ribbing-apparatus, in 1758. This invention enabled a ribbed web to be produced on Lee's machine, which had hitherto been able to make only a plain one, except by hand, by selecting the threads and arranging them in order to form the pattern. Derby ribbed hosiery soon raised itself into high and extensive favour, and the principle is as popular to day as ever. Strutt's invention was followed by the improvements of Morris, Crome, and Else, which, with others, laid the foundation of the modern machine-wrought lace. The success attending the labours of Strutt, and the wealth secured by several individuals who adopted his improvements, greatly stimulated invention, and the patents taken out during the remainder of the century were numerous and important, much advancing the perfection of the machinery. An enumeration of these would be uninstructive, unless accompanied by full explanatory details, and, for this reason, they are mostly passed over. The most remarkable feature developed was the great capacity for the manufacture of fancy hosiery, which, as a consequence, became exceedingly popular. The demand for this class of goods endured until the close of the century, when the fashion began to decline in public estimation, until a point of deep depression was reached. Great sufferings were consequently entailed upon the workers for many years afterwards, a revival seldom being more than partial or temporary.

This depressed period did not terminate until subsequently to the year 1845, when considerable changes were introduced into the machinery employed in the trade, circular frames taking the place of those previously existing. A more important movement was the adoption of the factory system of employment, by which a better organization of labour was effected, and habits of steady industry were fostered, the development of which have carried the hosiery trade to its present high prosperity, as one of the best paid industries in the United Kingdom.

Depression and low wages constituted a great obstacle to the introduction of improved machinery, by which further reductions could be made in the price of the finished article, and the consumption be correspondingly increased. At the above-mentioned date, however, a considerable number of new frames, working by steam power, and yielding a much larger production, had been got to work with beneficial results. The great change in the commercial legislation of the country, which was inaugurated by the repeal of the Corn Laws, and the subsequent abolition of nearly all import duties, was near at hand, and this transformation took place just in time to meet the greatly improved demand, which the stimulus derived from a liberated commerce gave to the trade.

Some difficult problems in connection with the improved machinery remained to be solved, such as the shaping or fashioning of the fabric by automatic means, and without the cessation of its action. Barton, an inventor, partially accomplished this, by a plan in which the stitches were shifted automatically, in addition to the movements previously necessary, in a frame known at the time as a "wide rotary frame." In 1816, Sir Marc Isambert Brunel invented a circular knitting-frame of considerable merit, which has since been rendered most effective and useful. This machine, Brunel called the "tricoteur," or "frame-work knitter"; it produced a tubular web, which was cut up and finished by subsequent operations. The general aversion at that time to unshaped hose, however, caused it to be neglected, and it passed out of notice until about 1844, when Pagets, of Loughborough, reintroduced it, with modifications which greatly increased its value. It was further improved by Peter Claussen, of Brussels, who took out a patent in this country in 1845, and exhibited his machine in Nottingham. The manufacturers of that town, though strongly averse to the introduction into the trade of the "leg-bag" machine, saw that further opposition would be unavailing, and that if not adopted there, it would become a formidable competitor elsewhere, yielded in detail to the force of circumstances. Claussen, in 1847, added further improvements, rotating hooks and a winding-up apparatus, which practically perfected the machine, as without these, the rapidity of its production of tube-web rendered the latter an encumbrance. After this addition, the adoption of this class of machinery extended rapidly. The "wheel frame" was soon afterwards introduced, and so-called because "the operations of supplying the yarn, dividing the loops, pressing them, and carrying them over the heads of the needles, are accomplished entirely by means of wheels." This mode of constructing and manipulating round machines continues to be most prevalent for making plain circular stocking-web. The cylinders have been increased greatly in diameter, so as to adapt the production to other purposes. Notwithstanding these changes, there still remained to overcome the initial defect of this class of frames. The product was a tube of equal diameter throughout: a "leg-bag," as it was contemptuously called by those who produced shaped hosiery. But about this date, an invention was perfected by a framework knitter, named Thompson, by means of which, the circular frame was enabled to produce ribbed hose, which, from its peculiar texture, conforming readily to the outline of the leg, dispenses with all necessity for "shaping" or "fashioning." This improvement opened a wide field of usefulness to the circular machine, and gave a great stimulus to the trade.

In 1847, M. Townshend, a framework knitter, patented the first of a series of great improvements, to which the trade has been much indebted. The first was for the adaptation of a machine like a point-net frame, to an ordinary stocking-frame. This invention was intended to take the work by the machine off from, and return it to, the frame instruments, in such manner that the direction of the loops might be reversed on the surface of the fabric from time to time, as it was effected by hand knitting, and by frames which were reversible by hand. In 1854, Townshend invented a plan for making round hose on the circular frame, the heels and toes being fashioned on other machines. Two years later, he came forward with another improvement, a method of raising looped pile on knotted fabrics for "terry." This he accomplished by employing a row of needles or points, or their equivalents, acting in combination with a jacquard apparatus. Using a bell crank and lever guides, similary actuated, for throwing different colours into the work, and using "hinge covering needles" in knitting double pile fabrics, and a notched sinker. In the same year, he took out another patent, in which these hinge covering needles are again employed, and probably in a more perfect form. The patent was for the application of jointed guides to the machinery of double barred knitted goods, so making figured patterns on both sides, which he accomplished by throwing threads on one row of needles or hooks, to form the pattern, and carrying surplus threads round the other row of needles, to form the pattern on the reverse, the result being that both sides appeared alike. Sliding needles or hooks were used, moved by the jacquard in the required direction. In this invention, rows or circles of double-ended needles, having hooks or beards at both ends, were introduced, and formed loops by a peculiar method. He also claimed the making of circular knitted warp fabrics, by using a row of "tumbler" needles, having hinged beards circularly placed, with lever guides to carry the threads forming the fabric.

This "tumbler" or "latch" needle has since become an important feature in many machines constructed for the manufacture of fancy hosiery. It is now in extensive use, in this country, as well as on the Continent, and in America, to which last country Townshend subsequently emigrated.

Thompson, whose name has been mentioned, in 1853, took out a further patent for improvements in looped fabrics, made upon the circular ribbing-machine, in conjunction with Hine, Mundella, and Co. By this improvement, the thread from the cop was carried under the frame needle beards by a looping-wheel. As these needles were carried around, they were depressed by the lower part of the collar, thereby bringing their beards to the frame-presser; after pressing, the work was pushed over by the top of the collar. The work was next drawn back ready for the machine-presser to operate upon it, at which position, a plate drew the machine needles back, and the work was pushed over, the frame needles rising and the machine needles being thrown out, which completed the course.

In 1854, Luke Barton improved the stocking-frame by the application of a narrowing apparatus, and patented the improvement in conjunction with Hine, Mundella, and Co. Both frame and attachment were actuated by rotary motion. Up to that time, only one or two hose of fashioned quality had been made in their widest parts on one machine; but by this invention, from two to ten hose were enabled to be made at once, with less labour to the workman, at less cost, and with a greatly increased production. The invention was also applied to the manufacture of other articles, as shirts, drawers, half-hose, &c.

Several minor inventions, but of a useful character, were brought out under the auspices of the same firm, and also by other individuals. Amongst these, may be mentioned one by Mowbray, of Leicester, which was an arrangement by which a stocking-frame was rendered capable of widening or narrowing at will, by the application of a jacquard apparatus. This plan has been used extensively by the Leicester manufacturers, it being better adapted for the woollen hosiery trade than for cotton and merino, of which the Nottingham trade chiefly consists.

The next inventor who has left an important impression upon the trade is William Cotton, of Loughborough, whose first patent was taken out in 1851, for the widening of the fabric by the action of the machine working upon rotary power. In 1860, he added an arrangement by which it was rendered capable of narrowing as well as widening. In 1863, he effected further improvements on the above, rearranging the parts so as to place them on a horizontal plan, instead of a perpendicular one, as previously. The widening and narrowing processes are accomplished by the action of ticklers, having one or more points in each, and which are placed on a movable rod so ingeniously and accurately adjusted as to obey a side movement either way, to the extent of the distance of one needle only, whatever may be the gauge, and to take off, remove, and put on to the next needles, any number of stitches required. The narrowed selvage was perfect; the widened one, though not so good, was sufficient for the purpose.

A notable improvement in hosiery machinery was contributed by W. C. Gist, an American, who took out an English patent in 1858 for a circular machine, to be supplied by any number of feeders up to eight, where only one had been worked before. This greatly increased the productive power, and enabled striped work, containing up to 16 colours, to be made at once. With a head of 12 in. circumference, 350 courses, or 1 yd., can be knit in a minute, which is equal to a length of web sufficient to form 150 doz. of women's hose in a week. Hine, Mundella, and Co. secured the patent-right of the machine in this country, and while in their hands, it was simplified and improved by Thompson, the inventor of the circular rib-frame. Thompson replaced the ordinary needle by Townshend's tumbler-needle, and the improvement was so manifest as to secure its immediate and extensive adoption in the Leicester trade.

The name of Moses Mellor is a distinguished one in the annals of invention connected with hosiery machinery. In 1844, Mellor improved Brunel's round stocking-frame, by placing the needles perpendicularly, instead of in a radial horizontal circle, and operated on them outside by an indented loop-wheel roller. Still further to secure an equal division of the loops, in 1849, he added a second wheel of the same kind to follow the first. In the same year, he devoted his attention to the wide power stocking-frame, into which he introduced a thread layer, by which the yarn was placed between the needles where the selvage had to be formed, without disturbing them, thus dispensing with the plan of raising them out of the way. In 1863, Mellor invented a series of modifications of the round stocking-frame, by which he was enabled to produce plain, striped, and fashioned fabrics. In the same year, he secured a patent for an invention to be applied to a reciprocating straight-bar frame, making one or more breadths at once, or to a reciprocating circular frame making one or more breadths at once, by the application of which, was produced a fabric either plain, or ribbed in one part and with loose loops on the other part, the patterns varying according to the setting of the machine. In 1863, he also constructed a wide or longitudinal fashioning rib-frame. This invention, which increased the production more than tenfold over the original Derby rib-frame, he threw open to the trade.

In conjunction with Edward Attenborough, W. Cotton patented further improvements in 1869; these consisted of a better general arrangement of the parts of the frame; the construction of the thread-carriers of steel, so that the points or feed-ends might bear upon and more readily follow the course of the traverse provided for them; and a tension arrangement for tightening the threads when passing to the carriers, in making the plain or unfashioned portion of the fabric, when the thread-carriers were at the end of their traverse, and the loops were being divided. For this purpose, each thread was made to pass between a spring, and an arm with capability of varying—increasing or diminishing—the pressure by stationary wedge-pieces or similar means in the forward movement of the arms and springs. Extra motion was given to the shifting instruments, when they were moving for widening, proportionate to the extra strain upon them at such a time, so as to secure their standing correctly in position for the laying of the loops on the needles to which the loops were being shifted, and similarly in relieving such extra movement for narrowing. Means were likewise provided for filling up the holes otherwise left by the action of separating the loops for widening. The inventors improved the presser-bar by introducing a rib of steel into a groove in the edge of the presser, which obviated a great portion of the wear so common when the bar is composed of soft metal. Increased capability of adjustment of the movement of the needles in relation to the sinkers, so as to be able readily to vary the stiffness of the fabric during working, was also obtained; and a further arrangement was introduced, whereby the movement of the thread-carriers was controlled at the termination of their traverse, by means of which, it was ensured that the thread at such times should be taken between the desired sinkers, thereby avoiding the production of bad selvages.

In 1879, Thomas Wigfield patented a method, by means of which, he claimed to produce fashioned and cleared fabrics of varying width, less than the breadth of needles, and by employing two thread-carriers and carrier-slides, by the same means to produce selvaged heels; and instead of taking away portions of the jack- and frame-sinkers, and frame- and machine-needles at each division, to produce such fabrics by employing the apparatus of which the invention consists.

About 1877, an American, Almet Reid, patented in this country an ingenious circular knitting-frame, capable of automatically knitting articles of every variety of shape, such as hats, caps, Scotch bonnets, and bags. Its principal features consisted in its having the equivalent of a Jacquard motion attached; in the capability of knitting simultaneously a greater number of threads than ordinary circular machines; in the fact that goods produced in it are composed of loops or stitches, so locked together that, in the ordinary way, they will not unravel when cut or torn; and lastly, a rate of production considerably exceeding that of ordinary knitting-machines.

The patent-right of the above machine was acquired in this country by a joint-stock company, and under its auspices, the principle of the above invention has been applied to a straight machine. As constructed, this has been brought into public notice as the "straight-bar knitting-loom." It is not complicated in its parts, nor as a whole; and can be made of any width. As it is designed to produce piece-goods, it requires to be 70–90 in. broad for wide descriptions. The needles are set on the bar, which may be of any required gauge. A loom 72 in. wide, 9-gauge, contains 6 needles to the inch = 432 in the width. The needle-bar has imparted to it a rapid vertical motion, of short stroke, during which, the needles rise and fall in front of and close to a bar perforated with holes, one for each needle. Through these holes, the yarn is passed, one end in each being delivered from bobbins or a beam, as may be most convenient. Each time the needle-bar rises and falls, every needle makes one loop, and the texture is thus produced simultaneously along its whole width. Each course of loops is drawn away by a thin blade called a "wiper," possessing a reciprocating action. A pair of fluted rollers receive and pass the cloth down in front of the machine. The number of loops put in the width naturally depends upon the number of needles in the bar; but without altering the gauge of these, the openness of the fabric can easily be varied, by altering the stroke of the needle-bar, and the rate at which the delivery and taking-up rollers operate, this being easily done in a few minutes. This variation is easily extended from 4 to 24, or any intermediate number of loops per inch, in the direction of the length of the fabric. The loops are effectually locked together, even those that form the selvage. The production from this machine is extremely large, the driving-pulleys actuating the main-shaft, making 200 rev. a minute, with the result that each needle makes a similar number of loops or meshes. The length produced depends upon the size of the mesh; with these 13 to the inch, working at the above rate, it produces about 15 in. of web a minute. At this rate, its production is equal to that of 10–12 ordinary power-looms, weaving woollen cloth of the same width. Upon this machine, the yarn can be used unsized, and softly spun, or containing little twist, one of the advantages claimed for it being its capability to work up soft or tender yarn unfitted for use in the ordinary loom. It is also capable of making stripes, either plain or "herring-bone," or combinations of these; but it is not in this direction that it will ever prove a formidable rival to the ordinary loom.

This brief review of the development of the machinery of the hosiery trade brings us to the present day.

Hosiery, as generally understood, and as considered here, is a production of the art of knitting—a subdivision of the greater art of weaving. It is a process by which a series of loops are made to intersect each other, the aggregate forming a web. It can be executed by hand, by machines wrought by manual power, and by others in which steam is employed as the motor. An expert operator by hand can make about 100 loops a minute; by manual power, this number is very largely increased; whilst in some modern machines worked by steam power, more than 300,000 loops a minute can be produced.

Hand knitting is now rarely practised as an industry, or a means of obtaining a livelihood. Here and there, in secluded districts, such as the Highlands of Scotland, some parts of Wales and Ireland, and similarly in many parts of the Continent, the peasantry follow the practice in the intervals of more laborious occupations, and by its means add some little to their earnings.

Machine knitting by manual power, though still followed to a considerable extent, is a decaying industry. The hand-machine is used chiefly for the production of what is termed "fancy hosiery," of elaborate or variegated patterns, such as it is difficult, if not impossible as yet, to produce by automatic machinery worked by steam power. Where it is still used as a competitor with the latter, it is retained at a great disadvantage, because the operator has to bestow his strength and attention upon the working of the machine, whilst it would be more profitably exercised in superintending a greater number actuated by steam power.

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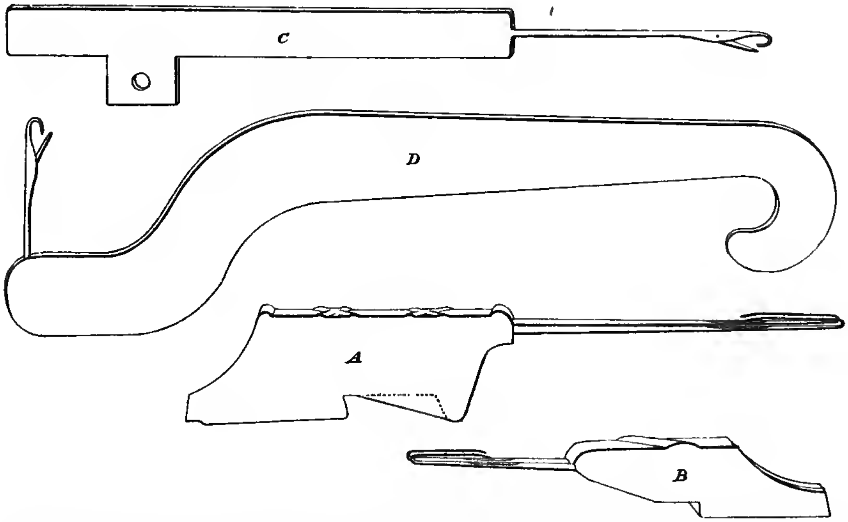

The essential part of both manual and steam-power machines is the needle. Of these, there are two kinds, as shown in Fig. 872. A B represent the one invented by Lee, but in the perfected form to which modern scientific mechanism has brought it. It consists of the shank, the hook, and the beard or returned point of the hook. Underneath the beard, a groove is cut in the shank, for the reception of the former when pushed down by the presser-bar or wheel. This is the needle in most general use. Those marked C D are latch-needles, a much more recent invention, and the use of which has led to important changes. Both sorts are shown as mounted for the machine. The manual stocking-machine has a framework of wood, on which the working parts are supported. In front is a seat for the operative. The yarn is supplied from a bobbin conveniently placed. The needles are arranged horizontally, as in Fig. 873. The chief parts are the sinkers *f*, locker *g*, jacks *h*, needles *i*, slur-bar *l*, slur *m*, pulley *n*, and locker-bar *p*. These constitute the parts of the machine as Lee left it: of sufficient capacity to make a plain looped fabric. Jedediah Strutt's improvement, by which a ribbed web was enabled to be produced, consisted of the addition of a second series of needles *c*, Fig. 875, mounted on a lever *e*, and jointed to a vibrating arm *f*, attached

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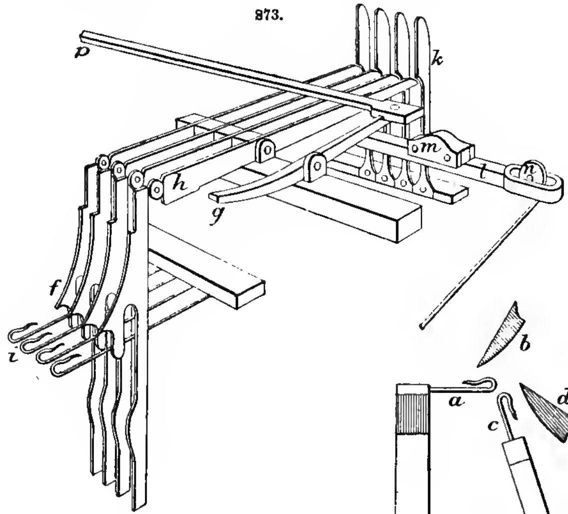

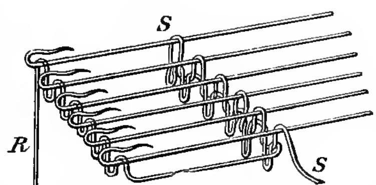

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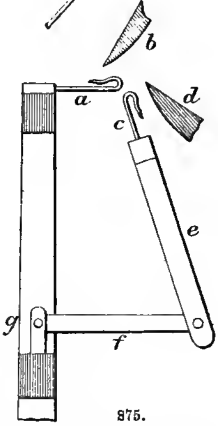

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to the standard by a pin on which it is free to oscillate. There are three treadles to the manual frame, placed conveniently for being actuated by the feet of the operative when at work. Two of these are connected with the jacks by means of cords passing around pulleys, placed in the centre of the frame, and the third is similarly connected with the presser, the attachment being made at the extremity of an arm, which projects towards the back of the frame.

There are two classes of sinkers, bar- and jack-sinkers; each of the latter, which are arranged alternately with the others, are attached separately to the end of a lever or "jack," and by means thereof can be depressed separately. It will be observed that the sinkers *f* are arched in the middle, so as to form a hook, and beneath this hook there is a projection. These sinkers having to pass easily, and very quickly, between the needles, are made with great exactitude, being blocked out of thin sheets of iron, and carefully finished by polishing, so as not to injure the threads in working. All parts of the frame require to be finished with the greatest accuracy of detail and perfection of workmanship.

The mode of operation and the action of the machine is as follows:—The thread is drawn across the needles in contiguity to the arch of the sinkers; the jack-sinkers are depressed by means of the treadle, which action forces the yarn down between alternate needles; the jack-sinkers are raised; then both frame- and jack-sinkers are depressed to half the depth of the first movement, the yarn being by this means equally sunk between all the needles. The sinkers are next advanced, and carry the yarn in the form of the wave line beneath the beards of the needle, as shown in Fig. 874. To simplify the description, it is assumed that two courses of loops have previously been formed, as shown at S. The last course will be in the arch or hook of the sinkers, and as the latter advance whilst the presser has closed the needles by compressing the beards into the grooves, the previous course of loops is carried over the heads or hooks of the needles, and placed upon the loops which the latter contain. The loops in the needles now form the top course of the fabric, which by means of the hook on the sinkers is then drawn back, to allow the process to be repeated. When the thread has been sunk between the alternate needles by the jacks, and it is required to sink it also between the remainder of the needles, the frame-sinkers must be depressed one at a time, which is accomplished by means of a cord from the treadle-pulley, by which the slur is drawn backward and forward as required. By this means, the thread is sunk progressively across the series of needles, which movement must be completed in the straight frame before the sinkers advance and carry the thread into the hook of the needles.

The thread is supplied in a continuous length from a large bobbin, but it will be evident that the substitution of different kinds or qualities during the progress of the work can be easily accomplished according to requirement. The width of the web is also varied as may be needed, according as the thread is carried over a greater or less number of needles of the series. A stocking-web is thus shaped or "fashioned" in its different parts, before it is sewn or looped together in a subsequent stage.

Such is the simple process of forming a looped fabric, which is essentially the same in all machines. A single thread may be used as described, or a considerable number, called "feeders," as in rotary machines, by which the production is enormously increased. Or, a thread may be used to each needle; when this is the case, the bobbins are arranged in a creel, or if preferred, the yarn is put upon a beam.

By means of a pin or hook, the loops upon one needle may easily be transferred to the next, or even a more distant one, without detriment to the fabric. Advantage has been taken of this to form patterns of great variety and beauty. So made, the product is called "lace hosiery," and though not much in vogue at present, it has formerly been very popular. A pin or point, called a "tickler" needle, fixed in a small handle, is used to effect the transfer.

Tickler-points have been introduced into machines in equal number to the needles. In these cases, they are arranged in a movable bar opposite the hooks. By advancing the bar, the needles are inserted into the loops; being then raised and moved to the right or left, which is called "shogging," they deposit the loop upon the needle adjoining, or such other as may be required for the pattern.

Besides tickler needles, other descriptions can be used with advantage. Strutt's invention was of this character, being the introduction of a second series of needles, by which the loops from any desired number of needles could be reversed, and narrow or wide ribs be made, from which the attachment received the name of the "Derby rib machine."

Nearly all classes of looped fabrics are now made with facility on the improved machines which are worked by power, and by which the production is largely increased, prices are lowered, and the consumption is greatly stimulated. Though hosiery goods are now obtained at lower prices than at any former time, yet the operative hosier earns more money than probably at any time in the previous history of the trade.

The following illustrations, for which, indebtedness is acknowledged to Blackburn and Attenborough, of Nottingham, will serve to show the present construction of the best hosiery machinery now being made.

Fig. 876 is a representation of Cotton's self-acting, fashioning hose-machine, which fashions the leg and makes cleared fashioned heels. The frame is generally constructed to produce eight webs at once, two in each section, as shown. All the movements are automatic, and in principle are the same as previously described. Making a 30-gauge web, and working 54 hours a week, an average production of 70 doz. pairs of hose is easily obtained on two machines by a man and a boy, whilst with extra good superintendence, 80 doz. is possible.

It is well to premise here that stockings are not usually completed on one machine, the ribbed top being made on one frame, the leg on another, and the foot on a third, the different parts being joined subsequently.

A footing-machine is made on the same principle as the preceding, and when constructed to make 18 feet at once—the usual dimensions—with one man superintending, assisted by a girl to run the heels and insteps upon the transferring or running-on bars, it will average a production of 100 doz. pairs of feet a week, working on the same gauge, and the same number of hours a week as the preceding, with a possible 120 doz.

This machine, though the term of its 14 years' patent right has nearly expired, with the numerous improvements that have been added, is still by far the best in the market for fashioned hosiery goods, no competitor coming near it in the estimation of the trade. Its price, including the royalty to the patentees, is about 250*l*.

The same machine, with the necessary modifi-

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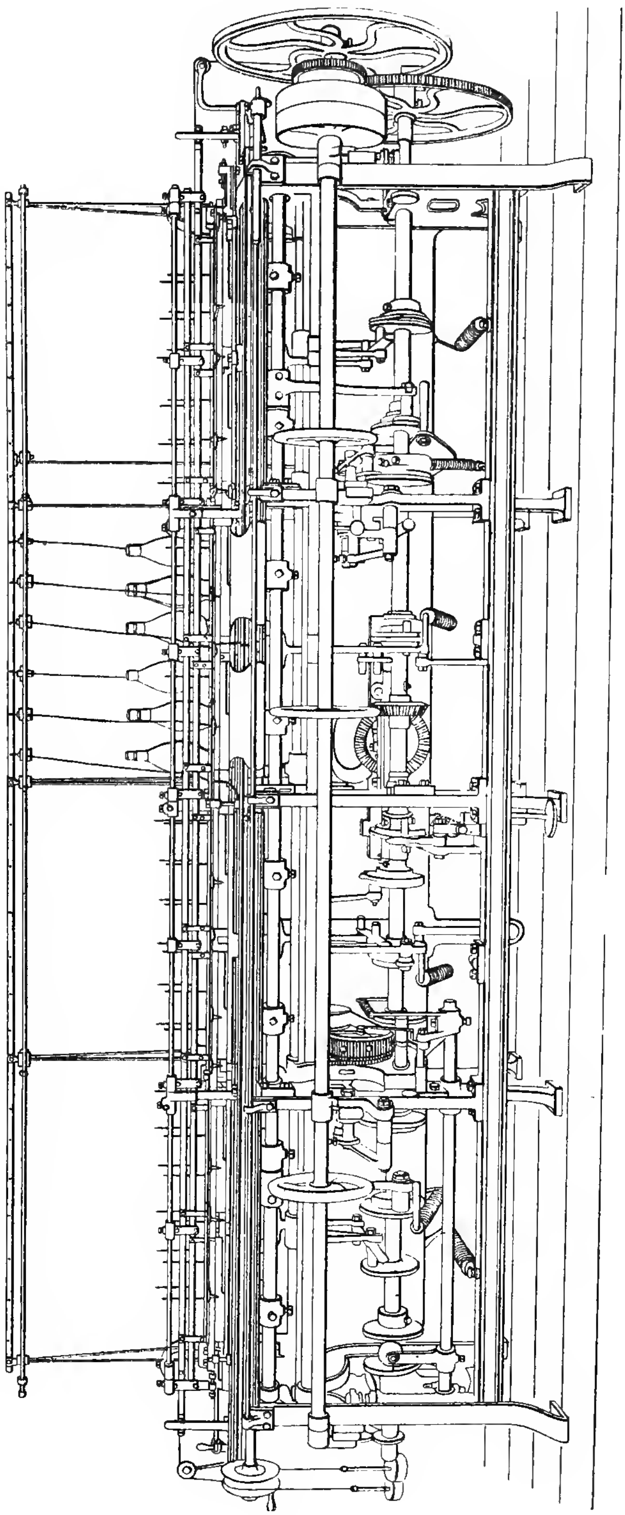

cations, is used for making men's fashioned drawers; and two of them, each making four at once, superintended by a man and a boy, in 54 hours produce 26 doz. pairs. For shirt-bodies, and fashioned sleeves, it is equally well adapted; two of them, each making four at once of the former, will produce 40 doz. as the result of the above number of hours' work; or 70 doz. fashioned sleeves in the same time. In addition to making plain or fashioned goods, as described, with the patented improvements or attachments held by Lamb and Lee, of Nottingham, they are capable of making odd or even courses, irregular striped work, cheviones, fancy welts with spliced heels, knee-caps, and the seats or pockets of pants or drawers; also 3–4 end stripes.

The ribbed tops of half-hose, bottoms of drawers, and sleeves of shirts, are made separately from the other portion of the fabric, and, in the common sorts, are subsequently attached by a sewing-machine; in better goods, they are ingeniously united by a modified knitting-frame or turning-off frame. Fig. 877 gives a view of the automatic, rotary, rib-top frame. It is entirely self-acting,

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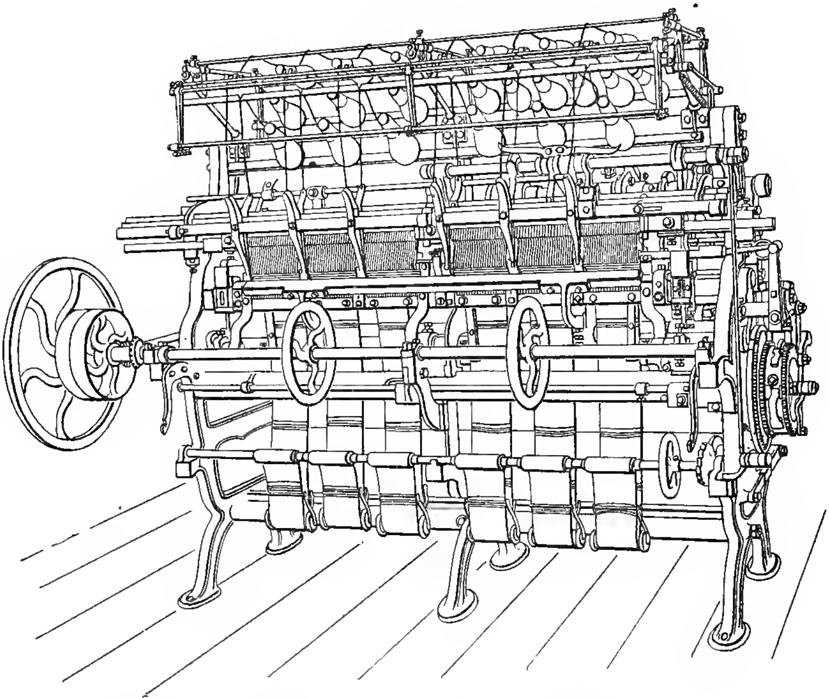

making the welt, and the slack course by means of which the top is joined to the other part, and putting in the splicing-thread, which, when withdrawn, separates the tops from each other. It is also adapted for, and much used in the production of, striped goods, the stripes obtained being in the direction of the width, not the length, of the fabric. It contains two sets of the bearded needle previously described. It is made in 4, 6, 8, or 12 divisions, and, in the larger size, is capable of producing 300 doz. tops in 54 hours.

Cheap hosiery for the million is made on the circular stocking-frame, Fig. 878, whose power of production is very great. In this machine, the tube web is woven sufficiently long to form a pair of hose, and is subsequently cut in a peculiar manner to form the foot, and finished by being sewn up. The machine is usually constructed with 12 heads, and is tended by one person. In a day of ten hours, it is capable of producing 1000 stockings, or, with fairly good superintendence, 250 doz. pairs a week. Of this description of hosiery, some of the large Nottingham firms manufacture 25,000–30,000 doz. a week. It is an exceedingly simple machine, requiring no skilled labour, and, on that account, better fitted than most others for introduction amongst populations whose mechanical aptitude and skill are comparatively undeveloped. As a consequence, it is the one most usually exported. At present, it is used extensively in Russia, Spain, and other parts of the Continent, and in America, and India.

Another important machine is the broad-ribbed circular stocking-frame, Fig. 879. This knits any size of rib. It contains two sets of the "tumbler" or "latch" needles, to the invention of which, allusion has been previously made. This needle is shown in CD, Fig. 872 It differs from the bearded or common needle in the manner in which it is closed, to enable the formed loops to be passed over its head. For many purposes, it is an important improvement upon the bearded

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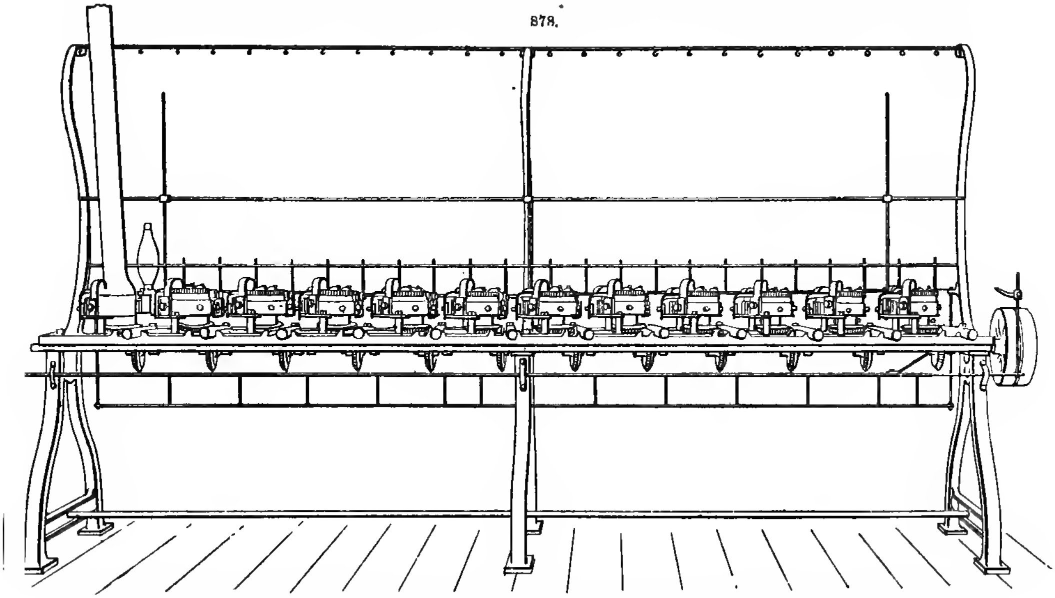

needle, and its use enables the presser-bar or wheel, as the case may be, and the mechanism necessary for working them, to be dispensed with. The shank of the needle near the hook is flattened, and divided for the reception of the latch, which is retained by a pin on which it oscil-

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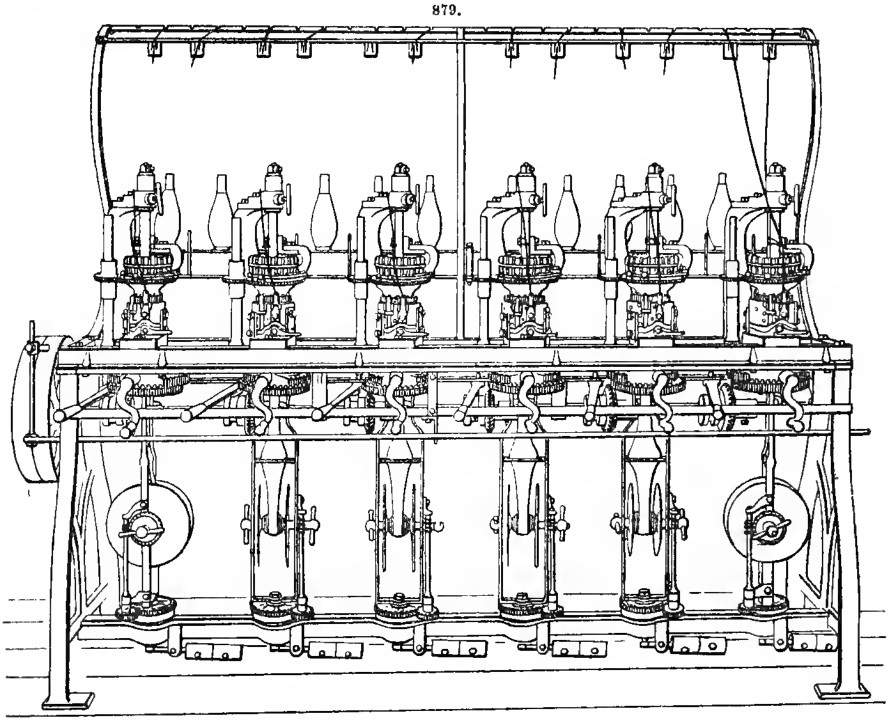
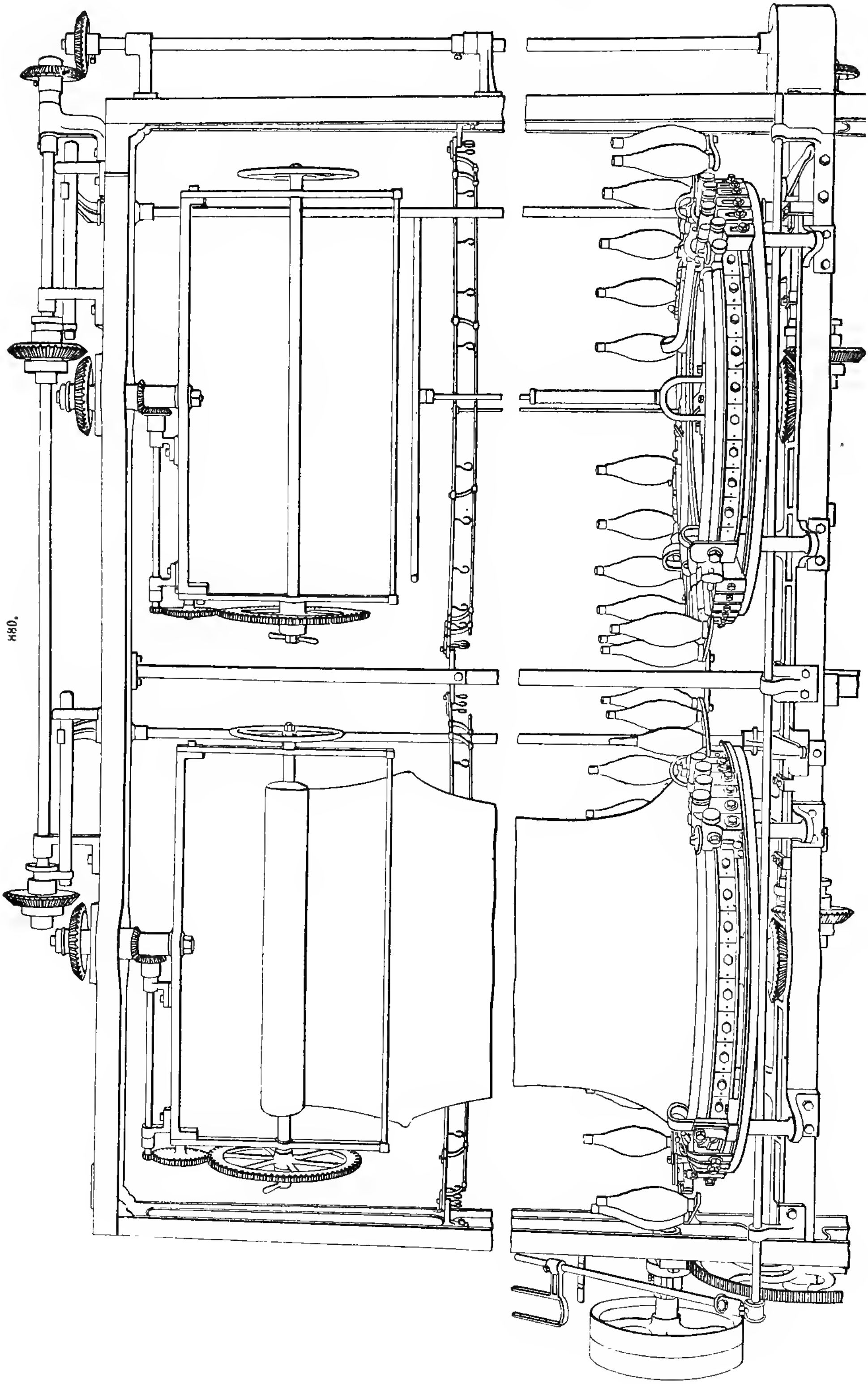


lates. When the hooks have received their course of thread, being drawn down the preceding course which is upon the shank, the latch is pushed up, and the hook is closed, which enables the



880.

threads to slip over the head of the needle, and upon the loops that are in the hooks, thus forming another course of the web. The needles being again elevated, the loops in the hooks slip down upon the shank of the needles, the latch falling back from the position shown in the illustration, in order to permit this action. The hooks, having received another thread, are again depressed, and the operation is repeated. This machine is also made for knitting cuffs, or tops, with welt and slack course, as in the rotary rib-top frame. It is self-acting in all parts, and is made in all gauges. A girl generally superintends it.

Of late, the demands of fashion have led to the adaptation of the knitting-machine to the production of wide-looped fabrics, composed of wool, and which may be finished as woollen cloths, or otherwise, so as to preserve on the front the characteristics of a knitted cloth. The advantage such a cloth possesses over an ordinary woven web is its greater elasticity, and equality of strength in each direction. The stockinette-machine, on which this class of fabric is produced, is illustrated in Fig. 880, which represents a 2-head machine, the heads being of 35 in. dia. A tubular cloth knit upon this frame would be 105 in. wide, but owing to shrinkage when taken from the machine, this would be reduced one-third, a shrinkage which applies to all machine-knit fabrics. When milled in the finishing processes, it is further reduced in width by 10–12 in. One person superintends a 2-head machine of this description, from which he produces 300 yd. of cloth in a week of 54 hours. Machines on the same principle, having four heads of less diameter, are used for making circular webs to cut up into pants and shirts. These also are superintended by one person. For other purposes, the heads are made in varying diameters, as may be desired.

The great capacity of production attained on the stockinette-machine, in making wide woollen fabrics, almost impels to the conclusion that, for many purposes, it may in the early future supersede

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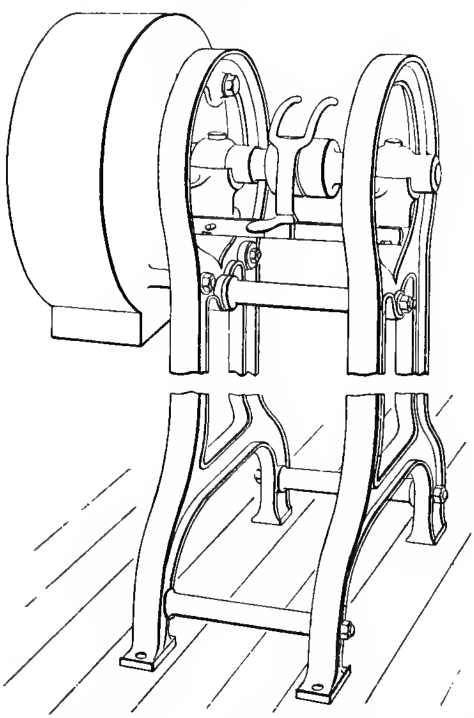

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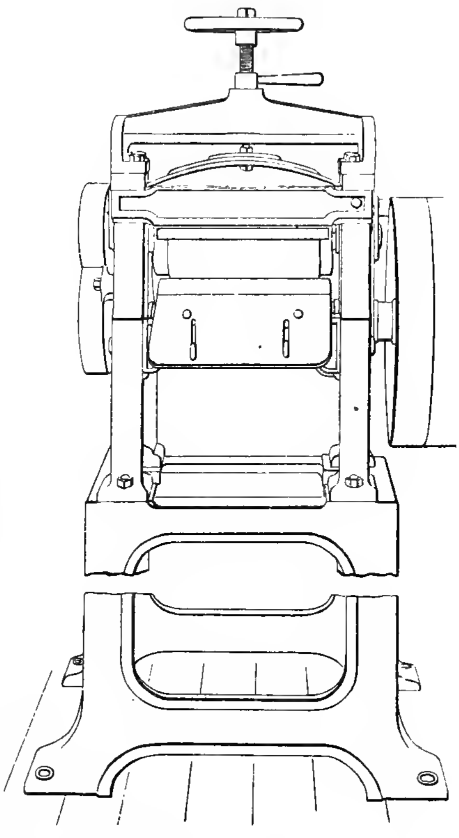

the ordinary loom. Up to the present, very promising results have been attained, and the rapidity with which it is being introduced into the woollen districts of Yorkshire lends countenance to this view. It would appear also that considerable economy will be effected in the cost of production by this process, owing to several operations in the ordinary system of manufacture being rendered unnecessary.

All circular hosiery-frames in working are liable, through knots or other irregularities in the yarn, to have their needles crossed or displaced, and thereby to "burr" or roughen the blades of the wheels. These imperfections are best removed, and the parts restored to order, by subjecting them to the action of the circular brushing-machine, represented in Fig. 881. Though perhaps not absolutely a necessary adjunct of a hosiery-factory, it is essential to secure a good quality of work, and a large production.

Hosiery manufacture, considering its magnitude, is distinguished by its simplicity. In rare instances only do those engaged therein spin the yarn they consume. The latter is generally ready for the hosiery winding-frame as it comes from the spinner, and being next supplied to the knitter, is fabricated into an article so perfect as to require but very little further treatment in the finishing processes.

The first in the series of finishing-machines, is the calendering-press, Fig. 882, used for rolling or calendering all circular hose, preparatory to cutting the feet. In this class of hose, a sufficient length is woven or knit in the frame in one piece to form a pair. These lengths are drawn upon a board, with the exception of about 1 in., which is left overhanging at the end. This part is presented to the calender-rollers, which, as they are rapidly revolving, seize it, and draw off the board the length of web; this, in its passage, is subjected to heavy pressure, and made to assume and retain the required form sufficiently long to undergo the next operation. As it emerges from the pressing-rollers, each length is received by an attendant girl, and laid in lots of a dozen each, in which quantities they are passed to the cutter.

Common hosiery, woven in the tubular form in double lengths, requires to be cut in a peculiar manner, in order to form the foot with comparative neatness and facility. The tube is first cut transversely half-way through, then longitudinally on each side for a distance of about 16–18 in., and the separation of the two portions is then effected by a transverse cut like the first. Each length then consists of equally-sized portions of hosiery web, about one-half of each part being tubular, and the remainder a longitudinal section of the same, flattened out. This cutting process is accurately and quickly performed on the machine shown in Fig. 883, which is so constructed as to cut with facility 100 doz. an hour.

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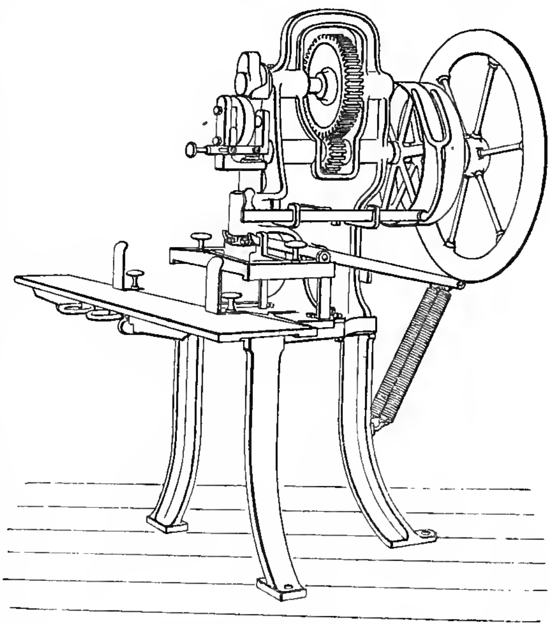

All frame hosiery, whether of the best or low qualities, requires more or less mending and finishing, by hand, sewing-machine, or looping-frame, by which the joining of the parts is effected more neatly than by the other ruder process. These finishers are usually women and girls, who are denominated "menders" and "seamers." By long practice, they become very expert and swift, and the various articles pass through their hands with surprising expedition.

After the menders and finishers have disposed of them, the last process previous to making up into dozens, or "boxing," in the case of fancy articles, is "hot pressing," which gives a certain degree of permanency to the form of the article.

The steam-heated press, Fig. 884, is the means by which this is accomplished. Its construction is exceedingly simple. Both the table and the top are cast with a series of passages through them into which the steam enters and circulates, and by which a great heat is obtained. Common tubular hose are drawn upon shaping-boards singly, and a dozen of these are put into the press together. A few moments' subjection to the heat and pressure is all that is necessary to give the desired shape, and while one set is undergoing treatment, another is being prepared. Fashioned goods, such as pants, shirts, hose, half-hose, &c., are treated in the same manner.

The commercial centres of the hosiery trade are Leicester and Nottingham, the former dealing chiefly in worsted goods, and the latter in cotton and merino articles, the last word being technically employed to indicate a mixture of cotton and wool. Each town is surrounded by a number of smaller places, in which much of the business of production is carried on, the articles being subsequently sent to the above centres respectively.

Cotton yarns are obtained from Lancashire, and chiefly from Ashton, Stayley Bridge, and

Bolton. Worsted yarns are mostly procured from Bradford and the neighbourhood, and merino or union yarns from Halifax and the localities around.

The Parliamentary Return for 1879, relating to the textile industries, gives the following figures concerning the number of manufacturing establishments and the people employed therein :—

HOSIERY FACTORIES OF THE UNITED KINGDOM.

England and Wales.	Number of Factories.	Number of Children working half-time.		Number of Males under 18 years working full time.	Number of Females above 13 years of age working full time.	Number of Males above 18 years of age.	Total number of persons employed.		
		Males.	Females				Males.	Females.	Total.
Middlesex, Surrey, and Kent	2	..	..	8	28	65	73	28	101
Leicester, Rutland, Lincoln, and Nottingham	165	145	222	756	6,990	4,486	5,387	7,212	12,599
Derby	8	2	..	88	603	378	468	603	1,071
Total for England and Wales	175	147	222	852	7,621	4,929	5,928	7,843	13,771
Total for Scotland ..	10	16	14	59	442	571	646	456	1,102
„ „ Ireland ..	1	7	..	9	10	93	109	10	119
Total for the United Kingdom	186	170	236	920	8,073	5,593	6,683	8,309	14,992

The Returns from which these figures are taken, being only those of the number of factories authorized to be inspected under the Factories and Workshops Acts, the persons still engaged in the domestic branch of the industry did not come within the cognizance of the enumerators, otherwise a considerable addition would have been made to these totals. A more important omission is the failure to give a census of the machinery employed in the various sections, or at least in the three broad divisions of worsted, cotton, and merino (union), productions.

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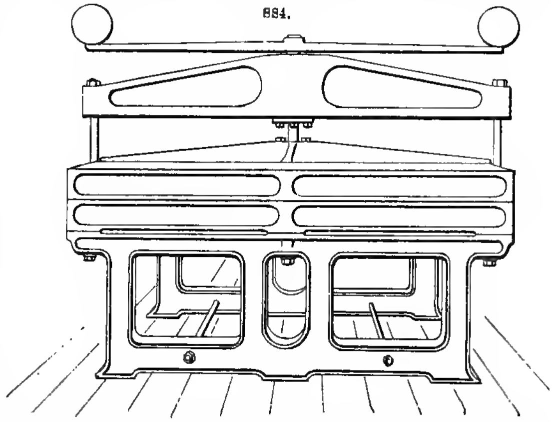

That the above enumeration conveys a very inadequate idea of the importance of the hosiery trade, may be judged from the fact that, in the hosiery business of Nottingham alone, there were at work in 1865, 11,000 narrow hand machines, employing domestically 7500 men and 3500 women and youths, at wages ranging from 6*s.* to 26*s.* a week, averaging 10*s.* 6*d.*; also 4250 wide hand machines, domestically employing 4250 men earning 10*s.*–30*s.*, and averaging 15*s.* a week. These 15,250 hand frames were scattered over eighty parishes in the county of Nottingham. These two classes of Nottinghamshire hand machines give employment to about 20,000 women and girls as winders and seamers, earning about 4*s.* each on an average. There were also about 1000 wide power rotary-frames employing 700 men, at 20*s.*–32*s.* a week; and about 1600 girls and women seamers and winders, whose average earnings were 5*s.* weekly. There were in addition to these, 1200 sets of circular round power frames improved, employing 500 men and 500 youths, at 12*s.*–25*s.* weekly; and 1000 women at 12*s.*–20*s.* weekly. The winders, cutters, menders, and others attached to these were about 11,000 women and girls, averaging 7*s.*–12*s.* weekly. On about 400 warp machines, making hosiery by power, 400 men were engaged at 14*s.*–35*s.* a week, and 200 youths at 12*s.*–20*s.*; besides 400 men warpers earning about 25*s.*, and 2000 women and girls stitching, &c., at an average of 8*s.* a week. In bleaching, dyeing, and as porters, 2000 men were probably employed, at 20*s.*–35*s.*; and 5000 menders, folders, &c., were occupied in the warehouses at 8*s.*–12*s.* weekly. To these should be added the staffs of warehousemen and clerks employed in the 80 establishments for finishing, and sale of goods, in Nottingham. These, all told, would make a total of fully 60,000 individuals.

The number of hands employed in the entire English hosiery trade in 1866 was computed to be as follows:—42,000 working narrow frames, 8000 at wide ones, and about 100,000 menders, winders, seamers, cutters, finishers, and makers-up, who are chiefly women and children—a total of 150,000 persons.

The value of the production in 1851 was estimated at 3,600,000*l.*; in 1862, at 6,480,000*l.*, and in 1865, at 7,795,000*l.*, which last advance was chiefly due to an increase in the price of the raw material. Afterwards there was a decline from this amount, but the subsequent growth of the trade will probably have carried it by this time to a point near 10,000,000*l.* per annum.

The hosiery industry has taken firm root in several foreign states, notably in France, and Saxony, and less firmly as yet in Russia, Austria, Spain, and Italy. In the United States of America, it has become comparatively flourishing, under the commercial policy adopted in that country. Several less important communities have also recently endeavoured to introduce the industry. When all chances of rivalry, however, are fully discounted, it is conclusively evident that there are no insurmountable obstacles to a still further great development of the English branch of the trade.

R. M.

LACE (FR., *Dentelle*; GER., *Spitze*).

Lace-making is the most artistic of the textile industries, and its productions have always been regarded as an especial appanage of the wealthy and luxurious classes of society. Lace is the last outcome of the development of those arts of ornamentation whose chief instrument is the needle: embroidery, tapestry, appliqué, &c., in which women have been skilled from time immemorial. Though tracing its evolution through the most civilized ancient peoples, the art itself is comparatively modern, the earliest discovered references to lace occurring during the 15th century. It is not improbable that society owes it to the system of monastic seclusion accompanying the Catholicism of the Middle Ages, when the gentler sex devoted much time to the cultivation of needlework and similar arts. There is little doubt that knitting also had its origin in the cloisters, and the transition from that art to lace-making would be comparatively short and easy. After its development, lace-making spread into the outer world, and became the favourite pursuit of ladies in the higher social circles of different nations, superseding the older feminine arts of needlework, embroidery, and tapestry. Female dependents doubtless also learnt the art, and taught it to the members of their own families, thus laying the foundation of those industries which, favoured by local circumstances, have grown into national importance. In the course of time, these different centres have developed special characteristics, by which the productions of one place can be distinguished from those of another.

Lace-making may be divided into two great branches; manual, or the system of making by hand; and mechanical, or the method of making by machine. The former is the original and most widely spread system; the latter is a development of the mechanical skill of the 19th century, and has already attained great perfection. By cheapening the production and reducing the price, it has brought the elegant productions of the art within the reach of nearly all classes; and while ministering to the refinement of public taste, has given rise to a new industry, employing many thousands of people, whose welfare cannot be an object of indifference.

The manual system of lace-making, which is still extensively followed in Belgium, France, and, to some extent, in this country, will naturally first claim attention, on account of its greater magnitude, its wider extent, and the much higher estimation in which its products are held, over those produced by mechanical appliances. Hand-made lace is generally known as "real" lace, whilst that produced by machine is regarded as a counterfeit, and called "imitation." In the best qualities of the former, only the finest flaxen thread is used; whilst in the latter, very fine cotton thread is substituted.

The materials from which lace is fabricated are various, and include flax, silk, cotton, gold, silver, and threads from several other fibres. These are used in various degrees of fineness, according to the character of the work required. Generally, however, the thread is very fine, and of good quality, when compared with that employed for other purposes.

HAND-MADE LACE.—Lace proper, or hand-made lace, usually consists of two parts: a ground of plain network, composed of honey-combed or six-sided meshes, formed in different ways, according to the variety of the article being produced. On this ground, the second part, the pattern, is worked. Sometimes the ground is dispensed with, and the parts of the pattern are connected by threads irregularly attached, overcast with the button-hole stitch, and ornamented according to the style of the design. In some kinds, there is no ground at all, the objects represented joining each other. In the varieties known as Mechlin, Valenciennes, and Buckingham laces, and in several others, the pattern or "gimp" is made with the ground. Brussels and Honiton laces are composed differently, the gimp being worked separately, and then sewn on the ground. Around the edge of the pattern, there is generally a little raised cord, called "cordonnet." The upper edge of lace is often composed of very small loops, which constitute what is called a "pearl" edge; whilst the lower or "footing" is a narrow lace, by means of which the work is attached to the material whereon it is to be worn. The fabric as a whole is exceedingly intricate. To the uninitiated, the ingenious entanglement of threads is an insoluble mystery, and still more so is the fact that out of this tangle are produced the most beautiful designs: geometric figures, leaves, flowers, and creations of the fancy of the most elaborate kind.

Hand-made lace may be broadly divided into two classes: (1) "point," or needle-made kinds, of which, some of the best as well as the earliest are the ancient laces of Italy, Spain, and Portugal, and for which Alençon, in France, has more recently become noted; (2) "pillow-lace," which, as its name indicates, is made by weaving, twisting and plaiting together upon the "lace-cushion" a number of threads supplied from bobbins.

Point-lace, as previously indicated, probably originated in the convent, and its invention is usually claimed for Italy. During the 16th century, it became widely known, and was in almost general use, being applied to a great number of purposes. The lace of this period was chiefly of geometric design: combinations of squares, circles, and other figures in repetition.

It was probably not more than ½–¾ of a century after the invention of point-lace, that the art of pillow-lace making was invented—the credit of this is generally assigned to the Netherlands. It was subsequently introduced into Germany by Barbara Etterlein, a lady of Nuremberg parentage, who went to reside in the Hartz mountains, where she married a rich master miner, Christopher Uttmann, of Annaberg. In the mining districts of the Hartz, it was customary for the workmen to wear their hair confined in nets, which were woven by the females. Barbara, observing this, introduced the pillow, and taught them to make a plain lace ground, as an improvement upon the articles they were fabricating. This art, it is alleged, she had acquired from a Brabant refugee. Pillow-lace making became so popular, that Frau Uttmann set up a workshop at Annaberg, where she taught the art to many, and made lace of various patterns. After her death, on Jan. 14th, 1575, an inscription placed upon her grave claimed for her the invention of pillow-lace. Whether this claim is justly grounded or not, cannot be decided here, but the fact is certain that, from Annaberg as a centre, the art spread over Germany, and thence into surrounding countries.

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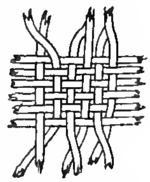

Point- or needle-lace is usually the production of one thread, upon which loops are made and joined to each other by intersections, in such a manner as to form patterns. In pillow-lace making, on the contrary, more threads are used, the number sometimes reaching 400–500, and in exceptional cases, 1500. It will be obvious that the management of such a number of threads is a more complicated matter than that of dealing with one, and that the fabrication of the beautiful patterns into which they are formed needs a more complete instrument than the simple needle. A series of pins, with a cushion in which to arrange them, were found the most pliable instruments, and to afford the greatest facility for the interweaving or twining of the threads. Pillow-lace is made by simply twisting, plaiting, and weaving together a number of threads, in such a manner as to form them into any desired pattern. The process is to first draw the pattern upon parchment, and make holes in the outline of the design, wherein to insert pins, around which the threads are twisted so as to form meshes. Fine and coarse threads can be combined, and two or more can be worked together for a time and then separated. With the progress of the work, the pins are moved to new positions. In making figured lace, it is necessary that the threads should be so arranged as to allow of their being passed around each other as often as required. In pillow-laces, the pattern is chiefly made by weaving the threads so as to form what may be termed a portion of plain cloth, Fig. 885; the ground or mesh by plaiting, Fig 887; and in other descriptions, by intertwining the threads, as in Fig. 886. The ground of Brussels and Honiton lace is formed as in Fig. 887, which represents a 4-thread ground.

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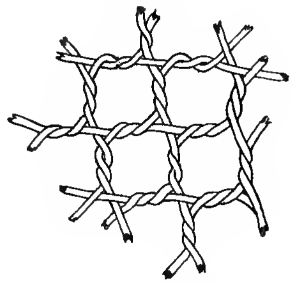

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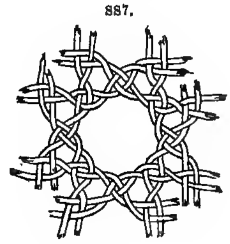


England owes its pillow-lace making industry to refugees from the Netherlands, who fled from the persecutions of the Duke of Alva, and sought an asylum in this country in the 17th century. The industry took root in the shires of Bedford, Buckingham, Oxford, Northampton, and Devon; but the two centres which have become most distinguished and successful, are the districts embracing Honiton, in Devonshire, and the county of Buckingham. In the former, the manufacture of lace is carried on over a district along the coast about 30 miles in length by about 12 in breadth, which includes Seaton, Beer, Branscombe, Sidmouth, Exmouth, and the vale of Honiton.

At one time, as many as 10,000 people have been employed in the lace industry in this district.

Honiton lace is made by placing a perforated pattern upon a pillow, and employing pins, bobbins, and spindles to twist and interweave the threads in such a manner as may be required. In the early stages of its existence, the Devonshire industry was confined to the production of sprigs and borders, but during the past half-century, such progress has been made as to result in the manufacture of articles of great value, displaying taste and beauty of design, and delicacy of execution. These comprise flounces, shawls, bridal veils, scarfs, handkerchiefs, &c., some of which range in value from 10*l.* to 300*l.*

The Devonshire lace resembles Brussels in the mode of manufacture: but within recent years the style has changed, and the ground has been replaced by the modern guipure. The "old ground," as it is now called, was beautifully fine and regular, and made of flaxen thread procured at Antwerp, where its market price in 1790 was 70*l.* the lb. During the wars at the close of last century and the beginning of this, when it was difficult to obtain the yarn, smugglers who succeeded in getting it into the country obtained as much as 100*l.* for 1 lb., and the lace-makers received as much as 18*s.* a yd. for making the ground of border lace not 2 in. wide. It was, however, with the sprigs and borders that Honiton achieved its fame. They are made separately on the pillow, and the former, in the early days of the industry, were worked in, but afterwards applied or sewn on the ground, which is now usually a machine-made net.

Beds, Bucks, and Northampton laces once stood very high in public estimation, being greatly admired for the clearness and beauty of their point grounds; but owing to fluctuations of demand, the industry in these districts has greatly declined. Formerly the class of laces chiefly made were narrow ones used in trimming infants' caps, robes, &c., but the fashion having changed in some respects, and machine-made goods superseding them, these have been abandoned, and the workers now produce the descriptions known as Cluny and Maltese.

There are several other descriptions of hand-made lace produced in the British Islands. Of these, the principal are British point, made in the neighbourhood of London, which is of good quality, regarded as an imitation of Brussels. Limerick lace has achieved a wide reputation, and vast quantities have been produced. Lace-making was introduced into Ireland during the last century, but, as an industry, made very little head-way until after machinery was adopted for the spinning of flax, which threw a large portion of the female population out of employment. Along with embroidery, lace-making began to make progress, though not to the same extent as the former. After the famine in 1846, training-schools were established in many parts, and lace was made with considerable success. Amongst the descriptions produced were point, guipure, imitations of ancient point, Ypres Valenciennes, tatting, and other kinds which secured public favour.

English hand lace-making has, however, always been a secondary industry compared with that of other countries. Amongst the states on the Continent, France occupies the premier place. Thirty years ago, the number of females employed in the hand-made lace industry of that country was estimated at over 200,000, ranging in age from 7 years to an advanced time of life. It is not probable that this number is diminished, or if so, it can only be to a small extent. The money earned by each worker ranges from 6*d.* to 1*s.* for a day's work of 10 hours, varying according to the demand there is for the article.

Hand-spun linen thread, cotton, wool, silk, and gold and silver thread mixed with silk, are the materials employed. About ½ century ago, all the white lace was made from hand-spun linen thread; but cotton yarns, ranging in Nos. from 120's to 320's, are now almost solely used.

The hand manufacture of lace as an industry is very widely spread in France, extending over many departments. Each district is remarkable for the possession of some peculiarity of style, which is well known in the chief markets, and easily recognized by experts amongst dealers. The most important centres of production are Caen and Bayeux, Chantilly and district, Lille, Arras, Mirecourt, Du Pay, Bailleul, and Alençon.

Caen and Bayeux, in the department of Calvados, are celebrated as the chief centres of the manufacture of silk-lace in length and piece-goods: veils, scarfs, mantles, robes, shawls, &c. The first silk blonde was made at Caen, and given that name from the fact that it was made of undyed silk. This article rose high in public favour, but subsequently the demand fell away to very small dimensions, and, for a long time past, the chief product has been black lace. The manufactures of these districts are widely celebrated, mainly on account of the skill of the workpeople, of whom there are 30,000–40,000 employed. The women are remarkably quick at the work, and, by means of a stitch called *rucroe*, join different parts together in such a manner as to be invisible to the closest scrutiny. By the use of this stitch, they are enabled to divide a task amongst a number of workers, whereby it can be completed in a much less time than if performed by one woman.

Chantilly lace possesses most of the characteristics of the preceding, but excels it in fineness of texture, beauty of design, and perfection of workmanship. It takes its name from the birthplace of the manufacture, but its fabrication has long since spread into the neighbouring districts. The manufacture is not nearly so extensive as that of Caen and Bayeux, and is confined to the production of articles designed to satisfy the taste of the most wealthy and luxurious classes of society.

The lace industry of Lille is said to be the oldest in France, but it has long been in a declining condition. *Fond clair*, or clear foundation thread-lace, was the best-known article produced here. Lille possesses several other industries which afford better-paid employment for the female portion of the population, the consequence being that lace-making has greatly declined. That of Arras is in a similar state to the above, and what remains of its manufacture is greatly wanting in novelty and good finish, but is sold at a low price, and hence meets with a demand sufficient to absorb what is made. Mirecourt, in the Vosges, makes a lace similar to that of Lille, but displays more enterprise and taste in the introduction of new designs than either that town or Arras. This place is also noted for the production of "guipure," similar to the lace of that name produced at Honiton.

Puy, in the Haute-Loire, is a great centre of the lace industry; in the town and district, there are 30,000–40,000 people employed. A great quantity of the lace produced is coarse, of low texture, and cheap in price. Other varieties are made in thread, silk, and wool, amongst which are included "point," "point de Chacey," and "point de Valenciennes." Blonde, black, and white lace, and many other descriptions in every colour, especially worsted laces, are also produced.

Bailleul is the chief place in France for the manufacture of Valenciennes, its production greatly resembling that of Bruges in Belgium. The lace made here is remarkably white, and is sold at a cheap rate. It is rather thick as compared with other descriptions.

The celebrated "point d'Alençon" is a needle-made lace of the highest quality. Its manufacture was introduced into France from Italy, in 1660, by the minister Colbert, who obtained workmen from Venice and Genoa. These at first made the lace to which they had been accustomed, called "point de Venise," and afterwards "point de France." Subsequently variations sprang up, and the manufacture then became known as "point de Alençon," from the town in which it was made. This lace is now very different from most other point laces, which need only one worker to complete the richest article, Alençon, on the contrary, requiring 12–16 different workers to complete the smallest piece of the simplest pattern. Amongst these, may be mentioned the *traceuses* and the *reseleuses*, who make the net or ground; the *bourreuses*, who do the heavy portions or patterns of the lace; the *modeuses*, who make the open work; and the *brodeuses*, who fabricate the border destined to surround and support the patterns. This lace is now the only kind made with pure handspun linen thread, the price of which ranges from 100*l.* to 120*l.* a lb. The women employed in making Alençon lace are extremely skilful, and the article is the strongest, finest, and richest of all laces, and commands the highest price.

The lace industry of France is of national importance. It employs a large proportion of the population, and a great amount of capital. It is essentially a domestic industry; all the females employed work in their own homes, under the immediate supervision of their elders, who are their chief instructors.

Next to France, Belgium possesses the greatest repute for hand-made lace. The chief centres of its lace industry are Brussels, Antwerp, Malines, Ypres, Bruges, Ghent, Menin, Courtrai, and Alost, with their surrounding villages. In these districts, a population of probably over 100,000 persons is employed in the fabrication of lace.

Brussels lace is of the highest quality, and consists of two kinds, point and pillow, the former being made entirely by the needle, and the latter on the pillow. The finest descriptions, which realize the highest prices, are made of fine flaxen thread. In others of great excellence, cotton yarns are used. In former times, these laces were only made upon "real" ground, but after the manufacture of net by machinery had been perfected in England, this was to a large extent substituted, and has had the effect of greatly reducing the cost. The "real" or hand-made ground was wrought on the pillow in narrow strips of 1–3 in. wide, which were then joined so perfectly as to render the line of attachment quite invisible. The best hand-made lace was so costly as to find customers only within the circles of royalty or families of the greatest wealth. Trimming laces 3–4 in. wide ranged in price from four to ten guineas a yd., whilst veils of the same qualities sold for 20–150 guineas. The introduction of the machine-made ground, however, so reduced these prices as to greatly enlarge the circle of consumers, and since that time they have been in extensive use by persons in the higher and wealthier circles of society. This change greatly stimulated the Belgian industry.

This modified or combined hand- and machine-made lace is known as the "application of Brussels," and, in its perfect resemblance to the real article, is calculated to deceive the most skilful and expert judges. The flowers or designs are made by hand, and then sewed upon the net. Brussels "plait-net" is extensively worn upon the Continent, but "point" has generally been in more favour in England.

The fabrication of Brussels lace is divided amongst a considerable numbers of workers, one class making the flowers in plait, another those in point, a third "real" ground, a fourth the ground in the flowers; a fifth fasten or combine the different parts, whilst a sixth attach the foregoing to the net ground. In some particular descriptions, there are two or three additional classes of workers. The quality of Brussels lace is only surpassed by the point d'Alençon made in the north of France.

The descriptions of lace known as Mechlin are made at Malines and Antwerp, and their vicinities. These laces are made on the pillow in one piece, and are of remarkably light and fine texture. They are peculiar in having a plait thread surrounding the designs and flowers, and forming their outline, which give them the appearance of embroidery.

Valenciennes constitute another variety, which rank amongst the most highly esteemed laces made in Belgium. These are chiefly produced in Ypres, Menin, Courtrai, Bruges, Alost, Ghent, and the villages surrounding these towns. This lace is also a pillow-lace, yet the production of each town displays such peculiarities that they can be easily distinguished by experts. The first-named town began the manufacture in or about 1656, but for a long time, it did not make much progress. Since the commencement of the present century, it has extended greatly, and, a few years ago, was estimated to employ in the town and environs fully 20,000 persons. The productions are exported to England, France, Germany, and the United States. Ghent makes very high-class articles, chiefly in narrow and medium widths, and employs 10,000–15,000 workpeople. The laces of Bruges are of a medium quality, and lower in price than those of Ghent; but they are of an eminently useful character, being especially adapted for trimmings. Alost makes some good laces of similar designs, but not equal in quality to those of Ypres. Grammont laces are white thread, and black point trimming laces of good quality.

In all hand-lace making districts, the industry is mainly of a domestic nature, hence there is not that close and continuous devotion to the labour that exists in other occupations more highly organized, and conducted on the factory system. In most cases, the females have charge of household duties, and take up their lacework in the intervals of domestic occupation. This can be done without detriment if they are careful not to injure their hands. Their earnings are very small. Where it is more persistently engaged in, the remuneration is better; but in the best circumstances, it is an ill-paid industry, requiring a long apprenticeship and close devotion to attain proficiency. It frequently takes several months, and often a year, to complete a short length of 3 yd.; and in these cases, the employer is compelled to make advances to the lace-maker, besides supplying the costly yarn for the manufacture. Ten years ago, the number of persons following the occupation in Valenciennes, was reduced to three, who were earning only 1*fr.* 30*c.*–1*fr.* 50*c.* for 12 hours' work. In the Belgian towns where the lace of this name is made, the wages are rather better, though not to an important extent. The price of a lace-maker's cushion is 8–10*fr.*, and the patterns cost 75*c.*–1*fr.*; the worker provides her pins and spindles, which number often 1500 pins and 250–500 spindles employed in the production of one piece of Valenciennes lace only 3 yd. in length.

Lace-making in Italy has become almost extinct, the method of making some of the most prized descriptions having been lost. One sort formerly of high repute was known as Burano lace, and about 12 years ago, an attempt, attended with some degree of success, was made to revive the industry. An old woman was found who was stated to be the last of her craft who still remembered the method of making this lace, and under the auspices of Princess Giovanelli and Countess Marcello, she was engaged to instruct a number of girls in the almost forgotten art. The first specimens produced sold very freely. The cost of the fabric was about 100*fr.* a metre of 12 *cm.* wide, and this was regarded amongst connoisseurs as beneath its proper value. The time required to produce this length is 150 days of 5 hours each, for which the workwoman receives 50*c.* per diem. Dr. Fambri, an Italian deputy, made the following estimate of the labour and cost involved in making one metre of this lace, of a kind and quality never surpassed in ancient times: (1) 3 months' wages of one hand for the net work; (2) one month's wages of one hand for the pattern or flowers; (3) one month's wages for the ornamental border. He also suggested that the industry should be carefully cherished and developed, not only in order to preserve the secret of the art, but also as offering an employment capable of affording maintenance to thousands of people on a merely nominal capital.

Machine Lace Manufacture.—The era of mechanical invention, which commenced in the textile trades in the middle of last century, has had a vast influence on every industry. Naturally, however, this influence has been most conspicuously exerted in the spheres in which it first made itself apparent. This will be admitted, when the fact is reflected on that the cotton trade, as it exists to-day, has entirely sprung from its development, that the woollen industry has been completely revolutionized, and similarly the manufacture of flax. The silk trade has perhaps hardly undergone quite so much change, but this is more owing to the nature of the fibre dealt with, than to the incapacity of inventors to meet its requirements. But in no section of the textile industries, have the latter been more successful than in the one under consideration—the manufacture of lace.

The wide area in this and other countries over which lace-making was spread, the slowness of its processes, and the high prices obtained for the product, soon attracted the attention of men anxious to emulate the success of Strutt, Hargreaves, Arkwright, and other pioneer inventors in the cotton trade. But it was some time before the vague notions entertained began to assume definite shape. The stocking-machine of Lee, as improved by Strutt, was the instrument generally regarded as most likely to yield satisfactory returns for careful study and development. Strutt's success led to the hope that the more intricate patterns of the hand knitter might be successfully imitated mechanically, and amongst these were the various lace patterns that had been introduced into hand-made hosiery. This anticipation, as the result has shown, was not baseless, for the machine-lace industry is entirely a development arising out of the Calverley curate's invention.

The addition of tickler-points to Strutt's improved machine, by which the loop formed upon one needle was removed to the next adjacent one on either side, was the first step in this direction. By the arrangement adopted, the loops on the needles were transferred to the tickler-points, and whilst they were upon these, the tickler-bar was "shogged" or moved in a lateral direction, by which the loops were carried to and placed upon the required needles. This ingenious arrangement was the invention of a stocking-maker named Butterworth, living near Mansfield. Butterworth had to entrust the details of his plan to a smith named Betts, whom he employed to make the necessary parts; but conjointly they were unable to proceed to secure it by a patent, or even to perfect the plan, so a third person was induced to join them, a man called Shaw. Betts appears to have been an unscrupulous man: he eliminated the inventor from the party, and introduced a more able capitalist than Shaw in John Morris, a Nottingham hosier. Betts, Shaw, and Morris went to London and secured a patent, in the names of John and Thomas Morris, and John and William Betts, leaving out of the instrument all mention of both the inventor and Shaw. In the absence of the latter, Betts transferred the whole property of the invention to Morris, and thus defrauded both of his former partners of their share. This particular invention is interesting, because the specification states that the invention was "for making by a machine, to be fixed to a stocking-frame, eyelet-holes or *net-work*."

Shaw, feeling disappointed and injured, subsequently went upon the Continent, where he saw a better method of making open work than any with which he was acquainted, and which he introduced into England on his return. In the meantime, the machine, which had become Morris' patent, was further improved by Else, who dispensed with one eye in the form, and with the ticklers. This was used in England for some time, but subsequently was superseded and almost forgotten. In the days when it was penal to export machinery, it was smuggled over to France, and the Convention liberally rewarded the person who succeeded in getting it across the Channel. Improved and developed, it is the machine which at Lyons is used to this day for the production of single and double silk net.

Morris, encouraged by his previous successes, laboured in the further development of the machine, and, in 1781, patented another improvement, whereby the sinker-loop was put across two needles, and the feat of making point-net was accomplished. These inventions in combination formed a remarkable advance in the progress from the hosiery-frame to the lace-machine. This was, however, soon surpassed by an invention perfected by Else and an associate, who discarded the tuck-presser, substituting and regulating the action of the tickler on a sliding needle-bar, and imparting to the latter a "shogging" or lateral motion to remove the stitch by means of the tickler alone. This nearly doubled the productiveness of the machine, but Morris, who still held the patent right of Butterworth's invention, sued Else for infringement.

Thomas Taylor, of Nottingham, invented a machine for making figured lace in 1769, which may be regarded as the basis of the idea so successfully developed afterwards by Jacquard. In Taylor's invention, a slide-lever tickler was used to every needle, and those which were desired to work were pushed into action by means of an organ-barrel, carrying pins upon its periphery, arranged according to the pattern. These acted upon pins at the ends of the tickler-slides which were required, leaving those not wanted to remain at rest. Any stitch in the row could thus be moved at pleasure and any pattern be produced.

Hammond, an ingenious workman, improved Taylor's machine in different points, and made upon the modification several varieties of looped fabrics to which he improperly and incorrectly gave the name of Valenciennes lace. About the same time, 1768, Crane, an inventor, of Edmonton, added a warp-frame to the stocking-machine, which subsequently formed the germ of the warp lace-machine. Some unknown person effected a great advance by devising a plan whereby the stitches were removed so as to leave large interstices, which received the name of "bullet holes," and these, being surrounded with needlework, formed the basis of the subsequent large business of lace-running, in which as many as 150,000 females are stated to have been employed.

Improvements followed each other in rapid succession, but they were chiefly in small details. About 1777, Holmes invented a plan of making what was called "two-plain" net, and Frost, in the same year, brought out the square net, and subsequently flowered net. A great advance was effected about this time by the invention of what was called the point-net machine, which is attributed to a journeyman stocking-maker named Flint, of Nottingham. Either pressed by poverty, or not appreciating the value of his improvement, he sold his invention to a neighbouring frame-smith, who effected further improvements, and disposed of the plan to Morris. This machine further improved by the application to it of an invention of John Rodgers, of Mansfield, laid the foundation of the prosperity of the lace trade of Nottingham. By it, was obtained a mesh which was perfect in shape, and fast in its texture. The fabric produced from it was subsequently embroidered in all sorts of designs, this process finding employment for many thousands of people in Nottingham and neighbourhood. The articles produced consisted of edgings, insertions, borderings, flouncings, veils, scarves, and other articles required by the fashion of the day. The widths varied from 1 to 30 in. Owing to changes in fashion, and deterioration of the quality, the lace made on this frame rapidly declined in quantity after 1810, and was nearly extinct in 1815.

The inventions described up to this point for lace-making purposes were all modifications of or additions to the stocking-frame. A distinct departure in the principle and style of the machine, and from which modern lace machinery has been developed, took place in 1775 by the invention of the hosiery warp-machine by Crane, a workman of Edmonton. In this invention, the warp of the ordinary loom was introduced, a thread was given to every needle, and the looped stitches of the stocking-frame were formed upon each. This frame was successively improved by other inventors, and so much increased in width, that its productions entered the market in rivalry with ordinary woven fabrics, with which they successfully competed for clothing purposes. It is singular that, in the present day, the stockinette-machine of Nottingham should threaten to become the successful rival of Yorkshire and West of England cloth-looms, yet such is the case.

The allotment of a thread to every needle greatly increased the capability of varying the mesh upon this machine over the hosiery-frame, though twenty years elapsed before the advantage was discovered or practical use made of it. About that time, attempts attended with considerable success were made to get open work from it with lace effects. These products were highly appreciated, and gave a great stimulus to further invention, by which the capacity of the machine was still more enlarged, and manufacturers were enabled to produce from it the finest silk-net lace, silk blonds and edgings, tattings, pearls, antimacassars, and doyleys, of all qualities and designs, which soon became and still remain articles of great consumptiou in the home and foreign markets.

The next improvement, and which greatly assisted in giving a distinct character to the lace-machine, was accomplished by William Dawson, a framework-knitter, of Leicester. By the device of a wheel irregularly notched on its edge, and which in its revolution operates upon horizontal bolts or bars, retained in position by springs on their edges, it effects such a displacement of the threads by this lateral movement, that a figure is wrought in the fabric according to the required design. These wheels are still known by the name of the inventor, who acquired considerable means by his invention, but squandered his wealth almost as fast as it was made, and, disappointed at not getting a renewal of his patent, died by his own hand.

The organ-barrel was the first embodiment of an attempt to obtain variegated productions in lace fabrics; this was followed and improved upon by Dawson's wheels, and finally perfected in the jacquard attachment, and the varied forms which the latter, in the hands of succeeding inventors, has assumed.

After the application of Dawson's wheels to the lace-frame in 1807, improvements followed one another in rapid succession. These can only be briefly enumerated. In the last-named year, the spotting-bar and wheels were invented; two years later, two-course silk-net was produced; and in 1811, dividing-bars were invented by Daycock and Morrison, which enabled them to make silk blonde. In 1816, warp-pearling was introduced by Fowkes and Kirkman. A new net called "mock-twist" next followed; and in 1822, warp-tattings were invented by Copestake and Read. In 1824, Hardy succeeded in spotting and figuring the above-mentioned mock-twist. Between 1830–5, there was a great demand for the productions of the warp-machine, which had attained the front rank of fashion, and won the favour of the Queen.

A most important improvement was made in 1839, when Draper successfully applied the jacquard machine to the warp lace-frame, by which its capacity was wonderfully extended, and articles of elaborate design, such as shawls, scarves, falls, and laces, were easily produced. Many other kinds of fabric besides lace were also made upon the warp-frame, such as elastic woollen cloth, hat-bands, glove-cloth, piece velvet, and velvet pile ornamented lace. Herbert, of Nottingham, an ingenious man, by successive improvements, made tattings, cords, and braidings. Others followed who made taffeta, single and double looped. The warp lace-machine has been a source of great wealth to Nottingham and surrounding district, and has laid the foundation of many considerable fortunes amongst those who were best acquainted with its capacity, and knew how to utilize its advantages.

But the most important invention connected with the mechanical production of lace, judging from both its principles and results, was the bobbin-net machine of John Heathcoat. All others had been modifications of the hosiery-machine, making looped fabrics. Much ingenuity, skill, and money were expended by different schemers to produce, by mechanical appliances, a perfect imitation of pillow-lace. John Heathcoat was a man of rare mechanical genius, and, having formed the conception of achieving this result, bent the whole of his energy and skill to its accomplishment.

In some pillow-lace, one set of threads extend in a wave-like line longitudinally through the fabric, like the warp threads of a plain fabric; the other set take a diagonal course right and left, and are twisted round the first set, by which means hexagonal meshes are formed. All inventors previous to Heathcoat had been foiled in the attempt to accomplish the diagonal traverse of the threads. He achieved this by a plan patented in 1808, in which the bobbins were made to traverse the warp from side to side, twisting around the warp threads in their passage, and forming an exact and perfect imitation of the net ground of pillow-lace. The machine on which this was accomplished was of limited capacity, making lace no wider than could be produced on the cushion, while a great desideratum was the production of wide laces that should obviate the necessity of joining the narrow strips together. Heathcoat, discovering this, laid his first effort aside, and nine months after, patented a second, which quite revolutionized the trade. Speaking of this attempt at a subsequent period, he says, "The value of lace is so much enhanced by its being made of greater width, that I was determined to make it even a yard wide. At this time (after his first success), I had arrived at the important point that having actually made lace as above described, I had satisfied myself that my principles were sound and well based. But I now clearly found out that, while half the threads must be active, the other half might be passive, and I therefore put the latter on a beam. Having thus fixed the warp to accomplish my wish for making wider lace, I tried to bring the threads to twist in a narrower compass. I first tried a machine with the bobbins spread out; then I tried the flat bobbin. The first flat bobbin machine was a single tier. I carried up the threads by means of a steeple top on the carriage. Great difficulty was experienced in getting bobbins and carriages thin enough, the space in which they were to move being so limited. At last I was driven to the double tier, and thus obtained the requisite space." This, when perfected, became the double-tier "Old Loughborough machine," so called from the place where it was constructed; it was able to make lace of any breadth required. This was the first successful traverse bobbin-net machine, and brought to its inventor, along with a great amount of litigation in order to protect himself from infringements of his rights, a very handsome competence.

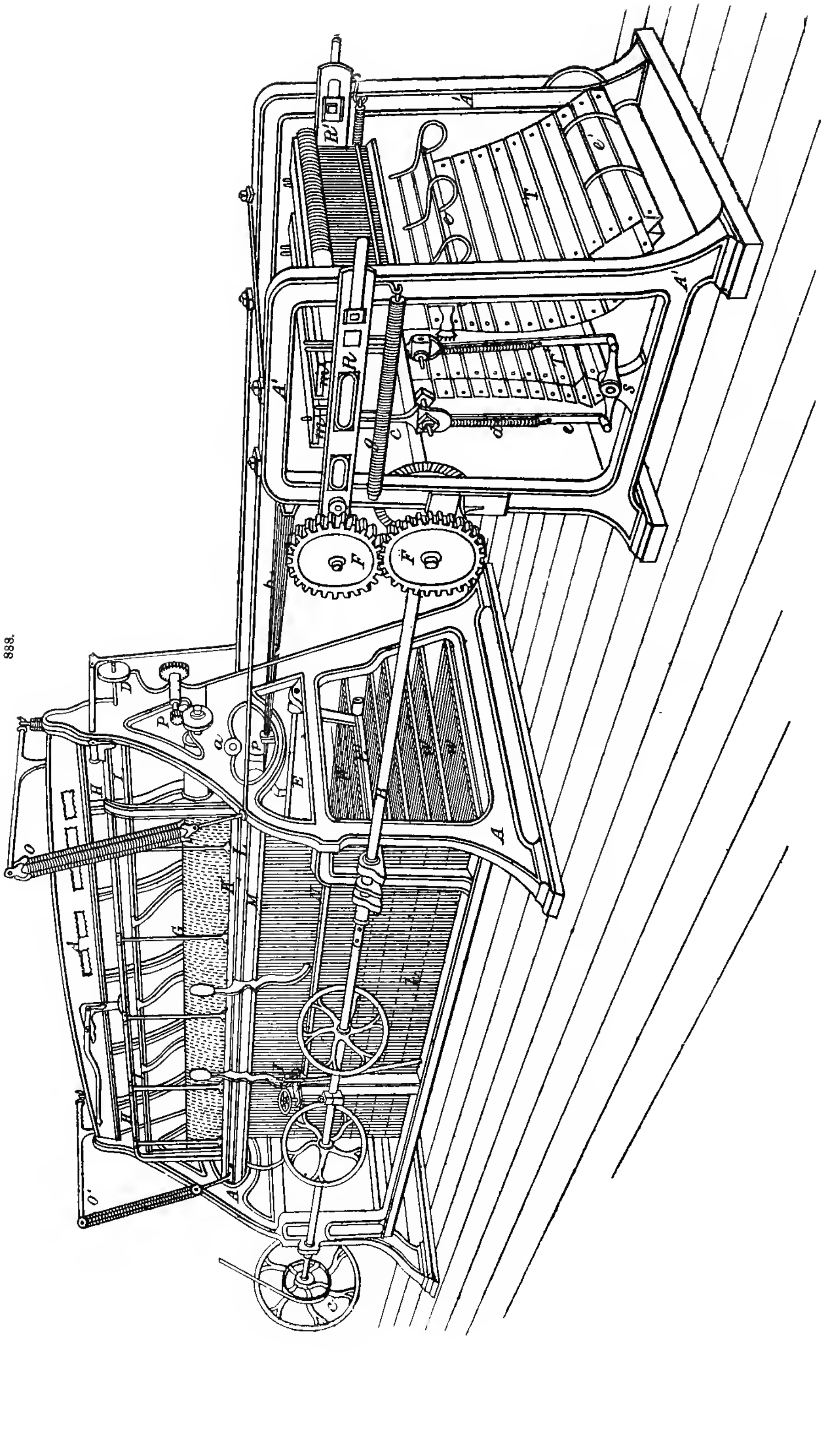
Like all successful inventors, Heathcoat had numerous imitators, some of whom, by a re-arrangement of the parts of his machine, sought to deprive him of the merits and reward of his invention; others again, stimulated by his success, sought to improve his machine in many respects, or supersede it by entirely new inventions. One of the most successful of the former was Brown's traverse warp-machine. This and several others were successfully worked for some years, owing to the discovery of a serious flaw in Heathcoat's specification, during the progress of a trial in an action brought by the latter to defend his rights. Soon after this, Moore invented a traverse warp-machine embodying considerable mechanical skill, which caused an action to be brought against him by Brown. The case was tried, and the principal result, though not the one sought, was to establish the validity of Heathcoat's invention, and to compel both parties to acknowledge his priority, and each as a consequence submitted to pay a royalty to him for the use of their machines. The inventor and others continued to work at the improvement of this machine for many years, each alteration increasing its capacity or perfecting its work. It has suggested many other changes in lace machinery, and in that respect has contributed greatly to the wonderful development of the lace manufacturing industry of this country.

In 1812, a lace-frame was constructed, called the pusher-frame, which with subsequent improvements has been worked with advantage to a considerable extent. It was the invention of Clark and Mart of Nottingham. It possessed some special advantages, and is stated to have been a clever modification of Heathcoat's machine.

But the most important outcome of the inventive faculty, which was being so extensively utilized in the Midland districts was the bobbin-net machine of John Levers, another modification of the Old Loughborough machine. This appeared in 1813, and from that date to the present time has continued in use, and has gained ground over all competing machines to such an extent as to have become the leading machine employed in the trade. Levers was originally a frame-smith, and, like many others, encouraged by Heathcoat's success, devoted himself to the improvement of the methods in vogue for the production of lace. His success was remarkable, but he did not possess the high qualities of personal character that distinguished Heathcoat, and so failed to secure corresponding advantages. His machine was subsequently improved by numerous persons, but to detail these would be somewhat tedious. A better course will be to describe the machine in its present perfected form, as the best representative that could be selected of the mechanical lace frame.

The inventor of the Levers' lace-frame held the opinion that as it passed out of his hands it was only in its infancy. This was an accurate observation, for what with subsequent improvements, and the successful application of the jacquard attachment, its capacity has been extended so greatly, that hardly any limit can be put to its power. It is the most delicate of all the lace-making machines, its interior parts occupying the smallest space, and requiring the nicest adjustment. When arranged to make fancy work, it is also the most costly. A 10-point machine is about

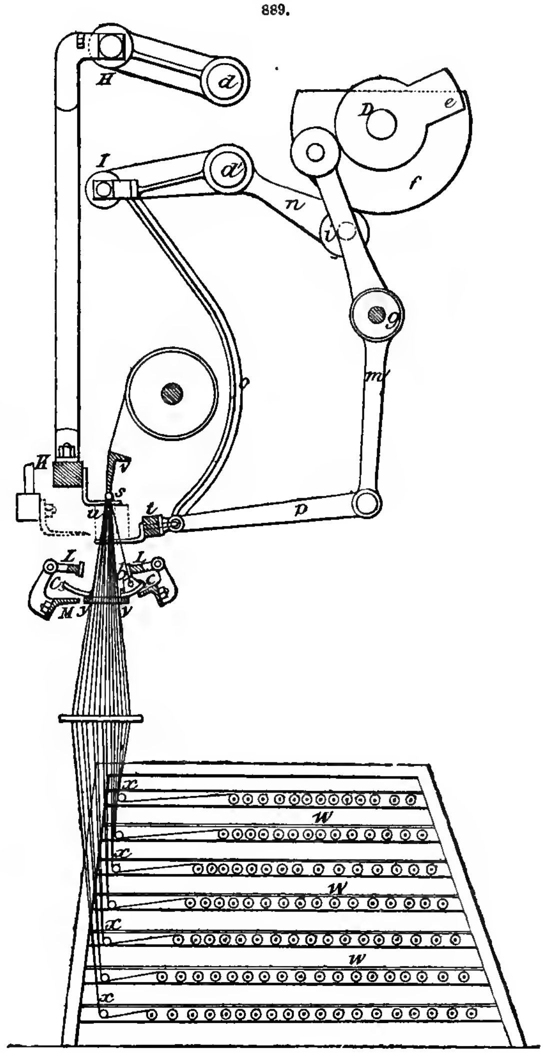
383.



152 in. in width, has 80 top bars, 400 bottom bars, 54 threading-beams, and a jacquard to enable it to produce ornamented laces. The framework is heavy and solid; its parts are highly finished, and its movements accurately adjusted: conditions essential to the satisfactory working of a lace-machine.

In Fig. 888, a general view of the machine with the jacquard attachment is given; the latter constitutes the right-hand part of the figure, whilst the left is the lace-frame proper. The frameworks of both the machines A A′ are massive, strong, and firmly attached to the flooring, in order to prevent vibration. The two parts are connected, and both actuated by the shaft B, which is driven by a strap on the pulleys *c*, near which is also fixed a balance- or fly-wheel, designed to secure steadiness in working. A shaft D arranged near the top of the back part of the frame carries several cams, and hence is called the cam-shaft; it is driven by means of a connecting shaft and wheels at the driving end of the frame. A shaft E extends the length of the frame, and by means of the connecting-rod E′, is rocked by cranks on the shaft B. Movement is imparted to the jacquard from the shaft B, through the wheels F. The sectional view, Fig. 889, will help to show the movements. The warp-beams *w* extend across the length of the frame, and contain the traversing threads of the fabric, each of which passes through eyelet-holes on the bars at *x*, and thence are conducted upward through the plate N and the slide-bars *y y*, and attached to the lace-beam C, which receives and winds up the lace as it is made. The bobbin in its carriage is shown at *b*, the thread from which passes up to the point *s*, the centre of the arc or oscillatory traverse in which the shuttles move. The carriages slide between the comb or guide-plates *c*, and as they pass from one comb-bar to the other, they necessarily go between the vertical warp threads. There is an angle-bar at M, and a corresponding one on the opposite part of the frame; these receive the carriages, which protrude through the comb-bar, as they pass through the warp threads, and are called landing-bars. The office of these bars is to receive the carriages, and diminish the friction that would otherwise arise from their large number, amounting to nearly 3000 in a frame of this description and width. Each landing bar has affixed to it at L a catch-bar, having a strip or blade which falls into slots *f* of the carriage Fig. 890, by which means the whole of the carriages are drawn across. On being returned to the opposite side, the catch-bar pushes them forward until within reach of the bar on the other side, the blade of which drops into the groove; the bar being withdrawn, brings with it the carriages. By these means, the carriages are transferred from one side to the other. The advance and recession of the landing- and catch-bars are accomplished by means of the rocking-shaft E, Fig. 888. These constitute the movements of the bobbins carrying the longitudinal threads of the fabric.

889.



The traversing or warp threads are operated very differently. From the beams *w*, they are conducted through the eyelets x upward, through the plate N, thence through the slide-bars y, whence they pass upward, and are attached to the lace-beam G. The slide-bars y are perforated to receive the threads. There are 100 of these bars in a machine such as represented here, and the threads are concentrated in them in sets or stops, as required by the design, and it is from these that the designer measures the distance that the threads must be deflected or drawn aside by the action of the jacquard.

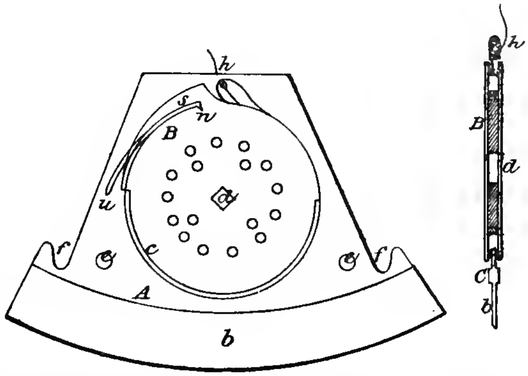
The lace-machine jacquard is specially constructed for the purpose, and differs in nearly all its details from that used in ordinary weaving. Each thread having to be moved through a known yet varying space, this is accomplished by using a series of wedges differing in size, which, being inserted between a sliding bar and a stud fixed upon each of the slides, is enabled by the movement of the bar to push the slide a distance corresponding to the size of the wedge which is adapted to the requirement of the pattern. The series of wedges consists of five: by the use of the first, the threads in the slides can be deflected over the space occupied by one bobbin in its carriage; by the second, two such spaces can be traversed; by the third, four; by the fourth, eight; the fifth being a repetition. The series thus stand in this order, 1, 2, 4, 8, 8; by the use of these, the warp threads can be deflected over any number of these "gates" from one to sixty-four.

The slide-bars (b, Fig. 888) are thin strips of fine steel, and contain holes for the passage through them of the warp threads. They are so thin that 100 do not occupy the space of an inch when set edgeways, the way they work, and yet allow space between them for the passage and deflection of the threads. The extremities away from the jacquard are attached to spiral springs, the opposite ones being connected with the slides of the jacquard, which move freely in sustaining guide-bars. Each bar at its extremity is furnished with a vertical projection or hook, which is for the purpose of preventing the spiral springs drawing them too far back after the action of the jacquard, the sustaining guide-bars arresting them at this point. Each bar also possesses two studs on its upper edge. The bars move simultaneously in opposite directions, according to requirement, and whilst in movement, have the wedges inserted between in such order as may be requisite; these are regulated by the action of the two series of cards T T′, one being all the odd numbers, and the other the even. The jacquard possessing a double action enables the speed of every part to be accelerated in proportion, the pace being double that of the single action. The cylinders are worked in the ordinary manner, and the wedges are fixed on the ends of thin flat springs, and have their lower ends made round in order to pass through the holes in the cards when required. The card-cylinders are actuated by a rocking-shaft, which alternately raises and lowers them for the purpose of changing the cards. The cylinders, as they rise, raise the two series of wedges, unless the cards present perforations into which their lower extremities enter. The cards are numbered on their margins, showing the spaces over which the sliding-bars operated by them can be moved, and which figures indicate the wedges that are required to be raised by them, either singly or in combination. The cylinders and wedges have also a lateral movement in connection with the slide-bars, which is arranged in order to keep the wedges in position. The slides are shown in Fig. 888, fitted between the cross-bars R R′, which are actuated by cams fixed on the shaft driven by the gearing F. A pair of these bars are fitted to each side of the jacquard, and the slide-bars m are mounted upon the top. The spiral springs g are for the purpose of returning the slides to the first position, after the revolution of the cams. The compound jacquard has lately come into wide use; it has a third set of cards for working the "thick" threads that outline the patterns. The cards of the jacquard are about 30 in. long by $2\frac{1}{8}$ in. broad, and contain as many rows of holes as there are needles of the jacquard, with the addition of those required to form the selvages at each side of the lace web.

Each thread in a fabric of lace has a separate beam or bobbin; and both are nicely regulated, so that the pace or delivery of the yarn shall not be greater than the requirement. The beams, of which there may be 100, or any other number according to the quantity of threads required to form the pattern, have a small pulley fixed upon one end, around which a cord is passed one or more times, according to the amount of tension that may be needed, to the end of which a weight is attached, or it may be secured by a spring. The beams are tin tubes about $1\frac{1}{2}$ in. in diameter, having small gudgeons at each extremity, on which they revolve. According to the number of times the pattern is repeated in a breadth of lace, or the number of separate breadths that may be produced at a time, will be the number of beams; for, should it be a narrow edge or insertion lace which requires 100 warp threads, and there are say 60 breadths being woven, the corresponding threads in each pattern, requiring to be delivered alike in each instance, can be all put upon one beam, and thus the 6000 threads in 60 patterns may be accommodated upon 100 beams.

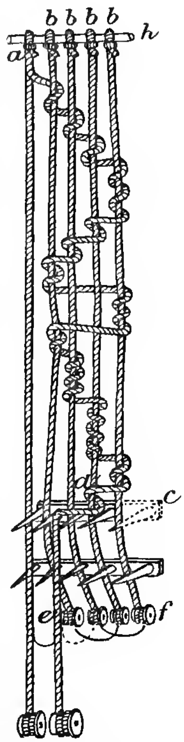
The other threads are individually provided for, being wound upon bobbins, which are formed of two thin discs of brass, about 2 in. diameter, joined by pins, and having a very small space between for the reception of the thread. When the bobbin is placed in the carriage, the end of the thread is drawn from it, and passed through a small hole as at h, Fig. 890, which shows the carriage and bobbin together. The former is made of thin steel, highly polished, cut in the shape shown, and having a circular hole in the centre for the bobbin. On the lower half of the circle, a thin flange *c* is adapted to fit between the discs of the bobbin, in order to secure it in position. The spring s, which is riveted into the carriage at *u*, has a projection or nib at *n*, which, passing between the discs, and pressing the bobbin upon the flange *c*, imparts the necessary tension to the thread as it is drawn off the bobbin. When the bobbins are filled, they are subjected to heat and pressure, which removes any slight inequality in thickness that may arise from filling, or other incidental causes. The bobbins are filled by placing them upon a spindle fitting the hole in the centre, and contain from 100 to 150 yards of thread, or more, according to fineness. The section of the carriage is shown much thicker than the reality, in order better to display its structure. The outline shows the carriage as a whole. The bottom part *b*, as will be seen in the section, is made thinner in order to pass easily between the divisions of the combs. The hooks *f* are termed drawing-hooks, being those into which the blades of the catch-bars drop, when the carriages are being passed through the warp, and drawn upon the landing-bars. The holes *e* are for the purpose of facilitating the withdrawal of the carriages when the bobbins are nearly empty. A wire is passed through the holes of a large number, and several hundred at a time are lifted from the frame.

890.



In operation, as the bobbins pass to and fro through the warp threads, around which the threads they carry are twisted, it is necessary that the portions of lace thus formed should be removed from the way of succeeding operations. This is accomplished by the action of the point or fork-bar K (Fig. 889) inserted into the warp beneath the twisting formed upon the threads, and then by the action of the cranks and levers is made to pull together in an upward direction the twisted threads, in order that the process may be continued. There are two of these combs acting alternately, as shown. After each movement, they are completely withdrawn, in order to be out of the way of the lateral movement of the warp threads.

891.



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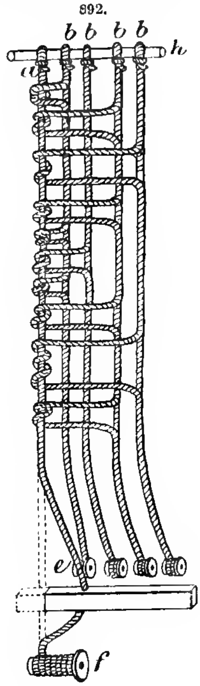


A simple illustration will dispense with a lengthy explanation. In Fig. 891, is a representation of five threads suspended from a rod *h*. The warp thread *a* has only a slight tension put upon it, compared with that upon the others. The four bobbins *e*, holding the remaining portion of the threads *b*, are intended to be represented as oscillating in the direction of the curved lines beneath them, the point from which they move being in a vertical line from the point from which they are suspended. These threads in a state of oscillation represent the motion of the carriages containing the bobbin threads when the machine is at work. Whilst the threads oscillate without any movement of the thread *a*, no effect is produced, the threads retaining the same relationship as before. But if, during the oscillation of the four threads *b*, the thread *a* be drawn laterally across the line being traversed by the bobbins, it will become twisted round the threads *b*. In this manner, the various threads round which the thread *a* has been twisted correspond to the lateral extent that it has been moved at each oscillation of the threads *b*. The function of the fork or comb has been previously explained. After each twisting, the greater tension of the threads *b* causes the thread *a* to be retained in the position to which it has been drawn, it not having power to deflect the threads *b*. Fig. 892 shows the effect that would result from the relative tensions of the above-mentioned being reversed. The threads b are, after each oscillation, drawn completely aside by the greater tension upon the thread a, and the whole structure of the fabric is thus changed. It therefore depends largely upon nice adjustment of the tensions upon the two sets of threads in relation to each other for perfect embodiment of a design. Ordinary laces draw the yarn mostly from the warp threads; high classes, from the bobbins.

A lace web, as it appears in the frame in the process of manufacture, presents a very different aspect to what the same fabric does when taken out of the machine. One set of threads, those from the bobbins, assume a longitudinal order, and appear scarcely deflected from a straight line, whilst the warp threads are interlaced with the preceding, as seen in Fig. 891. When the fabric is taken out of the frame, and all tension is removed, the meshes assume the form of the design, and show its beauty, though not to the full extent.

The Levers' lace-machines are made from 5- to 15-point in gauge. A 10-point requires 20 warp threads per in. to produce traversed net, which needs a full warp. In this, there will be 20 bobbins and carriages per in., in the single tier on the central comb-bar. In making fancy goods, there will be thick threads moved a greater or less distance sideways in addition. Of these, there may be from 40 upwards in an inch. The machine makes about 100 "shogging" or lateral movements of the warp threads, and the twisting movements of the weft threads as they pass backward and forward or through and around the warp threads, which makes about one inch of lace per minute. The bobbins and carriages are driven at this pace through the maze of tight and for the most part very fine threads of cotton or silk, or even untwisted filaments of the latter, in spaces of $\frac{1}{10}$–$\frac{1}{20}$ in., according to the gauge, working side by side, clear of each other and of the threads through which they pass, and which threads have all, between each movement of the carriages, been themselves moved $\frac{1}{10}$–$\frac{1}{20}$ in., so as to vary the particular intervals through which the carriages pass. Were the least irregularity to occur in this lateral movement, the threads would all be broken, and the machine injured.

As this is being written, great efforts are being made in Paris to introduce a new lace-machine, which is said to imitate the work of the pillow-lace maker much more perfectly than any previous machine has done. Having scarcely got beyond the experimental stage, it cannot receive further notice here.

The subsequent processes through which lace fabrics usually pass are gassing, bleaching, and finishing. By the first, all the loose, fibrous portion of the threads is singed off in passing over or through gas-jets, so arranged as not to injure the fabric. Bleaching restores the colour, which has suffered from contact with the parts of the machine in the process of working. Dressing is the final operation to which lace is subjected. In this, it is sought to extend the meshes to their proper shape, and by the application of a mixture of gum, starch, or other sizing compounds, to stiffen it so as to prevent its collapse, and enable it to exhibit the form and design intended.

This section, the mechanical branch of the lace manufacture, owes its origin, to and still flourishes principally, in this country. English-made machinery has, however, been exported to a considerable extent, and still continues to go abroad, so that it is not improbable that new centres of the industry may be in course of formation which will at some future day, to a larger extent than at present, share with us the task of supplying the demand for mechanically produced lace.

The following statistics relating to this branch of the lace trade are taken from the most recent government Returns. They refer strictly to those portions which come under the regulations of the Factory Acts, and are subject to inspection. In this respect, they are an inadequate return. As many of the subordinate processes can be carried on either at home, or in buildings which do not come under factory regulations, these are omitted. If included, they would bring the number of employés here given to an aggregate fully 4–4½ times as great.

SUMMARY OF LACE FACTORIES, 1879.

Counties.	Registration Districts.	Number of Factories.	Number of Lace Machines.	Number of Persons Employed.		
				Males.	Females.	Total.
Wilts, Dorset, Devon, Cornwall, and Somerset	South Western	4	..	693	905	1,598
Leicester, Rutland, Lincoln, and Nottingham	North Midland	237	..	4,757	2,234	6,991
Derby	"	37	..	743	616	1,359
Gloucester, Hereford, Salop, Stafford, Worcester, and Warwick ..	West Midland	4	..	72	144	216
Scotland. Ireland (none)	South Western	1	..	18	27	45
Total for 1879	..	283	..	6,283	3,926	10,209
Corresponding returns for 1874	..	311	3,462	6,945	3,428	10,373

From these figures, it will be seen that, during the five years which elapsed between the returns, there had been a small decline in the number of factories, and of the persons employed in the industry; but probably this was only a temporary falling off, owing to the severe depression of trade from which the country was suffering at the time the latest return was made. Of closed establishments, the enumerators took no account. Unfortunately there is also another important omission in the fact that no enumeration was made of the machinery, as in 1874. R. M.

LEATHER (Fr., *Cuir;* Ger., *Leder*).

The manufacture of leather is of very considerable importance, the capital invested in it in the United Kingdom having been some years since estimated at 30,000,000*l.* It is, however, very difficult to obtain any reliable statistics on the subject, the trade being now entirely free from excise restrictions, which were removed in 1830, when the duty realized amounted to 411,000*l.* Some idea of the expansion of the trade may be formed from the fact that while at that date the total export of leather and saddlery of British manufacture amounted to less than 200,000*l.*, during the year 1880, it was upwards of 3,300,000*l.*

The only information within reach as to the present extent of the trade is that which may be derived from the Board of Trade Returns of imports and exports, and from this it is exceedingly difficult to draw any definite conclusions, since large quantities of both leather and hides imported are re-exported, either in their rough condition or after manufacture. During the year 1880, the imports into the United Kingdom included upwards of 45,000,000 lb. of leather, in addition to 657,262 cwt. of dry hides, and 592,249 cwt. of salted. In the same period, were exported 346,554 cwt. of dry, and 85,213 cwt. of salted hides, leaving 310,708 cwt. of dry, and 507,036 cwt. of salted hides for tannage, in addition to the cattle killed in the United Kingdom. Of these, there were 343,659 imported, besides the very large number reared at home.

The principal sources of the leather imported into the United Kingdom are America, Australia, and the E. Indies, the two former sending sole-leather, and the latter the small hides known as "E. India tanned kips," which are used for dressing and insole purposes. Of these, 1,691,749 were sold in 1877, and 1,998,543 in 1878; but only 1,094,984 in 1879, and 846,267 in 1880.

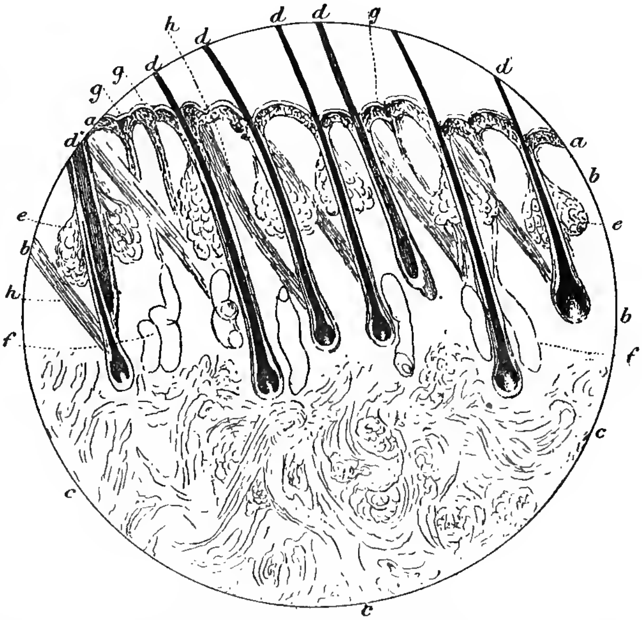
The principal seats of the heavy sole-leather manufacture from salted hides are Bristol and Warrington; light sole-leather is largely made in Bermondsey; while Leeds is famous for the tannage of E. India kips. Tanning is, however, by no means confined to these districts, many important tanneries being scattered over the country.

Leather manufacture may be broadly divided into two stages: "tanning," in which the raw hide is converted into the imputrescible and more or less flexible material known as "leather"; and "currying," in which this leather is further manipulated, and treated with fatty matters, to soften and render it more waterproof, and to improve its appearance. Glove-kid, and certain other leathers, however, are not tanned at all, but "tawed," or prepared with a mixture in which alum and salt are the most active ingredients; and many leathers can scarcely be said to be curried, although more or less oil is used in the final processes of "finishing" or "dressing." The first subject to be treated of in this article will be the operation of tanning, properly so called, taking for example the tannage of sole- and belting-leather. This demands thorough explanation, in both its practical and theoretical aspects, not only because it is one of the most important branches of the trade, but because the principles involved are those which equally underlie all other tanning methods. The next to be dealt with will be the modifications of the process which are necessary in tanning the more flexible leathers used for boot-uppers, hose-pipes, and saddlery purposes; then the currying of these leathers; and finally, the manufacture of moroccos, Russian, and japanned leathers, and calf- and glove-kid.

Anatomical Structure of Hide.—Before speaking of actual processes of manufacture, it is necessary to devote some attention to the structure and chemical constitution of hide or skin, which forms the raw material. Although a great variety of skins are employed in tanning, they are all constituted on the same general type, and an anatomical description of the hide of the ox will apply almost equally to those of the calf, sheep, and goat: but from differences in thickness and closeness of texture, their practical values differ widely. Fig. 893 shows a section of ox-hide, cut parallel with the hair, magnified about 50 dia.: *a*, epithelial layer or *epidermis*, consisting of horny layer above, and *rete malpighi* below; *b*, *pars papillaris*, and *c*, *pars reticularis* of *corium*, *derma*, or true skin; *d*, hairs; *e*, sebaceous or fat-glands; *f*, sudoriferous or sweat-glands; *g*, opening of ducts of sweat-glands; *h*, *erectores pili* muscles, for erecting the hair.

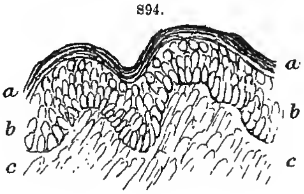
The fresh hide consists of two layers: an outer, the epidermis; and an inner, the true skin. The epidermis is very thin as compared with the true skin which it covers, and is entirely removed preparatory to tanning; it nevertheless possesses important functions. It is shown in Fig. 893 at *a*, and more highly magnified in Fig. 894. Its inner mucous layer *b*, the *rete malpighi*, which rests upon the true skin *c*, is soft, and composed of living nucleated cells, which are elongated in the deeper layers, and gradually become flattened as they approach the surface, where they dry up, and form the horny layer *a*. This last is being constantly worn away, and thrown off as dead scales of skin; and as constantly renewed from below, by the continued multiplication of the cells. It is from this epithelial layer that the hair, as well as the sweat- and fat-glands, are developed. It will be seen in Fig. 893 that each hair is surrounded by a sheath, which is continuous with the epidermis. In embryonic development, a small knob of cells forms on the under side of the epidermis, and this enlarges, and sinks deeper into the true skin, while the root of the young hair is formed within it. Smaller projections also form on the stalk of the knob, and in due time produce the sebaceous glands; this is shown in Fig. 895, *a b*. The process of development of the sudoriferous glands is very similar to that of the hairs. There is a great analogy between this process and that of the ordinary renewal of hair in the adult animal. At *d'*, Fig. 893, is seen an old and worn-out hair. It is shrunken and elongated, and is almost ready to fall out. It will be noticed

893.



that its sheath or follicle projects somewhat below the hair to stage of the right. This is the first production of a young hair, and is quite analogous to the knob of epithelium which has been described as forming the starting point of a hair in the embryo. At *d''*, the same process is seen further advanced, the young hair being already formed, and growing up into the old sheath. At *d'''*, it is complete, the old hair having fallen out, and the young one having taken its place.

894.



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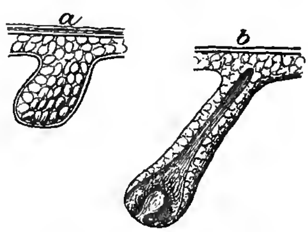
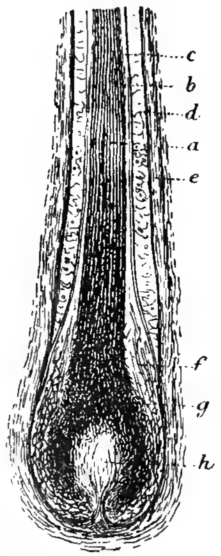


The hair itself is covered with a layer of overlapping scales, like the slates on a roof, but of irregular form. These give it a serrated outline at the sides, strongly developed in wool. Within these scales, which are sometimes called the "hair cuticle," is a fibrous substance, which forms the body of the hair; and sometimes, but not always, there is also a central and cellular pith, which is mostly transparent, though under the microscope it frequently appears black and opaque, from the optical effect of imprisoned air. On boiling or long soaking in water, alcohol, or turpentine, these air-spaces become saturated with the liquid, and then appear transparent.

The fibrous part of the hair is made up of long spindle-shaped cells, and contains the pigment which gives the hair its colour. The hair of the deer differs from that of most other animals in being wholly formed of polygonal cells, which, in white hairs, are usually filled with air. At its base, the hair swells into a bulb, which is hollow, and rests on a sort of projecting knob of the *corium* called the hair-papilla. This has blood-vessels and nerves, and supplies nourishment to the hair. The hair-bulb is composed of round, soft cells, which multiply rapidly; as they grow, they press upward through the hair-sheath, become elongated and hardened, and form the hair. In dark hairs, both the cells of the hair itself and those of its follicle or sheath are strongly pigmented, but the hair much the more so, and hence the bulb has usually a distinct dark form. The dark-haired portions of a hide from which the hair has been removed by liming still remain coloured, from the pigmented cells of the hair-sheaths, which can only be got out by bating and scudding. The cells outside the bulb shown at *f*, in Fig. 896, pass upwards as they grow, and form a distinct coating around the hair, which is called the "inner root-sheath." This again consists of two separate layers, of which the inner is "Huxley's," the outer, "Henle's." They arise from the same cells in the base of the hair; but in the inner layer, these remain polygonal and nucleated, while in the outer, they become spindle-shaped and without nuclei. The inner root-sheath does not extend to the surface of the skin, but dies away below the sebaceous glands. This figure represents an ox-hair root, mag. 200 dia.: *a*, fibrous substance of hair; *b*, hair cuticle; *c*, inner root-sheath; *d*, outer root-sheath; *e*, dermic coat of hair-sheath; *f*, origin of inner sheath; *g*, bulb; *h*, papilla.

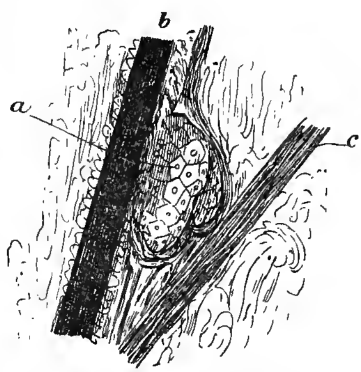
896.



Outside the inner root-sheath is a layer of nucleated cells, continuous with those of the epidermis, and of the same character. This is the "outer root-sheath," and is shown at *d*, Fig. 896. This, together with the whole of the epidermis, is covered next the *corium* with an exceedingly fine membrane, called the "hyaline" or glassy layer. The whole of the hair-sheath is enclosed in a coating of elastic and connective-tissue fibres, which are supplied with nerves and blood-vessels, and form part of the *corium*. Near the opening of the hair-sheaths to the surface of the skin, the ducts of the sebaceous or fat-glands (*e*, Fig. 893), pass into them, and secrete a sort of oil to lubricate the hair. The glands themselves are formed of large nucleated cells, arranged somewhat like a bunch of grapes; one is shown highly magnified in Fig. 897: *a*, sebaceous gland; *b*, hair-stem; *c*, part of *erector pili* muscle. The upper and more central cells are most highly-charged with fat, which is shown by the darker shading.

As already remarked, the sudoriferous or sweat-glands are also derived from the epidermis layer. They are shown at *f*, Fig. 893, and on a larger scale (200 dia.) in Fig. 898: *a*, windings laid open in making section; they consist, in the ox and sheep, of a large wide tube, sometimes slightly twisted. In this, they differ considerably from those of man, which form a spherical knot of extremely convoluted tube. The walls of these glands are formed of longitudinal fibres of connective tissue of the *corium*, lined with a single layer of large nucleated cells, which secrete the perspiration. The ducts, which are exceedingly narrow, and with walls of nucleated cells like those of the outer hair-sheaths, sometimes open directly through the epidermis, as shown at *g*, but more frequently into the orifice of a hair-sheath, just at the surface of the skin. Each hair is provided with a slanting muscle (*h*, Fig. 893), called the *arrector* or *erector pili*, which is contracted by cold or fear, and causes the hair to "bristle," or stand on end; by forcing up the attached skin, it produces the effect known as "goose-skin." The muscle, which is of the unstriped or involuntary kind, passes from near the hair-bulb to the epidermis, and just under the sebaceous glands, which it compresses.

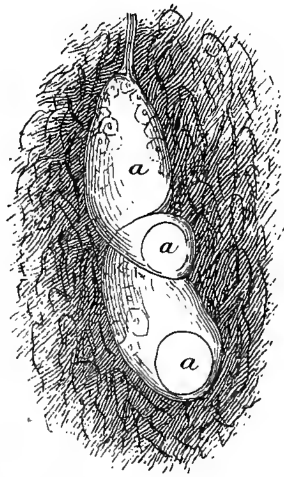
897.



The *corium* or true skin is principally composed of interlacing bundles of white fibres, of the kind known as "connective tissue"; these are themselves composed of fibrils of extreme fineness, cemented together by a substance of different composition from the fibres themselves. This may be demonstrated by steeping a small piece of hide for some days in a stoppered bottle in lime-, or baryta-water, in which the interfibrillar substance is soluble, and then teazing a small fragment of the fibre with needles on a glass microscope-slide, and examining with a power of at least 200-300 dia. In the middle portion of the skin, these bundles of fibre are closely interwoven; but next the body, they gradually become looser and more open, forming the *pars reticularis* (or netted part); and the innermost layer is a mere network of loose membrane, generally loaded with masses of fat-cells. It is this which is removed in the "fleshing" process. On the other hand, the outermost layer, just beneath the epidermis, is exceedingly close and compact, the fibre-bundles that run into it being separated into their elementary fibrils, which are so interlaced that they can scarcely be recognized. This is the *pars papillaris*, and forms the lighter-coloured layer, called the "grain" of leather. It is in this part that the fat-glands are embedded, while the hair-roots and sweat-glands pass through it into the loose tissue beneath.

Besides the connective-tissue fibres, the skin contains a small proportion of fine yellow fibres, called "elastic" fibres. If a thin section of hide be soaked for a few minutes in strong acetic acid, and then examined under the microscope, the white connective-tissue fibres become swollen and transparent, and the yellow fibres may then be seen, as they are scarcely affected by the acid. The hair-bulbs and sweat- and fat-glands are also rendered distinctly visible.

898.



The nerves of the skin are very numerous, each hair being supplied with fibres passing into both the papilla and sheath. They also pass into the skin papillæ. They cannot readily be seen, without special preparation, and so far as is known, exercise no influence on the tanning process. "Breaking the nerve" is a technical term, which signifies a thorough stretching and softening of the skin, but has nothing to do with nerves properly so called. The blood- and lymph-vessels are, from the present point of view, somewhat more important. They may often be seen in sections, and are lined with nucleated cells, similar to those of the glands. These are surrounded by coatings of unstriped muscular fibre, running both around and lengthways, and also by connective-tissue fibres. In the arteries, the muscular coating is much stronger than in the veins.

It may be thought that the space above devoted to the anatomical structure of the skin is disproportionately large; but there can be no doubt that, in order to make improvements, nothing is of more importance than a clear conception, even to the smallest details, of the materials and causes to be dealt with. The illustrations are from actual specimens, and enable the various parts of the hide to be identified under the microscope, which instrument is destined to play a most important part in the development of tanning.

If it be required to see how far the cellular structure of the hide, such as hair-sheaths and fat-glands, are affected or destroyed in any stage of liming or bating, the following ready method may be employed. If a strip of hide be cut $\frac{2}{3}$ through from the grain side, as shown at *a* in Fig. 899, and the flap be turned down, and held between the finger and thumb, the fibrous tissue will be put on the stretch, and will then allow a moderately thin shaving (including the grain and parts immediately below it) to be cut by a sharp razor. The hide should be held in the position shown, and a steady drawing cut be made from flesh to grain, the razor being steadied on the tip of the forefinger, and its hollow surface flooded with water. If the thin section be now placed on a glass slide, moistened with a drop of water, and examined on the microscope under a strong light from above, with a 1-in. objective, the fat-glands will be seen as yellow masses, embedded in the white fibrous tissue. If a drop of a mixture of equal vols. of strong acetic acid, glycerine, and water be used to moisten the section, the fibrous tissue will become quite transparent, and whatever remains of the cellular tissue will be easily visible, and may even be studied under tolerably high powers if covered with a thin glass, and lighted by the mirror from below.

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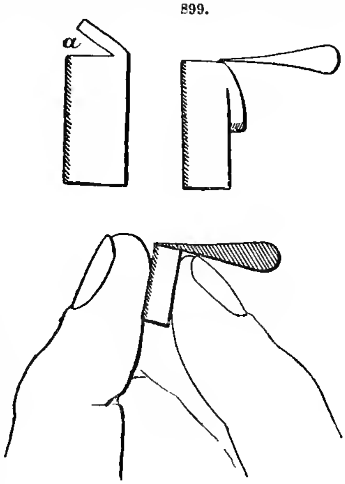


The same method is applicable for ascertaining the completeness of the tannage of leather, and to decide whether the hide fibre is really tanned, or only dyed. Actually tanned leather is unaffected by the acetic acid, but raw or only stained hide swells and becomes transparent.

To prepare the very thin sections necessary for detailed study of the hide, more complicated methods are required. Small slips of hide, not exceeding $\frac{1}{4}$ in. wide, and cut directly across the lie of the hair, are placed first in weak alcohol (methylated spirit and water), and, after a few hours, are removed into strong methylated spirit. In 24 hours, the hide is hard enough to give fine shavings, and may be cut either when held as above described, or when embedded in paraffin wax. The razor must be wet with alcohol, and the section be made exactly in the plane of the hair-roots, which may be seen with a hand-lens. The slices may now be stained by placing them in a watch-glass with water and a few drops of the logwood or picrocarmine staining-mixtures sold by opticians, and afterwards either examined in glycerine, or, after soaking some hours in absolute alcohol, may be transferred to clove-oil, and afterwards to a slide, and covered with a drop of dammar varnish and a cover-glass for permanent preservation. If picrocarmine be used, the connective-tissue fibres (gelatinous fibres) and the nuclei of the cells will be coloured red, and the cells themselves of both epidermis and glands, together with the muscles and elastic fibres, will be yellow.

For further information, the reader is referred to microscopic manuals, such as Schaefer's 'Practical Histology.' Some important researches on the structure of hide, and its modification in tanning, have been made by F. Kathreiner, of Worms, who has invented refined and convenient methods of microscopic research, specially adapted to the purpose. Particulars of these are in course of publication.

Chemical Composition of Hide.—The chemical composition of skin is very imperfectly understood. The bulk of the skin is, as has long been known, converted by boiling into gelatine or glue. The yellow fibres and cellular tissue remain undissolved. Müntz, who made some interesting researches on the subject, found that completely dried hide contained—3·086 per cent. of cellular tissue insoluble in hot water, 1·058 of fat, 0·467 of mineral matter, and 95·395 of matters soluble in hot water. Müntz counts the whole of the tissue soluble in hot water as converted into glue; but this is not strictly the case. Gelatine is not identical with the fibre of the hide, which is only converted into it by boiling. The nature of the change is not well understood; but it is either simply molecular, or depends on the addition of one or more molecules of water. Raw hide, unhaired and purified, contains, according to Müntz—carbon, 51·43 per cent.; hydrogen, 6·64; nitrogen, 18·16; oxygen, 23·06; ash, 0·71; while gelatine has, according to Mulder—carbon, 50·1 per cent.; hydrogen, 6·6; nitrogen, 18·3. Probably, however, neither substance was quite pure.

Gelatine is insoluble in alcohol, ether, and cold water, but swells in the last. It is soluble in hot water, but is reprecipitated on the addition of a sufficient quantity of alcohol. This reaction is common to gum, dextrine, and other substances. Moist gelatine exposed to the air rapidly putrefies. It first becomes very acid, from formation of butyric (and perhaps other) acids, but afterwards alkaline, from evolution of ammonia. Boiled with concentrated potash, it yields leucine, glycocine (sugar of gelatine), and other substances.

The same products are obtained by boiling with sulphuric acid, and probably also more gradually, and in greater or less proportions, by the prolonged action of lime or barium hydrate, by putrefaction, and by any other influence which tends to resolve the gelatine molecule into its simpler parts. Gelatine is precipitated by all tannins, even from very dilute solution. A solution containing $\frac{2}{10000}$ parts is rendered turbid by infusion of gall-nuts or gallotannic acid. The precipitate is soluble in excess of gelatine. Solution of gelatine dissolves considerable quantities of phosphate of lime, hence this is always largely present in common glue. It is not precipitated by ferrocyanide of potassium, by which it is distinguished from albuminoids, and it differs from albumen in not being coagulated by heat. On the contrary, by prolonged boiling, glue loses the property of gelatinizing, but is not altered in composition.

The connective-tissue fibres are partially converted into gelatine by the action of strong acids and alkalies, as well as by heat. By weak acids, they are swollen and gradually dissolved, and Reimer has found that the fibrous material may be reprecipitated by lime-water. It forms an irregular fibrous mass, which has not the sticky feel of gelatine, but is at once converted into the latter by boiling. Rollet has demonstrated that when hide and other forms of connective tissue are soaked in lime- or baryta-water, the fibres become split up into finer fibrils, and as the action proceeds, these again separate into still finer, till the ultimate fibrils are as fine as can be distinguished under a powerful microscope. At the same time, the alkaline solution dissolves the substance which cemented the fibres together, and this may be recovered by neutralizing the solution with acetic acid, when it comes down as a flocculent precipitate. This was considered by Rollet as an albuminoid substance; but Reimer has shown that it is much more closely allied to the gelatigenous fibres, if indeed it is not actually produced from them by the action of the alkaline solution. Reimer used limed calf-skin for his experiments, and subjected it to prolonged cleansing with distilled water, so that all soluble parts must have been pretty thoroughly removed beforehand. He then digested it in closed glasses with lime-water for 7–8 days, and precipitated the clear solution with dilute acetic acid. He found that the same portion of hide might be used again and again, without becoming exhausted, which strongly supports the supposition that it is merely a product of the partial decomposition of the hide fibre. The substance, which he called "coriin," was purified by repeated solution in lime-water, and reprecipitation by acetic acid. It was readily soluble by alkalies, but insoluble in dilute acids, though in some cases it became so swollen and finely divided through the latter as to appear almost as if dissolved. It was, however, very soluble in common salt solution of about 10 per cent., though it was precipitated both by the addition of much water, and by saturating the solution with salt. Reimer found that a 10 per cent. salt solution was equally effective with lime-water in extracting it from the hide, and that it was partially precipitated on the addition of acid, and completely on saturating the acidified solution with salt. Other salts of the alkalies and alkaline earths acted in a similar manner, so that Reimer was at first deceived when experimenting with baryta-water, because, being more concentrated than lime-water, the coriin remained dissolved in the baryta salt formed on neutralizing with acid, and it was necessary to dilute before a precipitate could be obtained. The slightly acid solution of coriin gave no precipitate with potassium ferrocyanide, nor was it precipitated by boiling, being thus distinguished from albuminoids. The neutral or alkaline solution was not precipitated by iron or mercuric chloride, copper sulphate, nor by neutral acetate of lead; but was precipitated by basic lead acetate, basic sulphate of iron, and excess of tannin. Its elementary composition is—carbon, 45·91; hydrogen, 6·57; nitrogen, 17·82; oxygen, 29·60; and Reimer proposes the following equation as representing its relation to hide fibre:—

$$\underset{\text{Hide fibre.}}{C_{30}H_{46}N_{10}O_{12}+O} \quad + \quad \underset{\text{Water.}}{2H_2O} \quad = \quad \underset{\text{Coriin.}}{C_{30}H_{50}N_{10}O_{15}}.$$

Hide Albumen.—The fresh hide, besides this coriin (which, very possibly, is only evolved by the action of the lime), contains a portion of actual albumen, viz. that of the blood serum and of the lymph, which is not only contained in the abundant blood-vessels, but saturates the fibrous connective tissue, of which it forms the nourishment. This albumen is mostly removed by the liming and working on the beam, which is preparatory to tanning. Probably for sole-leather, the albumen itself would be rather advantageous if left in the hide, as it combines with tannin, and would assist in giving firmness and weight to the leather. It is, however, for reasons which will be seen hereafter, absolutely necessary to get rid of any lime which may be in combination with it. The blood also must be thoroughly cleansed from the hide before tanning, as its colouring matter contains iron, and, in combination with the tannin, would give a bad colour.

The reactions of blood and lymph albumen are very similar to those of ordinary white of egg. It is precipitated by strong mineral acids, especially nitric, and also by boiling. The precipitate produced by strong hydrochloric acid re-dissolves by the aid of heat to a blue or purple solution. Tribasic phosphoric, tartaric, acetic, and most other organic acids, do not precipitate moderately dilute solutions of albumen, but convert it into a sort of jelly, which, like gelatine, does not coagulate, but liquefies on heating. It is precipitated by neutral salts of the alkali metals. Albumen slightly acidified (with acetic acid) is precipitated by potassium ferrocyanide.

Elastic Fibres.—The elastic or yellow fibres of the hide are of a very stable character. They are not completely dissolved even by prolonged boiling, and acetic acid and hot solutions of caustic alkalies scarcely attack them. Probably they do not combine with tannin, and are very little changed in the tanning process.

The hair, epidermis, and glands are, as has been seen, all derived from the epithelial layer, and hence, as might be inferred, have much in common in their chemical constitution. They are all classed by chemists under one name, "keratin," or horny tissue, and their ultimate analysis shows that in elementary composition they nearly agree. It is evident, however, that the horny tissues are rather a class than a single compound.

The keratins are gradually loosened by prolonged soaking in water, and, by continued boiling in a Papin's digester, are dissolved to an extract which does not gelatinize on cooling. Keratin is dissolved by caustic alkalies; the epidermis and the softer horny tissues are easily attacked, while hair and horn require strong solutions and the aid of heat to effect complete solution. The caustic alkaline earths act in the same manner as dilute alkaline solutions; hence lime easily attacks the epidermis, and loosens the hair, but does not readily destroy the latter. Alkaline sulphides, on the other hand, seem to attack the harder tissues with at least the same facility as the soft ones, the hair being often completely disintegrated, while the epidermis is still almost intact; hence their applicability to unhairing by destruction of the hair. Keratins are dissolved by fuming hydrochloric acid, with the production of a blue or violet coloration, like the albuminoids. They also resemble albumen, in the fact that their solution in sulphuric acid is precipitated by potassium ferrocyanide. By fusion with potash, or prolonged boiling with dilute sulphuric acid, keratin is decomposed, yielding leucine, tyrosine, ammonia, &c. The alkaline solution of keratin (hair, horns, &c.) is precipitated by acids, and, mixed with oil and sulphate of baryta, is employed under Dr. Putz's patent as a filling material for leather, for which purpose it acts in the same way as the egg-yolks and meal used in kid-leather manufacture. Eitner has also proposed its use for the same purposes with bark-tanned leather.

Hides used for Sole-leather.—The principal sources of hides for sole-leather are:—

(I.) Market hides, from the cattle slaughtered for food in the United Kingdom. These are received by the tanner, fresh or slightly salted, and are either bought directly from the butcher, or, now more commonly, through the auction markets established in all large towns. The latter system, while it perhaps slightly enhances the price of the hides to the tanner, ensures him a better classification according to weight, and, in some cases, as notably in that of Glasgow, a better flaying, through an organized system of inspection and sorting. The Scotch hides, being mostly from Highland cattle, are many of them small and very plump, for, as a rule, the hides are thickest on those animals which are exposed to cold and the hardships of out-door life. On the other hand, the hides of highly-bred cattle are apt to be thin and spreading; and, if they have been kept much indoors, and negligently managed, the grain of the hide is injured by the dung which adheres to it. The Irish hides are usually somewhat roughly flayed.

(II.) South American hides are from the River Plate, Uruguay, and Rio Grande. Those from the River Plate are considered the best, as being stoutest and finest in texture. They are usually cured by salting, and are known as "saladeros," "estancias," and "mataderos," according to the slaughter and cure. The saladeros are the best, and are from cattle killed at large slaughtering establishments on the coast. The estancias are from cattle killed in the interior, and are worse in flaying than the saladeros, but free from the objectionable dark cure of the mataderos, which are killed by the city butchers. Many hides are brought from Brazil, and are generally both salted and sun-dried, or simply stretched out and dried. Hides are also imported from Valparaiso, both dry and wet-salted.

China and W. Indies hides are mostly dried. French market hides have been of recent years largely imported; they are mostly well-flayed, and some of them very heavy, but are sold at original butchers' weight, and, in the experience of some tanners, the result in leather is 5–6 per cent. less than from English market hides. They usually lose about 25 per cent. in sculling and salting. Lisbon hides are often well flayed, but are frequently branded, and the grain is injured by insects. They yield considerably more leather than market hides in proportion to weight. Hambro hides are salted, but mostly wet and ill-flayed.

Preparation of Hides for Tanning.—Market hides merely require a slight soaking in fresh water, to remove blood and dirt, before unhairing. Salted hides should be soaked somewhat longer, and in several changes of water, so as to remove the salt before limeing. Dried hides, however, require more lengthened treatment. Before they are prepared for tanning, they must be brought back as far as possible to the condition of fresh hides, and, for this purpose, must be thoroughly soaked and softened in water. There are many ways of doing this: sometimes hides are suspended in running water; sometimes laid in soaks, which may be either renewed, or allowed to putrefy; sometimes in water to which salt or carbolic acid has been added, to prevent putrefaction.

The first of these methods, were it desirable, is rarely possible in these days of River Pollution Acts; of the others, it is difficult to say which is better, since the treatment desirable varies with the hardness of the hide and the temperature at which it has been dried. The great object is to thoroughly soften the hide, without allowing putrefaction to injure it. As dried hides are often damaged already from this cause, either before drying, or from becoming moist and heated on shipboard, it is frequently no easy matter to accomplish this. The fresh hide, as has been seen, contains considerable portions of albumen, and if the hide is dried at a high temperature, this becomes wholly or partially coagulated and insoluble. The gelatinous fibre and the coriin (if indeed the latter exists ready formed in the fresh hide) do not coagulate by heat, but also become less readily soluble. Eitner experimented with pieces of green calf-skin of equal thickness, which were dried at different temperatures, with results given in the following table:—

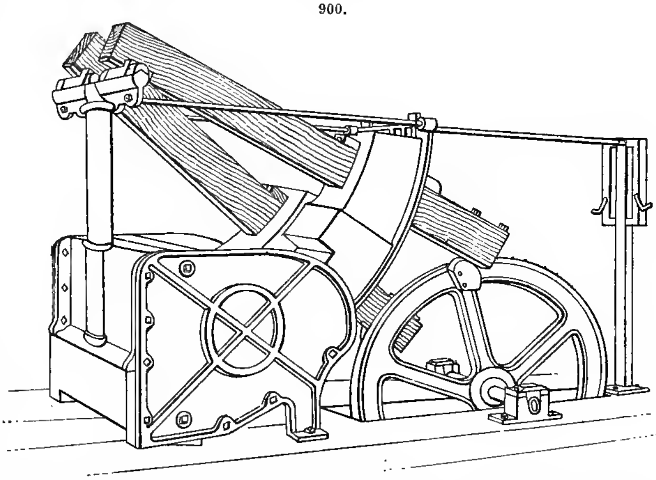
	Temperature of Drying.	Remarks.	Time of Softening in Water.	Remarks.	Coriin Dissolved by Salt Solution.
Sample I.	15° C.	In vacuo	24 hours	Without mechanical work	1·68 per cent.
" II.	22° C.	In sun	2 days		1·62 "
" III.	35° C.	In drying-closet	5 "	twice worked	0·15 "
" IV.	60° C.	"	Refused to soften sufficiently for tanning		Traces.

Hence it is evident that, for hides dried at low temperatures, short soaking in fresh and cold water is sufficient, and, except in warm weather, there would be little danger of putrefaction. With harder drying, longer time is required, and it may be necessary to use brine instead of water. A well-known tanner recommends a solution of 30°–35° barkometer (sp. gr. 1·035, or about 5 per cent. of NaCl). This will have a double action, not only preserving from putrefaction, but dissolving a portion of the hide-substance in the form of coriin. Although this is undoubtedly a loss to the tanner, it is questionable if there is any process which will soften overdried hides without loss of weight: even prolonged soaking in cold water at too low a temperature to allow of putrefaction will dissolve a serious amount of hide-substance. Water containing a small quantity of carbolic acid has been recommended for the purpose, and will prevent putrefaction, while it has no solvent power on the hide, but, on the contrary, will coagulate and render insoluble albuminous matters. Borax has been proposed for the same purpose, and, in strong solution, certainly prevents putrefaction, but is probably too costly. Sulphide of sodium and other sulphides seem to have considerable effect in softening dried hides, from their property of attacking hard albuminous matters, without injuring the true hide-fibre. A little sulphide of sodium is sometimes added to obstinate hides in the stocks.

For some descriptions of hides, however, and notably for India kips, putrid soaks seem actually to be an advantage, the putrefactive action softening and rendering soluble the hardened tissue. Putrefactive processes are always dangerous, as the action, through changes of temperature, or variation in the previous state of the liquor, is apt to be irregular, and either to attack one portion of the hide before another, or to proceed faster than was expected. Hence hides in the soaks require constant and careful watching, and the goods must be withdrawn as soon as they are thoroughly softened, for the putrefaction is constantly destroying as well as softening the hides. It is probable that putrefactive softening is less injurious to kips, and such goods as are intended for upper-leather, than to those for sole purposes, as it is necessary in the former case that the albumen and interfibrillary matter be removed, and that the fibre be well divided into its constituent fibrils for the sake of softness and pliability; the putrid soak, if acting rightly, only accomplishes a part of the work, which would afterwards have to be done by the lime and the bate. The actual fibre of the hide seems less readily putrescible than the albuminoid parts; hence the putrefaction may soften the latter better, and even at less expense of valuable hide-substance, because more rapidly, than fresh water. On this point, there is room for investigation. Putrefaction is a general name for a class of decompositions which are caused by a great variety of living organisms, each of which has its own special products and modes of action. It is quite possible that, if we knew what precise form of putrefaction was most advantageous, we might by appropriate conditions be able to encourage it to the exclusion of others, and obtain better results than at present. It will be necessary to revert to this subject when speaking of the bates used in preparing dressing-leather, which also owe their activity to putrid fermentation.

Beside merely soaking the hides, it is necessary to work them mechanically, to promote their softening, which was formerly accomplished by "breaking over" the hides on the beam with a blunt knife. This process is now usually superseded or supplemented by the use of the "stocks"; these consist of a wooden or metallic box, of peculiar shape, wherein work two very heavy hammers, raised alternately by pins in a wheel, and let fall upon the hides, which they force up against the side of the box with a sort of kneading action. The ordinary form of this machine is shown in Fig. 900. A more modern form, which seems to possess some advantages, is the American double-shover, seen in Fig. 901.

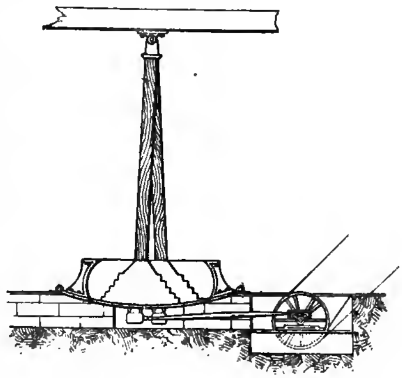
900.



The number of hides which can be stocked at once naturally varies with the size of both hides and stocks, but should be such that the hides work regularly and steadily over and over. The whole number should not be put in at once, but should be added one after another, as they get into regular work. The duration of stocking is 10–30 min., according to the condition and character of the hides. Hides should not be stocked till they are so far softened that they can be doubled sharply, without breaking or straining the fibre. After stocking, they must be soaked again for a short time, and then be brought into an old lime. A small quantity of sulphide of sodium added to the soaks or in the stocks has been recommended as of great value in softening obstinate hides, and probably with justice, from its well-known softening action upon cellular and horny tissues.

Unhairing.—In England, lime is the agent universally used for this purpose, though every tanner admits its deficiencies and disadvantages. It is hard, however, to recommend a substitute which is free from the same or greater evils, and lime has one or two valuable qualities, which will make it very difficult to supersede. One of these is that, though it inevitably causes loss of substance and weight, it is also impossible, with any reasonable care, totally to destroy a pack of hides by its use; this is by no means the case with some of its rivals. Another advantage is that, owing to its very limited solubility in water, it is a matter of comparatively small consequence whether much or little is used; and even if the hides are left in a few days longer than usual, the mischief, though certain, is only to be detected by careful and accurate observation. With all other methods, exact time and quantity are of primary importance, and it is not easy to get ordinary workmen to pay the necessary attention to such details. Again, the qualities of lime, its virtues and failings, have been matter of experience for hundreds of years, and so far as such experience can teach, we know exactly how to deal with it. A new method, on the other hand, brings new and unlooked-for difficulties, and often requires changes in other parts of the process, as well as in the mere unhairing, to make it successful. As our knowledge of the chemical and physical changes involved becomes greater, we may look to overcoming these obstacles more readily; this constitutes one of the main advantages of a really scientific knowledge over an empirical one.

901.



Slacked lime is soluble in water at 15° (60° F.) to the extent of 1 part in 778. Unlike most substances, it decreases in solubility at higher temperatures, requiring 972 parts of water at 54° (130° F.), and 1270 parts at 100° (212° F.). Its action upon animal tissues increases rapidly, however, with temperature, though no doubt it is moderated to some extent by the lessened solubility. Calculating from Dalton's numbers, pure lime-water at 15° (60° F.) contains 1·285 grm. of CaO per litre, and should require 459 cc. of decinormal acid to neutralize it. This estimate in some cases appears to be slightly too high; e. g. a saturated lime-water from carboniferous limestone at 13° (56·5° F.) required only 433 cc. of decinormal acid, which equals 1·211 grm. of CaO per litre, and this lime-water gave nearly constant results for many months together: on the other hand, any traces of other soluble bases would raise the strength of the lime-water above its normal amount. Thus a magnesian limestone lime-water tested at the same time required 472 cc. of $\frac{1}{10}$th normal acid, confirming the old observation of tanners, that such lime is stronger than that made either from chalk or carboniferous limestone. This increased strength must arise from the presence of some soluble base other than lime, and may be due to the magnesia, which, however, is very slightly soluble.

The action of lime on the hide has already been spoken of to some extent. This is throughout a solvent one. The hardened cells of the epidermis swell up and soften, the *rete malpighi* and the hair-sheaths are loosened and dissolved, so that, on scraping with a blunt knife, both come away more or less completely with the hair (constituting "scud," as some English tanners name it, Ger., *gneist* or *grund*). The hair itself is very slightly altered, except at its soft and growing root-bulb, but the true skin is vigorously acted on. The fibres swell and absorb water, so that the hides become plump and swollen, and, at the same time, the "cement-substance" (coriin) is dissolved, the fibres become differentiated into finer fibrils, and the fibrils themselves become first swollen and transparent, and finally corroded, and even dissolved. This swelling of the fibres is produced both by alkalies and acids, and is probably due to weak combinations formed with the fibre-substance, which have greater affinities for water than the unaltered hide. It is useful to the tanner, since it renders the hide easier to "flesh" (i. e. to remove the adhering flesh), on account of the greater firmness which it gives to the true skin. It also assists the tanning, by opening up the fibre, and so exposing a greater surface. This is advantageous only in dressing leather which is afterwards tanned in sweet liquors, and must have the cement-substance dissolved and removed for the sake of flexibility; but, in the case of sole-leather, it is probable that the same effect might be produced with less loss of substance and solidity by suitable acidity of the liquors. A more certain advantage of lime is that it acts on the fat of the hide, converting it more or less completely into an insoluble soap, and so hindering its injurious effects on the after tanning process, and on the finished leather.

The customary method of limeing is simply to lay the hides flat in milk of lime in large pits. Every day, or even twice a day, the hides are drawn out ("hauled"), and the pit is well plunged up, to distribute the undissolved lime through the liquor. The hides are then drawn in again ("set"), care being taken that they are fully spread out. Great differences exist in the quantity of lime used, the time given, and the method of working. Jackson Schultz prescribes 1 bush. (56 lb.) of fresh lime to 60–70 hides, and 3–4 days as sufficient time to unhair and plump them; while a well-known English tanner states that, after working for 6–10 days through a series of old limes, the hides (presumably wet-salted S. Americans) should have 4 days in a fresh lime, made with 3–12 lb. of lime per hide. It is obvious that if the American authority is right, the English process is wasteful in the extreme, both in hide-substance and lime. It is probable, however, that it would be found impossible to unhair and flesh hides, to suit the English market, in cold limes with the quantity and time mentioned, and if the limes are steamed, it is quite likely that the destructive action on the pelt may be even greater than by the longer and slower process in the cold. Most likely a compromise between the two is the most desirable, and about 2–4 lb. of lime per hide, according to weight, should be sufficient, while a week for market hides, and 14 days for heavy salted, will loosen the hair and plump the pelt as much as is requisite. This is on the supposition that the limes are kept at a uniform average temperature of about 15° (60° F.) in winter and summer. If they are heated to 27°–32° (80°–90° F.), of course much less time is required, but there are no published experiments showing the relative weights made by the two processes, and, from the fact that warmed limes are principally used for descriptions of leather where weight and solidity are not of primary importance, it may be concluded that, in this direction, the results are unsatisfactory.

Another undecided point is whether the best results are obtained by making fresh limes for every pack, or by strengthening up the old ones. An old lime becomes charged with decomposing animal matter and with ammonia, and, within limits, loosens the hair more effectually than a new one. An experienced tanner states that, by using old limes, better weights are obtained, but that the leather is thinner than when a fresh portion of lime is used, and this is quite in accordance with theory. If, however, the old lime-liquor be retained too long, it ceases to swell the hides as it should, and, in warm weather, the limeing proper is complicated by a putrefactive process allied in principle to sweating.

Several variations in the above-described method of limeing have been proposed. A well-known patent claims the plan of suspending the hides on laths, and agitating the liquor by plunging in place of hauling. Probably this is an actual improvement, especially if some mechanical agitating contrivance be substituted for hand plunging. It has, however, the drawback that much room is required, though this may be, to some extent, compensated by the hides limeing more quickly. As the method has been long in use in America, and had been tried in several places in England before the patent was obtained, it is not probable that it could be legally sustained, in this respect resembling a large proportion of the patents referring to leather manufacture. Two other American labour-saving methods in connection with limeing may be mentioned here. One is to have the limeing-vat double the ordinary size, and, instead of hauling the hides, to simply draw them from one side to the other by two strings, which are attached to the fore and hind shank of each hide. The strings are either looped over iron rods at the four corners of the pit, or have simple knots, which are placed in notches sawn in wood. Of course, while the hides are at one side of the pit, the other side may be plunged or warmed. The other method is to have a spindle with discs at each end, to which the hides or sides are attached by hooks set round the edges. The hides are wound up by turning the spindle with a handspike, and the whole spindle is also capable of being raised and lowered in the liquor.

An American plan, known as the "Buffalo method," is described by Jackson Schultz. The hide is prepared in the usual way, and is then thrown into a strong lime for 8–10 hours, when it is taken out and immersed in water heated up to 43° (110° F.), in which it remains 24–48 hours. The warm water soaks, softens, and swells the roots of the hair, and much the same result is obtained as in "scalding" pigs. So little lime really permeates the inner fibre that, after a slight wheeling, the hides may be thrown into cold water, and allowed to cool and plump, preparatory to taking their places in the handlers. The process is strongly recommended for sole-leather, particularly where great firmness of fibre is desired. The tanner who tries it must be satisfied if he gets 20–30 sides a man unhaired and fully ready for the liquor per diem.

On the Continent and in America, the prevalent mode of loosening the hair, at least for sole-leather purposes, is called "sweating," and consists in inducing an incipient putrefaction, which attacks the soft parts of the epidermis and root-sheaths, before materially injuring the hide-substance proper. The old European method of "warm-sweating" consisted simply in laying the hides in pile, and, if necessary, in supplying heat by covering them with fermenting tan; but as this crude and dangerous process is everywhere being supplanted by the American plan, where sweating at all is adhered to, it is not necessary to do more than describe the latter. This is called "cold sweating," but really consists in hanging the hides in a moist chamber, kept at a uniform temperature of 15°–21° (60°–70° F.).

The "sweating-pit" now in use is sometimes of wood, but usually consists of a building of brick or stone, protected from changes of temperature, both above and at the sides, by thick banks of soil or spent tan. If soil be used, it will form an excellent bed for vines, &c., which are fertilized by the ammonia penetrating from below. Though called a "pit," it is undesirable that it should be actually below the level of the ground; it should be arranged so that the hides can be wheeled in and out in barrows. It is lighted and ventilated by a lantern roof above a central passage, and should be divided into chambers, each capable of suspending a pack of hides. By means of sprinklers above and steam-pipes below, the chambers may be cooled or warmed, as required, and when working properly, the temperature should stand at 15°–21° (60°–70° F.), with globules of condensed water collecting on all parts of the suspended hides.

The process is principally used in America for dried hides, but may be employed either for wet or dry salted, after complete removal of the salt. It is imperatively necessary that dried hides should be completely softened before sweating. As the sweating process advances more rapidly in the upper than in the lower part of the pit, and as the thick portions are more resistant than the thin ones, the hides, after about 3 days' sweating, require constant attention in changing their positions, and in checking the forward ones by taking down and laying in piles on the bottom of the pit.

The usual treatment for sweated hides, when the hair is sufficiently loosened, is to throw them into the stocks, and work out in this way the slime and most of the hair. This has the disadvantage of working out too much of the dissolved gelatine, and of fulling the hair so firmly into the flesh, that it is difficult again to remove it. To overcome these evils, some American tanners now pass the hides, after sweating, through a weak lime. This, to a great extent, prevents the hair fixing itself in the flesh, and tends to counteract the injurious effect of the vitriol (which is almost invariably used in plumping sweat stock) on the colour of the leather. By this process, 10,000 Texas and New Orleans wet-salted hides gave an average yield of leather of 73 per cent. on their green weight, and the leather was excellent in quality.

It must be clearly understood that all sweating depends on partial putrefaction. This is proved both by the plentiful production of ammonia in the pits, and by the fact that all antiseptics, such as salt or carbolic acid, entirely prevent sweating till they are removed. Although the process undoubtedly has advantages, and especially so in the treatment of dried hides, it is an open question whether it gives the extreme gains over limeing in weight and firmness, which are claimed by some of its advocates.

An unhairing process, largely coming into use on the Continent, depends on the action of alkaline sulphides, and particularly sulphide of sodium, upon the hair. While all the methods already spoken of involve the softening and destruction of the hair-sheaths, either by lime or by putrefaction, the sulphides are peculiar in attacking the hair itself; when strong, they disintegrate it rapidly and completely into a sort of paste. From very early times, sulphide of arsenic ("rusma") mixed with lime has been used in unhairing skins. About 1840, Böttger concluded that the efficacy of arsenic sulphide was due simply to the sulphydrate of lime formed by combination of the sulphur with the lime, and proposed sulphydrate of lime, formed by passing sulphuretted hydrogen into milk of lime, as a substitute for the poisonous and expensive arsenic compound. This proved a most effective depilatory, but has never obtained much hold in practice. This is probably due to the fact that it will not keep, oxidizing rapidly on exposure to the air; hence it must be prepared as it is required, which is both troublesome and expensive. A minor objection is the unpleasant smell of sulphuretted hydrogen, which is inseparable from its use.

It was proposed to replace it by sulphide of sodium, which, though at first said to be only effective when mixed with lime, so as to produce calcic sulphide, has since proved a powerful depilatory alone. Its use has been greatly extended on the one hand by its production on a large scale, and in the crystallized form (presumably by reduction of sulphate by heating with small coal), and on the other, by the great interest which Wilhelm Eitner, the able director of the Austrian Imperial Research Station for the Leather Trades, has taken in its introduction. The substance, as manufactured by De Haen, of List, Hanover, is in small crystals, coloured deep greenish-black, by sulphide of iron, which must have been held in suspension at the time of crystallization. If the salt be dissolved in water, and the solution be allowed to stand, this is gradually deposited as a black sediment, leaving the supernatant liquor perfectly clear and colourless.

For sole-leather, the method recommended by Eitner is to dissolve 4–5 lb. of sulphide per gal. of water, making the solution into a thin paste (of soupy consistence) with lime or pipe-clay. This is spread liberally on the hair side of the hides, one man pouring it down the middle of the hide from a pail, while another, with a mop or cane-broom, rubs it into every part. The hide is then folded into a cushion, and in 15–20 hours will be ready for unhairing, the hair being reduced to a paste. In the writer's experience, the concentrated solution here prescribed will completely destroy all hair wetted with it in 2–3 hours, and if left on longer, will produce bluish patches, and render the grain very tender. The hides should be thrown into water before unhairing, to enable them to plump, and to wash off the sulphide, which is very caustic, attacking the skin and nails of the workmen. There is no doubt that this process gives good weight, and tough and solid leather; but there are several difficulties attending its use. Unless the mopping is done with great care, it will fail to completely destroy the hair, and the patches of short hair left are very difficult to remove. The expense of the material and the loss of hair are also important considerations. The hides will be very difficult to flesh, unless previously plumped by a light limeing, and it is generally considered necessary to swell the hides with acid before tanning, as the sulphide has but little plumping effect.

Another method, which is more generally adopted for dressing hides, is to suspend in a solution of sulphide of sodium, containing about ¾ lb. a hide; the hide is said to unhair in 24 hours. Very weak solutions loosen the hair, without destroying it; but it is always injured, as the specific action of the sulphides is on the hair itself. After unhairing, the hides may receive a light limeing, to plump them, or lime may be added to the solution of sulphide.

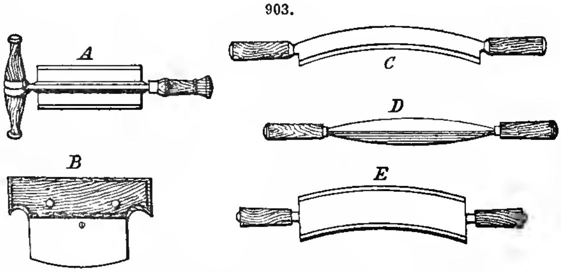
Various other depilatories have been proposed, but as they have not come into general use, brief mention of the most important will suffice. Anderson, in 1871, patented the use of wood-charcoal, applied in a similar manner to lime in the ordinary process. The hair was probably loosened simply by putrefaction, as in sweating, while the charcoal acted as a deodorizer. Caustic potash and soda will loosen hair, but seem to have no decided advantage over lime. They are more costly, and their corroding action on the hide-substance is more powerful. Squire, Claus, and J. Palmer, have all taken out patents for the use of tank-waste as a depilatory. It consists of impure sulphides of calcium, and when brought into the form of soluble sulphydrate, either by boiling in water, or, it is said, by the oxidizing action of the air, it will unhair hides. The conversion is, however, very imperfect in either case, and its action is uncertain and slow; while the iron present is apt to cause unsightly stains. It is probable that the weights obtained may somewhat exceed those by limeing. Palmer employs sulphuric acid to plump the hide and remove stains, and then reduces it by a bate of whiting and water. He claims that this prepares the hide for rapid and heavy tanning, but the swelling and subsequent reduction almost certainly entail loss of weight and quality.

902.

Whatever method of loosening the hair may be adopted, the next step is to remove it by mechanical means. This is usually accomplished by throwing the hide over a sloping beam, and scraping it with a blunt two-handled knife (Fig. 902), the workman pushing the hair downwards and away from him. The beam is now usually made of metal. The knife employed is also shown at C, Fig. 903.

When a hide is lightly limed, it is often easy to remove the long hair, but excessively difficult to get rid of the short under-coat of young hairs, which are found in spring, and which can sometimes only be removed by the dangerous expedient of shaving with a sharp knife. The reason of this difficulty is obvious: not only do the short hairs offer very little hold to the unhairing knife, but, as has been explained in describing the anatomical structure of the skin, their roots are actually deeper seated than those of the old hairs they replace. Several attempts have been made to unhair by machinery, but so far without such success as to lead to their general adoption. The fleshing-machine invented by Garric and Terson, and manufacured in this country by T. Haley and Co., of Bramley (Fig. 904), is furnished with a special wheel for unhairing. An American machine for the purpose, invented by J. W. Macdonald, and said to be capable of unhairing 800 sides a day, is shown in Fig. 905.

903.



When the hair is very thoroughly loosened, as by sweating, or destroyed, as by sulphide of sodium, it is not uncommon to work it off by friction in the stocks; but it is very doubtful whether the saving of labour is not more than compensated by the loss of weight, consequent upon submitting the hide, while its gelatine is in a partially dissolved condition, to such rough usage.

After unhairing, the loose flesh and fat are removed from the inner side of the hide by a sharp-edged knife E (Fig. 903), partly by brushing or scraping, partly by paring. It is necessary not only to cut off the visible adhering fat, but to work the hide well, so as to force out that contained in the loose areolar tissue, which would not only impede tanning, but is liable to soak completely through the hide, producing most unsightly blotches. Several machines have been introduced to supersede hand-fleshing, but with only partial success. One of the best is Garric and Terson's machine (Fig. 904), which gives a very level flesh, free from galls, and without so much loss of weight, but

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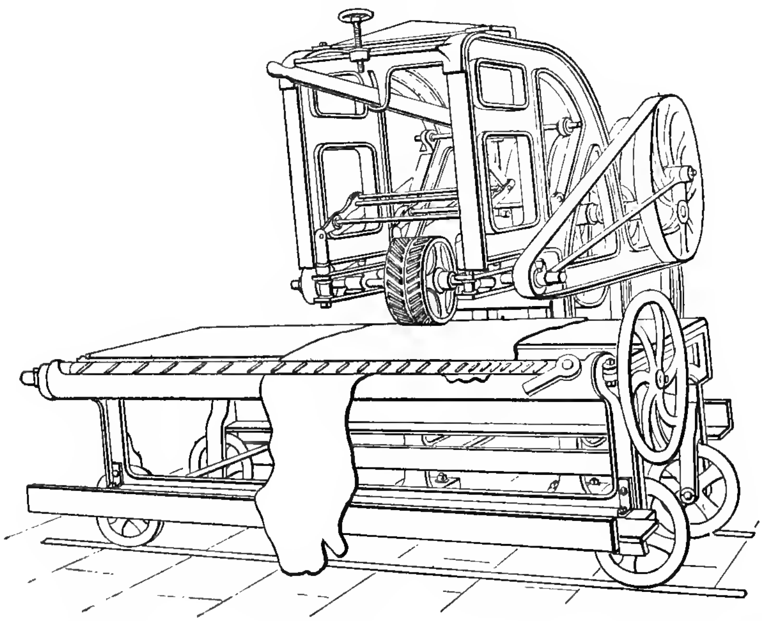
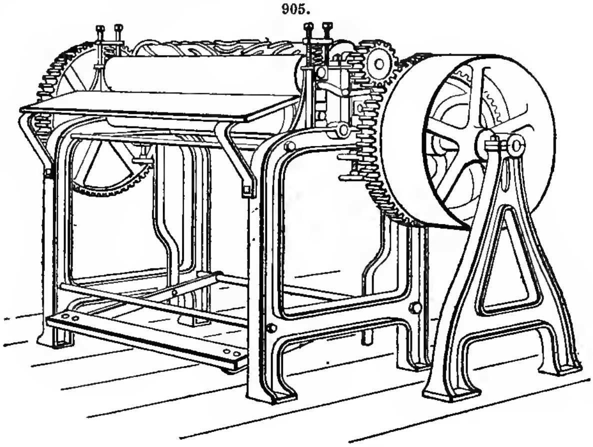


scarcely so clean as desirable, while the saving in labour is not great. Molinier's machine (Fig. 906), and that of Jones and Rocke, are well adapted for skins, but hardly capable of fleshing an entire hide. All these machines are very similar in principle, the working parts consisting of drums with oblique or spiral knives.

When unhaired and fleshed, the hides intended for sole-leather, are, in England, almost invariably "rounded," or separated into (1) "butts," which are the best and thickest parts, and receive the most solid tannage, and (2) "offal," which is thinner, and for which a cheaper and more rapid tannage is sufficient. Fig. 907 shows the customary division. Frequently the butt is divided down the centre, and the halves are then called "bends." A piece called a "middle" is sometimes taken between the butt and the shoulder.

905.



After rounding, it is necessary to get rid of the lime, as completely as possible, before taking into the tan-house. For this purpose, the butts are usually suspended in fresh water for 12–24 hours, and frequently shaken up in it to remove adhering lime and dirt. If the water is hard, it is best to add to it, before putting in the butts, a few pailsful of clear lime-water, to precipitate the acid carbonate of lime, which would otherwise cause a deposit of chalk on the surface of the butts; this would not only make the grain harsh, but afterwards, by combining with the tannin of the liquors, would cause bad colour. For the same reasons, it is important that limey hides should be as little exposed to the air as possible, as the latter always contains a small amount of carbonic acid, which renders the lime insoluble.

This suspension in water is generally considered sufficient for sole-leather, but it removes the lime very imperfectly. In olden days, it was customary not only to wash the hides much more thoroughly in water, but to "scud" them (i. e. work them over with a blunt knife), to remove lime, and the detritus of hair-roots and fat-glands. This is now frequently omitted from sole-leather treatment, but no doubt leads to a more complete removal of the lime.

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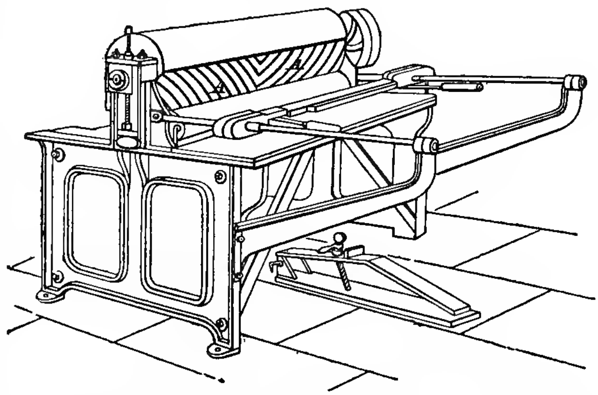

Tanning Materials. — Before describing the management of the hides in the tan-house, it is necessary to say a few words about one or two of the principal materials used, and the methods of preparing them. Further details of their nature and origin will be given in the article on Tannin.

Oak-bark is one of the oldest of tanning materials, and the leather produced by its aid is still considered for many purposes the best. For sole-leather, its weakness in tannin (8–12 per cent.), the slowness of its action, and the light weight of the leather produced, render it unavailable alone except for the very finest class of work. It is, however, generally used in admixture with stronger and cheaper materials, such as valonia.

Valonia, the acorn-cup of an evergreen oak growing in Greece and the Levant, is perhaps the most important of materials to the sole-leather tanner. It contains 25–35 per cent. of a tannin somewhat similar to oak-bark, and, like it, communicating a light-coloured bloom to the leather, but giving much greater firmness and weight, and a browner colour.

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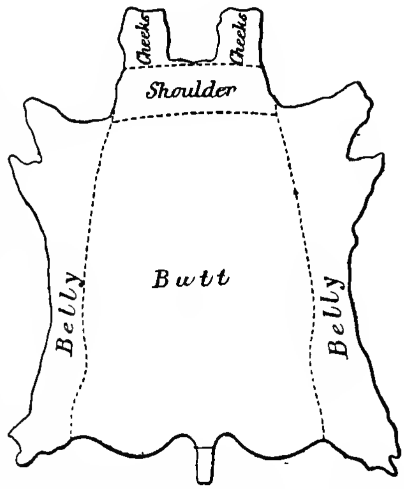


Myrabolanes or myrobalams, the fruit of an Indian shrub, contains about as large a percentage of tannin as valonia, and gives a similar bloom, and excellent colour; but it can only be used very sparingly on butts, since it produces a soft and porous leather.

Divi-divi is a S. American bean, which contains much of a brown tannin in the pod, being considerably stronger than valonia. It makes a heavy and solid but somewhat horny leather. Its great danger arises from a tendency to sudden fermentation, which produces brown or red stains on the leather.

Mimosa-bark is the product of several Australian acacias, and is probably nearly as strong as valonia. It gives a hard and heavy leather, but of a dark-red colour.

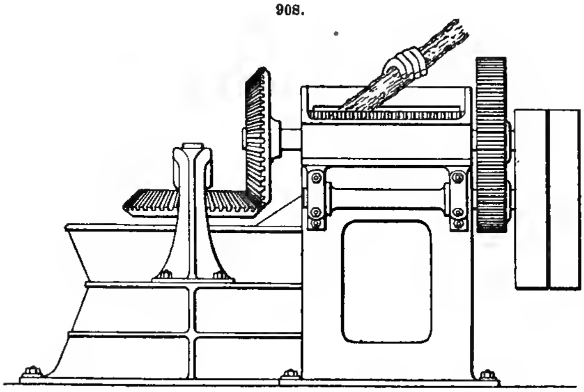
Hemlock-extract is a deep-red syrupy extract of the bark of the hemlock pine of America.

Chestnut-extract is a similar product from the rasped wood of the Spanish chestnut. Its colour is paler and yellower than that of the hemlock, and hence it is often employed to correct the red tone produced by the latter.

Grinding and Exhaustion of Tanning Materials.—Before tanning materials can be exhausted, it is almost invariably necessary to crush or grind them, so as to enable the water to get freely at the tannin, which, in most cases, is enclosed in the cellular tissue of the plant. It may be thought that for this purpose it would scarcely be possible to crush too finely, but in practice, a very fine powder is extremely difficult to spend, as it cakes into compact and clay-like masses, through which liquor will not percolate. The object, therefore, is to grind finely enough to allow the liquor ready access to the interior, but not so finely as to prevent liquids running through the mass. The mill most usually employed for this purpose consists of a toothed cone, working inside another cone, also toothed on its interior, precisely like those of a coffee-mill. As bark is frequently delivered "unhatched," or in long pieces, it is necessary to crush it preparatory to grinding, and this is usually accomplished by rollers composed of toothed discs, called breakers. In Fig. 908 is illustrated such a mill, as made by Newall and Barker, of Warrington, combining both utensils. Fig. 909 shows a section of the well-known American "keystone" mill, in which the preliminary breaking is accomplished by the arms A; the bark is then finely ground by the toothed cones N, and discharged at the spout R by the revolving shover M.

Now that a large variety of other materials besides bark are required by tanners, the mill just described is not always sufficient for the purpose. Myrobalams and mimosa-bark have proved specially troublesome, the former from its very hard stones and clogging character, and the latter from its combined hardness and toughness. "Disintegrators" of various makes have proved admirably adapted for grinding both of these materials, their advantage being the universality of their reducing powers, ranging from oak-bark to bones or brick-dust, and their disadvantages, the somewhat considerable power they consume, and the rather large portion of fine dust they make. Their principle is that of knocking the material to powder by rapidly revolving beaters, which, in the smaller mills, are driven at so high a speed as 2500 rev. a minute. Wilson's is shown in Fig. 910, as an example. It is one of the oldest tanners' disintegrators, and probably still one of the best. In the figure, it is opened, showing the disc with its steel beaters attached. When myrobalams are only required roughly crushed, a machine with fluted rollers (Fig. 911) acts better than a disintegrator, making less dust, and requiring less power.

908.



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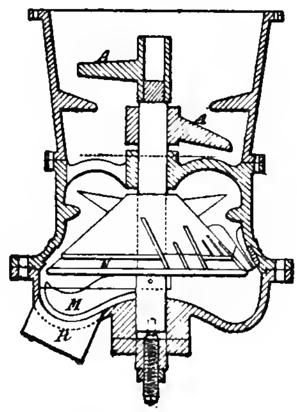

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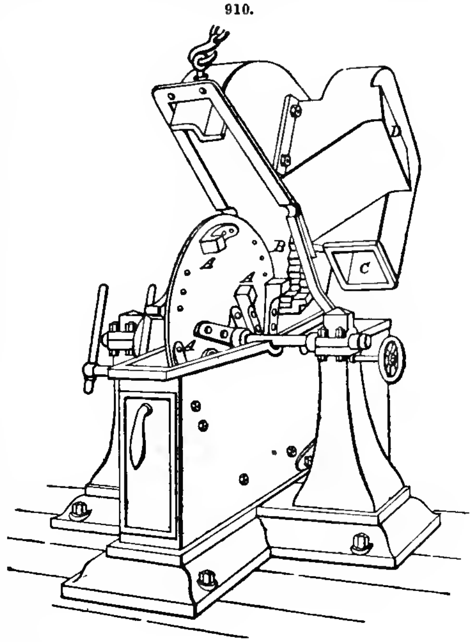

In England, the tanning material is generally carried from the mill, to the pits where it is exhausted, in baskets or barrows; in America, this is frequently accomplished by a "conductor," or horizontal spout, in which a double belt with wooden cross-pieces carries the bark forward, on the same principle as the elevators of corn-mills. Another American plan is to use circular tubs for extraction. These are mounted on wheels, and are worked on a railway, coming up to the mill to be filled, and thence under a series of sprinklers like those used by brewers, and finally "dumping" their contents before the boilers, which are heated solely by the wet bark, burnt in a peculiar furnace with brick chambers. This furnace for burning wet bark seems worthy of extended adoption in Europe, as spent tan is frequently not only valueless, but costly to get rid of. Full details and scale drawings may be found in Jackson S. Schultz's book on 'Leather Manufacture,' and in Fig. 912, is shown a modification of it, patented by Huxham and Brown, which has been very successfully used in burning wet tan, either alone or with a portion of coal. In American sole-leather tanneries, where the bark is resinous and almost unlimited in quantity, sufficient steam may be raised with tan wet from the lecks; but in England, where material is more sparingly used, it is advisable partially to dry it before burning. This is accomplished by powerful roller-presses, as shown in Fig. 913.

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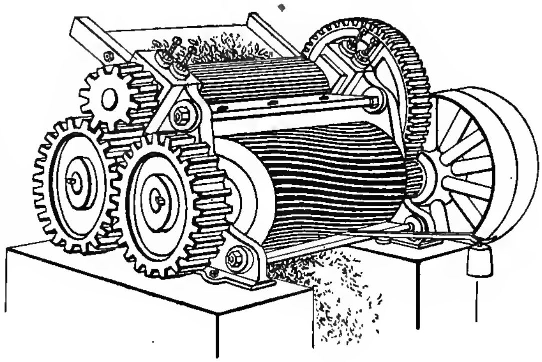

In England, the tanning material is usually exhausted in pits called "lecks," "latches," or "taps." These, in large yards, are made capable of holding about 50 cwt. of material. The new material is first flooded with a pretty strong liquor. When this has gained as much strength as possible, it is pumped off, and is followed by a weaker one, and so on till the material is exhausted. Much of the economy of a tan-yard depends on the way, systematic or otherwise, in which this is done. It is customary to complete the exhaustion with hot liquors, or water, but opinions differ on the expediency of the practice. By the use of heat, however, stronger liquors and more rapid spending are attained; and with some materials, such as mimosa, complete exhaustion is impossible in the cold. Careful tanners also cast their material over from one pit into another, before throwing away, so as to lighten it up, and allow the liquor to penetrate to every part. In bark-yards, latches are frequently worked in series, which are connected by pipes, so that the liquor flows from the bottom of one upon the top of the next stronger. This is an excellent plan for bark, which is open and porous, but is scarcely adapted to such materials as valonia or myrabolams, which have a tendency to form compact masses, through which the liquor does not circulate. The same objection, in an almost higher degree, must be urged against the Allen and Warren, or sprinkler leck, in which the liquor, distributed on the surface by a rotary sprinkler, is allowed to percolate downwards, and run freely away at the bottom. In this case, it is almost sure to form channels, instead of flowing uniformly, and, in addition, the material is constantly exposed to the action of the air, which causes fermentation, with its attendant discoloration and loss of tannin.

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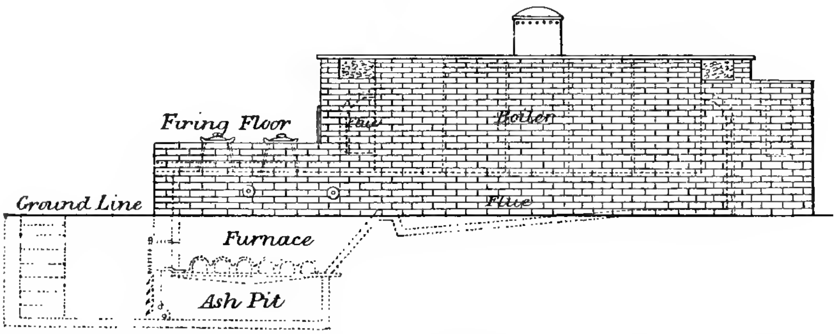

It is one of the great attractions of extracts that they avoid almost all the expense and labour inseparable from the exhaustion of other tanning materials. It is usually necessary to dissolve the fluid extracts in water or liquor of as high a temperature as has been employed in their preparation, as otherwise, from some unexplained chemical change, a large portion of the tannin is precipitated. Gambier is usually dissolved by boiling or steaming, but is said to give a better colour when dissolved cold. This may be accomplished in a rotating latticed drum, sunk in a pit of liquor.

Construction of Tanneries.—The old-fashioned method of sinking pits is to make them of wood, and carefully puddle them round with clay, which should be well worked up before use. Loam mixed with water to the consistence of thin mortar may also be employed, the pits being filled up with water, to keep them steady, at the same rate as the loam is run in. Probably the best materials for pit-sides are the large Yorkshire flagstones. Where these are not attainable, very durable pits may be made of brick, either built with Lias lime, and pointed with Portland cement, or built entirely with the latter. Common lime cannot be used, as it spoils both liquors and leather; and even cements with too large a percentage of lime are unsatisfactory. Brick and common mortar are, however, suitable for lime-pits. If possible, both latches and handler-pits should be provided with plugs and underground pipes, communicating with a liquor-well some feet below their levels. Glazed fireclay is very suitable both for pipes and plug-holes, which should be in the pit-corners. Iron should, as far as possible, be avoided wherever it can come into contact with liquor, as it discolours the leather.

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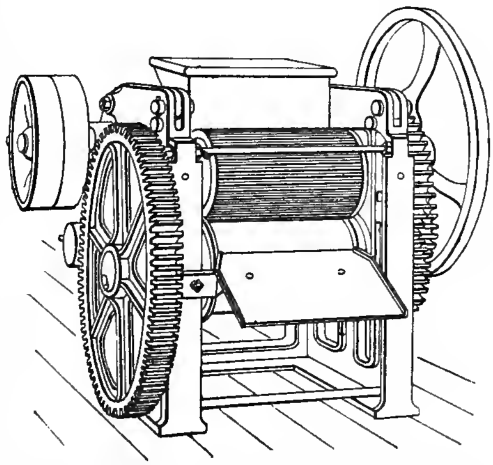

Management of Sole-leather in the Tan-house.—After suspension in water, the hides are usually taken at once into weak tan-liquors; but occasionally they are treated with dilute acids before the actual tanning, both to remove the lime still remaining in the pelt, and to plump them. If the sole object be the former, hydrochloric acid is probably the most suitable, since the calcic chloride formed is very soluble, and, in small quantities, hydrochloric acid has not the bad effect, often produced by sulphuric, of causing a dark layer to form immediately beneath the grain during tanning. If acid is to be used for plumping, it is, no doubt, best to use it mixed with the early liquors, where its influence is modified and restrained by the tannin; but it seems probable that, where lime is used for unhairing, the fibre is sufficiently opened up by this agent to receive the tanning, and that, in a well-managed yard, the natural acids of the liquors are sufficient, in conjunction with suitable tanning materials, to give the hides all the weight and substance of which they are capable.

On first coming into the yard, the butts are usually suspended by the necks from sticks placed across the pits. They should be kept in almost constant movement, either by raising and shaking them by hand, or by supporting them on frames, which are rocked, or otherwise worked. Perhaps the best device for this purpose is the "travelling handler" of W. N. Evans, which consists of a frame supported on wheels, and worked slowly backwards and forwards by power. This frame should extend the length of a range of pits sufficient to take in at least a 3 days' stock of butts, which should be tied by the neck end to sticks resting crossways upon it. It should have a stroke of 1–2 ft., repeated, say 6 times a minute.

The suspender pits should be supplied with old handler liquors, which, if the tannage is a mixed one, may range from 12°–16° barkometer, as a large proportion of the weight consists only of lime-salts, gallic acid, and other worthless products. If the tannage is pure bark, it may perhaps be advisable to let the strength be somewhat less, but something depends on whether the exhausted liquors are returned with all their impurities to the "taps" or liquor-brewing pits, or whether the liquors are made with water, and hence purer. In any case, the free acid in the suspenders should always be sufficient in quantity to neutralize the lime brought in by the butts, or bad colour will certainly result, making itself visible in the shed, or as the tanning proceeds. If the butts, when first brought into liquor, take a lemon-yellow colour, especially in places that have been imperfectly exposed to it, this is an indication of danger which must not be disregarded. It may be met either by cleansing the butts more thoroughly before bringing into the yard, or by adding acid (acetic, hydrochloric, or sulphuric) to the liquor. It can, however, often be remedied, either by altering the way of working the liquors, so as to bring more sour liquor down to the suspenders, or by using a larger proportion of materials capable of yielding acetic acid by fermentation, such as myrobalams. It is a common error to call all the free acid of sour liquors "gallic," as this is not even present in pure bark-yards, and at the best is a feeble acid, scarcely reddening litmus, or capable of swelling hides. The most abundant acid is usually acetic, though butyric, lactic, and other acids are frequently present. It must here be explained that the barkometer (also called "barkrometer" or "barktrometer") is a hydrometer, graduated to show the sp. gr. thus—20° Bark. = 1·020 sp. gr.

The butts should at first be brought into the weakest liquor; a circulation system, by which the liquors are all pumped in at one end of a set of suspenders, and run out at the other, the butts being moved forward in the opposite direction, seems to have much to recommend it. In this case, the top of one pit should be connected by a wooden box with the bottom of the next.

It is usually advisable to run away the first liquor into which butts are brought from the lime-yard, as it is very completely spent, and highly charged with lime salts and impurities. Whether other exhausted liquors are to be retained or rejected is largely a question of climate, and mode of working. In hot weather, such liquors, charged with organized ferments (moulds, *bacillus*, and *bacteria*), are apt to cause ropiness, and other fermentive diseases of the liquors. This danger may be lessened by boiling all spent liquors, so as to kill the ferments, before running on the taps, or prevented by the free use of antiseptics, such as carbolic acid. Small doses of carbolic acid, however, are useless; at least $\frac{1}{10}$ per cent. must be employed.

The suspender liquors should be acid enough freely to redden litmus-paper. H. R. Procter has published a simple and instructive volumetric method for the determination of the free acid: 10 cc. of the carefully filtered liquor is placed in a beaker, and clear lime-water is run in from a burette till permanent cloudiness is produced. The quantity of lime-water employed is that which the acid is capable of neutralizing, without producing discoloration of the leather, and care must be taken that the lime introduced with the butts does not exceed this proportion. The explanation of the reaction is that dark-coloured tannates of lime are formed, which are dissolved by the free acid so long as it remains in excess.

From the suspenders, the butts are transferred to the "handlers," where they are laid flat in the liquor. The handlers are generally worked in sets, to each of which a fresh liquor is daily run, and the most forward pack is pulled over into it, and is often also dusted down with a little fine bark or myrabolams. The second pack follows into the liquor out of which the first has been taken; the third into that of the second, and so on. Frequently the greenest packs are handled up a second time in the course of the day, and put down again in the same liquor. The strength of liquors, and the length of time for which butts are retained in the handlers, are varied; but a time of 1–2 months, and liquors of 20°–35° are usual. A little gambier may be appropriately used in the liquors.

At the end of this period, the butts are taken to the "layers" or bloomers, in which they are laid down with stronger liquors and much larger quantities of "dust"; the latter is usually bark or valonia, though mimosa is occasionally used. The liquors vary from 40°–60° or 70° in strength in mixed tannage, and the duration of each layer from 10 days in the earlier stages to a month in the later ones. For the best heavy tannages, 6–8 layers are required. Each time the butts are raised, they should be mopped on the grain, to remove dirt and loose bloom. In pure bark tannage, which, however, is gradually becoming extinct, the liquors used are of necessity much weaker, as it is extremely difficult to obtain liquors of more than 25°–30° from this material. The last layer, however, should always have liquors of the greatest strength which can possibly be obtained, or the leather will be deficient in firmness.

The great point to aim at, in arranging the mode of work of a tannery, is to contrive that butts should always receive the strongest liquors they can bear with safety, and that the strength should constantly increase in a regular and systematic way. To attain this end, very frequent handling and change of liquor are requisite in the early stages, when the butts rapidly absorb the tannin presented to them. As the process advances, the exterior part of the butt becomes thoroughly tanned, and the liquor only slowly reaches the interior, which is yet susceptible of its action, and hence longer layers in stronger liquors are permissible.

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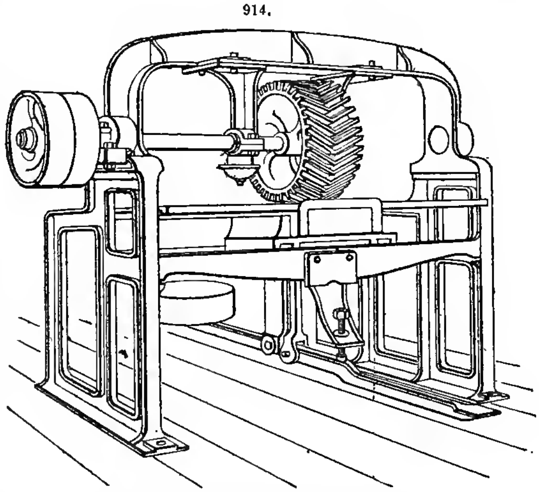
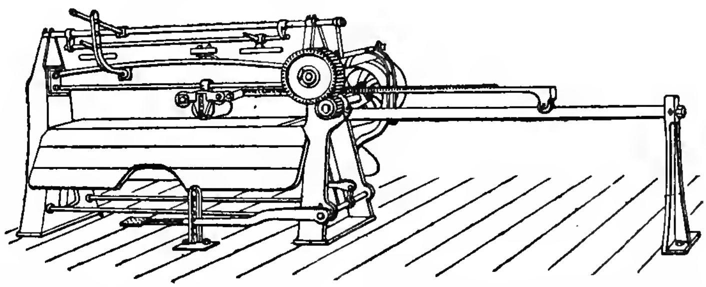


The varied requirements of the trade render it difficult to give any practical information as to selection of tanning materials. As a general rule, it is important at the outset to give the required colour; and if materials undesirable in this respect are to be used for the sake of cheapness, they should be introduced in the form of liquors in the middle stages of the process, i.e. in the later handlers or earlier layers. Materials used as dust generally have more effect in producing bloom and colouring the leather, than those used in liquors at this stage. Some information as to the respective qualities of the different tanning materials will be fond in the article on Tannin; but even practical men are very deficient in accurate information on these points, since many materials are never used alone, but invariably in connection with others which mask their effects.

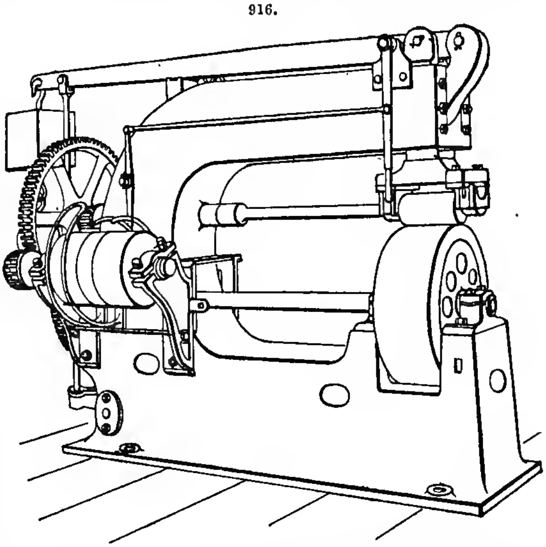
The use of extracts, and the demand for low-priced leathers, to compete with the American tannages, has introduced still more rapid methods than those described, and very fair-looking heavy leather has been tanned in 5–10 weeks. These tannages are very various, but their main feature is the free use of hot liquors, composed principally of extracts and gambier. This treatment imparts great firmness, or more properly speaking, hardness; but the leather is deficient in toughness, and the grain usually cracks on bending sharply. Extract properly used is, however, capable of making excellent leather.

Treatment of Sole-leather in the Shed.—The butts, after being well mopped on both flesh and grain in a clear liquor, are taken into the drying-lofts, where they are hung on poles till about half dry. They are then laid on the floor in piles, and covered up till they heat or "sweat" a little, which facilitates the succeeding operation of "striking." This is performed by laying the butt over a horizontal "beam" or "horse," and scraping its surface with a triangular pin, shown at D in Fig. 903. This pin has an even, though tolerably sharp, edge, and is so used that it stretches and smooths out the grain, without breaking it; at the same time, it removes a portion of the white deposit called "bloom," which has been mentioned. Common goods are frequently struck by the machine introduced by Priestman, of Preston Brook, shown in Fig. 914; but the work is not very uniform, and the leather is much compressed and stretched. After a light oiling and a little further drying, the butt is laid on a flat "bed" of wood or zinc, and is rolled with a brass roller loaded with heavy weights. Various machines are also in use for this purpose. In Fig. 915, is shown a roller adapted for rolling butts, in which the pressure is produced by springs immediately above the roller, which works backward and forward over a flat table. Fig. 916 represents a machine in which the roller is fixed, and works over a brass drum; it is specially adapted for offal, and, when used for butts, is apt to make them "baggy." In both these machines, the reversing motion is obtained by using two belts, one being crossed. The leather is now frequently coloured on the grain with a mixture, for which each tanner has a recipe of his own, in order to hide uneven or dull colour, and, when sufficiently dry, is rolled a second time, and dried-off in a room gently heated by steam. This is the Bristol method of finishing. In the Lancashire district, butts are generally struck out much wetter, and "stoned," so as to remove the whole of the bloom, and show the natural brown "bottom" of the grain. When sufficiently dry, they are struck a second time, to set the grain, and rolled as described, the painting being omitted. This method has the disadvantage of requiring more labour, and causing a loss of weight; but leather so got up brings a higher price, as the method is only applicable to such tannages as make a fair colour.

915.



916.

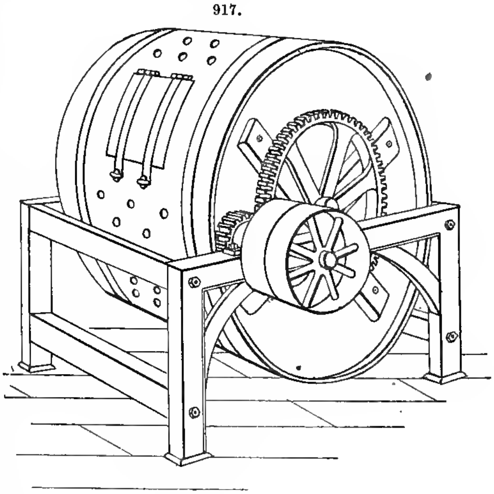


It is very important, and especially so with heavy mixed tannages, that the drying should be conducted in the dark, and not too rapidly. No artificial heat should be used, except in frosty weather, to wet leather; and it should be carefully protected from harsh drying winds. After the leather is finished, it should be dried-off in a well-ventilated drying-shed, heated to about 21° (70° F.). The same observations apply to the drying of rough dressing-leather, except that artificial heat should be avoided. Frost makes dressing-leather porous, and prevents its carrying a proper quantity of grease in currying.

Tannage of Dressing-leather. Common, and Shaved Hides.—Hides which are intended for purposes where softness and flexibility are required, as for instance, for the upper-leathers of boots, and for saddlery purposes, are called "dressing" or "common" hides, or, if they are shaved down to reduce their thickness before tanning, they are denominated "shaved" hides. Hides for this purpose are limed much in the same way as has been described for butts; but if they are required very soft and flexible, a somewhat louger limeing is permissible. After unhairing, fleshing, and washing in water, they are usually transferred to a "bate," composed of pigeon- or hen-dung, in the proportion of about 1 peck to 25–30 hides.

In this they are retained for some days, being handled frequently. They completely lose their plumpness, and become soft and slippery; the caustic lime is entirely removed; and the remaining portions of hair-sheaths and fat-glands are so loosened that they are easily worked out by a blunt knife on the beam. This final cleansing process is called "scudding." The theory of the action of the "bate," or "pure," as it is sometimes called, is somewhat imperfect. It is frequently attributed to the action of ammonia salts, and phosphates, contained in the fermenting dung. Ammonia salts certainly will remove caustic lime, but, in this case, free ammonia is liberated in its place, which is just as powerful in swelling the pelt, and hence will not account for the rapid reducing effect; while the phosphates of dung are mostly, if not entirely, in the form of phosphate of lime, which is quite inert. In point of fact, the process seems to be a fermentive one, the active bate swarming with *bacteria;* to this, rather than to its chemical constituents, its action must be attributed. The *bacteria* act not only on the organic constituents of the dung, but on those of the hide, producing sulphuretted hydrogen, together with tyrosine aud leucine, and other weak organic acids, which neutralize and remove the lime, and, at the same time, soften the hide by dissolving out the coriin, and probably also portions of the gelatinous fibre. The truth of this theory is supported by the fact that, in warm weather, the activity of the bate is greatly increased, and that, if one pack of hides is over-bated, the next following is much more severely affected, the hides having in fact themselves furnished food for the multiplication of the bacterian ferment from the destruction of their own tissues. It also explains the effective use (as a substitute) of warm water with a very small portion of glucose, which, in itself, would be insufficient to dissolve the lime, but with a small quantity of nitrogenous matter, forms an excellent *nidus* for the multiplication of these organisms. In this connection, may be mentioned the fact that, when bran drenches are used, in which lactic acid is developed, the butyric fermentation is liable, in hot weather, to take its place, and as butyric acid is a powerful solvent of gelatinous tissue, and the dissolved tissue itself feeds the fermentation, rapid destruction of the skins is the result.

917.



If the removal of the lime be the only object aimed at in bating, the ordinary process is most wasteful, as well as disgusting, from the loss of pelt it entails. It is easy to find chemical reagents which will remove the lime; but the resultant leather has been found wanting in softness, and it is probable that the solution of the intercellular matter is in many cases advantageous.

The bating required may, however, be shortened, and probably with advantage, by washing the hides with warm water in a "tumbler," or rotating drum, Fig. 917, prior to putting them into the bate, or the whole bating may be done in the tumbler. After a short bating, also, the hides may be softened and cleansed by stocking for 15–20 minutes.

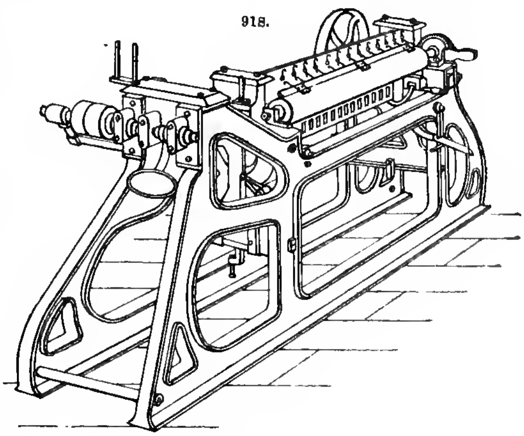
Various machines have been proposed to take the place of hand-labour in the beam work, and, at least as regards the smaller skins, with considerable success. As a type of these, may be mentioned

Molinier's hide-working machine, Fig. 906, which consists of a drum covered with helical knives, rotating at a speed of about 500 rev. a minute, over a cylinder coated with indiarubber. The skin is allowed to be drawn in between these drums, and the two being pressed together by a treadle, it is drawn out by a mechanical arrangement in a direction contrary to the rotation of the knives, which scrape off the flesh, or work off the hair.

After bating, "shaved" hides are reduced in thickness in the stronger parts by a shaving-knife, on an almost perpendicular beam. The workman stands behind the beam, and works downwards. The knife is represented at A, Fig. 903, and is a somewhat peculiar instrument. The blade is of softish steel, and after sharpening, the edge is turned completely over by pressure with a blunt tool, so as to cut at right angles to the blade. There is an obvious economy in shaving before tanning, since the raw shavings are valuable for glue-making, while, if taken off by the currier, they are useless for this purpose. The hide also tans faster.

Instead of shaving, the untanned hide is frequently split, by drawing it against a rapidly vibrating knife. The piece removed is tanned for some inferior purpose, if sufficiently perfect. In sheep-skins, which are split by a special machine, the grain-side is tanned for French morocco or basil, while the flesh-side is dressed with oil, and forms the ordinary chamois or wash-leather. Such a machine is shown in Fig. 918.

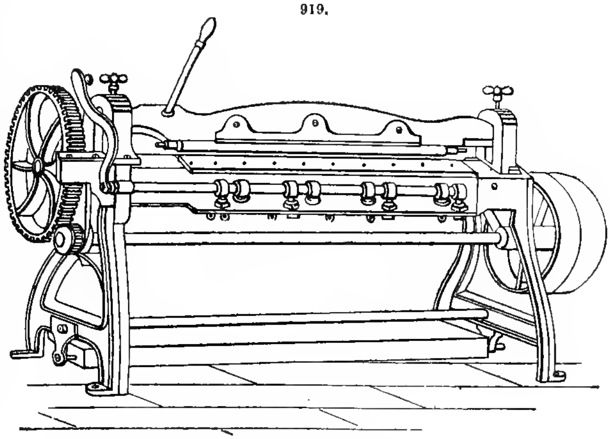
918.



Tanned leather is usually split by forcing it against a fixed knife, as in the American "Union" machine, Fig. 919.

After bating, scudding, and shaving, the hides are taken into the tan-house, where they are grained, either by frequent handling, or by working in a paddle-tumbler (a vat agitated with a paddle-wheel), with a liquor of suitable strength. What this strength should be depends on whether a well-marked grain is required or not. The stronger the liquor, the more it contracts the hide, wrinkling the surface into a network of numberless crossing furrows, which form the well-known marking of "grain-leather." In bark tannage, the after management is much like that described with sole-leather, except that weaker infusions are employed, and acid liquors, which would swell the hide and produce a harsh leather, are avoided. In old-fashioned country yards, which produce some of the best bark-tanned shaved hides, the liquors rarely range above 10°–15° of the barkometer, and the time employed is 3–6 months. The hides, after passing through a set of handlers, of gradually increasing strength, in which they are at first moved every day, are laid away with bark liquor and layers of fresh bark, receiving perhaps 4–5 layers of 2–4 weeks each. Unfortunately, these tannages are so unprofitable that they are rapidly being supplanted by quicker and cheaper methods.

919.



These more rapid and cheap tannages mostly depend on the use of "terra" (block or cube gambier) in combination with bark, valonia, or myrabolams. Liquors warmed to 43° or even 60° (110°–140° F.) are employed, and a bright colour is finally imparted by handling in a warm sumach or myrabolams liquor, which dissolves out much of the colour imparted by terra or extracts. The tannage is helped forward by frequent handling, by working in tumblers, or sometimes by suspension on rocking or travelling frames, after the American fashion.

To this class of tannage belongs that of E. India kips, which is largely carried on in the neighbourhood of Leeds. These kips are the hides of the small cattle of India, and are imported in a dried condition, and with their flesh side protected (and loaded) with a coat of salt and whitewash or plaster. They are usually softened in putrid soaks, and unhaired with lime, and are used in England for many of the purposes for which calf-skins were formerly employed. A variety of E. India kips, called "arsenic kips," are treated (instead of plastering) with a small quantity of arsenic before drying, to prevent the ravages of insects, which are often very destructive to these goods. Many kips tanned in India have also been imported of late years, and have greatly interfered with the profits of English tanners.

Drying Upper Leathers.—In yards where the leather is intended to be sold uncurried, it is taken up into the drying-sheds, well oiled on the grain with cod-liver oil, and either simply hung on the poles to dry, or stretched with a "righter," a tool shaped somewhat like a spade-handle, and finally set out with it to a smooth and rounded form. It is, however, now very common for the tanner who produces such leather also to curry it, and, as this effects a considerable economy, both in labour and material, it is likely to become universal. When leather is to be sold rough, it is necessary to tan it in such a way as to give it a white appearance, from the deposit of "bloom" already mentioned, this being regarded by curriers as an essential mark of a good tannage, although the first step in the currying process is to completely scour it out. When the tanner curries his own leather, he of course aims at putting in as little bloom as possible, thus saving both tanning material and labour. In addition, the leather goes direct from the tan-house to the currying-shops, thus saving both drying and soaking again, and, it is said, gives better weight and quality. The tanner, too, is enabled to shave his hides or skins more completely, utilizing the material for glue-stuff, which, had the leather been for sale in the rough, must have been left on to obtain a profitable weight.

Currying.—In general terms, the process of currying consists in softening, levelling, and stretching the hides and skins which are required for the upper-leathers of boots, and other purposes demanding flexibility and softness, and in saturating or "stuffing" them with fatty matters, not only in order to soften them, but to make them watertight, and to give them an attractive appearance.

It is obvious that great differences must be made in the currying process, according to the character of the skin and the purpose for which it is intended, since the preparation of French calf for a light boot, and of the heaviest leather for machine belting, equally lie within the domain of currying. In this case, however, as in that of tanning, the clearest idea of the general principles involved will be gained by taking a typical case, and afterwards pointing out the different modifications needed for other varieties. The French method of currying waxed calf is selected as an example, since the well-known excellence of this leather makes it interesting to compare the details with the methods ordinarily in use in this country.

After raising the skins from the pits, and beating off the loose tan, they are hung in the sheds till partially dry (*essorage*), great care being taken that the drying is uniform over the whole skin. In modern shops, this drying is usually accomplished at once, and in a very satisfactory manner, by means of a hydraulic press. If dried in the air, they must be laid in pile for a short time to equalize the moisture, and then brushed over on flesh and grain. The next process consists in paring off loose flesh and inequalities (*dérayage*). This is done on a beam, and with a knife similar to that used in bate-shaving, and shown in A, Fig. 903. This knife has the edge turned by rubbing with a strong steel, and is called *couteau à revers*.

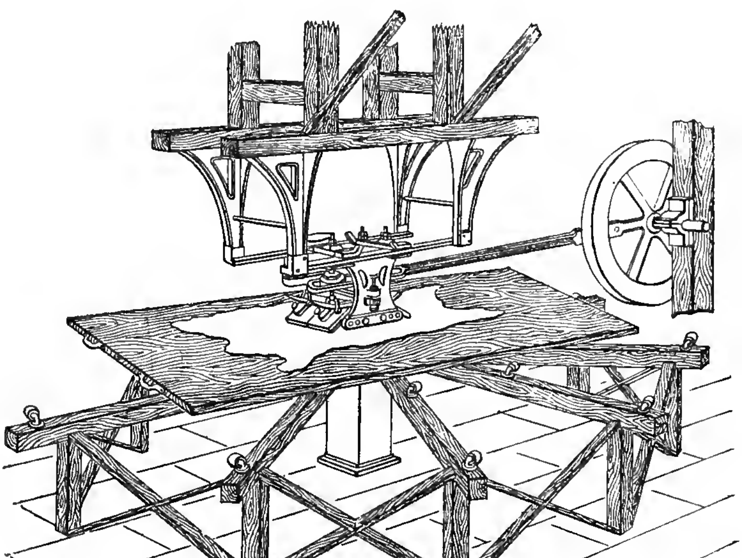
Next follows the *mise au vent*. The skins are first placed in a tub with water or weak tan-liquor for 24 hours; they are then folded and placed in a tub with enough water to cover them, and beaten with wooden pestles for ¼ hour. At the present day, stocks (*foulon vertical*), or a "drum-tumbler" (*tonneau à fouler*), a machine on the principle of the barrel-churn, usually take the place of this hand labour. The skin is next placed on a marble table, flesh upwards, and with one flank hanging somewhat over the edge, and is worked with a "sleeker" or stretching-iron (*étire*), B, Fig. 903. The first two strokes are given down and up the back, to make the skin adhere to the table, and it is then worked out regularly all round the side on the table, so as to stretch and level it. The flesh is then washed over with a grass-brush (*brosse à chien-dent*), the skin is turned, and the other flank is treated in the same way. It is lastly folded in four, and steeped again in water. The next process is the cleansing of the grain. The skin is spread again on the table, as before, but grain upwards, and is worked over with a stone (*cœurse*), set in handles, and ground to a very obtuse edge. This scours out the bloom; after washing the grain with the grass-brush, it is followed by the sleeking-iron, as on the flesh.

The next step is re-setting (*retenage*). For this, except in summer, the skins must be dried again, either by press or in the shed. This is another setting out with the sleeker, and, the skin being dried, it now retains the smoothness and extension which is thus given to it. The skins are now ready for oiling in the grain, for which whale-oil or cod-liver oil is generally employed. Olive-oil, castor-oil, and even linseed-oil may, however, be used, and are sometimes made into an emulsion with neutral soap and water. After oiling the grain, the skins are folded and allowed to lie for 2–3 days before oiling the flesh.

The oiling on the flesh is done with a mixture of *dégras* and tallow, in such proportions as not to run off during the drying. *Dégras* is the surplus oil from the chamois-leather manufacture, which in France is effected by daily stocking the skins with oil, and hanging in the air for oxidation. The *dégras* (*toise, moëllon*) is obtained, not by washing the skins in an alkaline ley, as in the English and German method, but by simple pressing or wringing. This oil, altered by oxidation, is so valuable for currying purposes that skins are frequently worked simply for its production, being oiled and squeezed again and again till not a rag is left. It is generally mixed in commerce with more or less of ordinary fish-oil. Eitner recommends, where the *dégras* is of indifferent quality, a mixture of 65 parts *dégras*, 20 of neutral soap (i. e. soap without the usual excess of alkali), and 15 of soft tallow. After oiling the flesh, which is accomplished by extending the skin on the marble table with the sleeker, and applying grease with a sheep-skin pad, it is hung to dry at a temperature of 18°–21° (65°–70° F.). After drying, the surplus oil is removed by a fine sleeker from both flesh and grain, and the skins are ready for "whitening" (*blanchissage*). This consists in taking a thin shaving off the flesh, and was originally accomplished by the shaving-knife on the currier's beam, and some curriers are still in favour of this method. It is now, however, done by a sleeker with a turned edge. The grain then undergoes a final stoning and sleeking, to remove the last traces of adhering oil, and the skin is grained by rubbing it in a peculiar way under a pommel covered with cork. It is then coated on the flesh with a mixture, of which the following is a specimen:—5 parts of lamp-black are rubbed with 4 of linseed-oil, and 35 parts of fish-oil are added; 15 parts of tallow and 3 of wax are melted together and added to the mixture; and, after cooling, 3 parts of treacle. This compound is put on with a brush, and allowed to dry for some days. Finally, the skins are sized over with a glue-size, which is sometimes darkened by the addition of aniline-black.

The preceding account will give some idea of the care and labour expended on these goods in France. In England, cheaper productions are more in vogue, and almost every process is accomplished by machinery. An illustration of the Fitzhenry or Jackson scouring-machine, which is largely employed both for scouring and setting out, is given in Fig. 920.

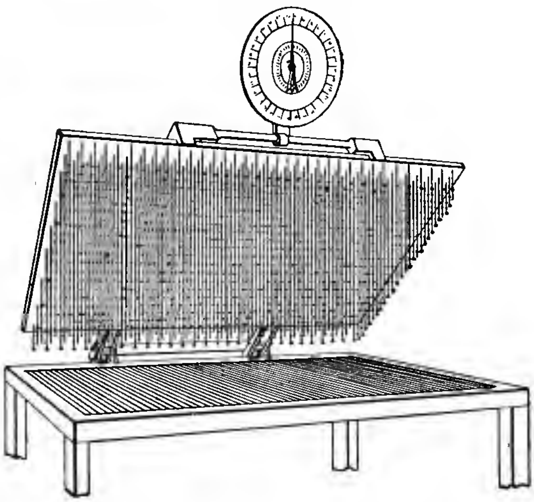
920.



In the case of strap-butts, the currying is, of course, far less elaborate. They are well scoured out, heavily stuffed, and stretched in screw-frames, to prevent their giving afterwards when in use. In England, curried leathers are generally sold by weight, which leads to the use of glucose and other materials to add to the weight. In America, all upper leathers are sold by measure, and this is now ascertained by a very ingenious machine (Fig. 921). The skin is laid on a latticed table, and a frame, from which rows of bullets are suspended, is let down upon it. The total weight of the frame is indicated by a spring balance, and as the bullets which are over the skin are supported by it, the diminution of weight indicates the measurement.

Enamelled, Patent, or Japanned Leather.—These are terms used to designate those leathers, whether of the ox, the horse, the calf, or the seal, which are finished with a waterproof and bright varnished surface, similar to the lacquered wood-work of the Japanese. The term "enamelled" is generally used when the leathers are finished with a roughened or grained surface, and "patent" or "japanned" are the terms used when the finish is smooth. Though generally black, yet a small quantity of this leather is made in a variety of colours.

921.



Leather destined to be finished in this way requires to be curried without the use of much dubbing, and to be well softened. The English practice is to nail the skins thus prepared, and quite dry, on large smooth boards, fitted to slide in and out of stoves maintained at a temperature of 71°–77° (160°–170° F.), coating them repeatedly with a sort of paint composed (for black) of linseed-oil, lamp-black, and Prussian blue, well ground together. Each coating is allowed to dry in the stoves, before the next is applied. The number of coatings varies with the kind of skin under treatment, and the purpose for which it is intended. The surface of every coat must be rubbed smooth with pumice; finally, a finishing coat of oil varnish is applied, and, like the preceding coats, is dried in the stove. The exact degrees of dryness and flexibility, the composition of the paint, and the thickness and number of the coats, are nice points, difficult to describe in writing.

This branch of the leather industry, so far as it relates to calf-skins, is carried on to a larger extent, and has been brought to greater perfection in Germany and France than in England. In the former countries, the heat of the sun is employed to dry some of the coatings. The United States have also brought this style to a high degree of excellence, especially in ox-hides. There, use is made of the oils and spirits obtained from petroleum, and without doubt, French and German emigrant workmen have materially assisted in attaining this high standard.

Leather finished in these styles is used for slippers, parts of shoes, harness, ladies' waist-belts, hand-bags, &c., and has now maintained a place among the varieties of leather for a long period of years.

Morocco Leather.—Morocco leather is produced from goat-skins. Rough-haired or "blue-back" seal-skins are also used, and produce an excellent article; while an inferior description, called "French morocco," is produced from sheep-skins. The skins are unhaired by limeing in the usual way, and are then baited with a mixture of dogs' dung and water. The tanning is done chiefly with sumach, at first in paddle-tumblers, and then in handlers, lasting about a month in all. Sheep-skins are usually tanned through in about 24 hours, by being sewn up into bags, grain side outwards, and nearly filled with strong sumach infusion. A little air is then blown in, to completely distend the skin, and they are floated in a sumach bath, and kept moving by means of a paddle. After the first day's immersion, they are thrown up on a shelf, and allowed to drain; they are then again filled with sumach liquor; when this has a second time exuded through the skin, they are sufficiently tanned, and the sewing being ripped open, they are washed and scraped clean, and hung up to dry, making what are called "crust-roans." The dyeing is sometimes done by brushing on a table, grain side upwards, but more usually the skins are folded closely down the back, flesh side inwards, so as to protect it as much as possible from the influence of the colour, and then passed through the dye-bath, which is now generally of aniline colours. The original oriental method of manufacture for red morocco was to dye with cochineal before tanning, and this is still customary in the East, but is quite obsolete in this country. A grain or polish is given to the leather, either by boarding, or by working under small pendulum rollers, called "jiggers," which are engraved either with grooves or with an imitation of grain. A well-cleaned sumach-tanned skin is capable of being dyed in the finest shades of colour; and this branch of the manufacture of leather has been brought to great perfection.

Russia Leather (Ger., *Juchtenleder*).—This is tanned in Russia with the bark of various species of willow, poplar and larch, either by laying away in pits, or handling in liquors, much like other light leathers, the lime being first removed by bating, either in a drench of rye- and oat-meal and salt, by dog-dung, or by sour liquors. After tanning, the hides are again softened and cleansed by a weak drench of rye- and oat-meal. They are then shaved down, carefully slecked and scoured out, and dried. The peculiar odour is given by saturating them with birch-bark oil, which is rubbed into the flesh-side with cloths. This oil is produced by dry distillation of the bark and twigs of the birch (see Oils—Birch-bark). The red colour is given by dyeing with Brazil-wood; and the diamond-shaped marking by rolling with grooved rollers.

Much of the leather now sold as "Russia" is produced in Germany, France, and England. It is tanned in the customary way, occasionally with willow-, but more generally with oak-bark, and probably other materials. Economy would suggest the use of such materials as, from their red colour, are objectionable for other purposes, and therefore cheap. The currying is in the usual manner, care being taken that the oil used does not strike through to the grain, which would prevent it taking the dye. The colour is given by grounding with a solution of chloride of tin (100 parts perchloride tin, 30 parts nitric acid, 25 parts hydrochloric acid, allowed to stand some days, and the clear solution poured off, and mixed with 12 volumes of water). The dye-liquor may be composed of 70 parts rasped Brazil-wood, 3 parts tartar, and 420 water, boiled together, strained, and allowed to settle clear. The grounding and dyeing is done on a table with a brush or sponge (see Glove-kid dyeing, p. 1239). The odour is communicated by rubbing the flesh-side with a mixture of fish-oil and birch-bark oil, which sometimes contains no more than 5 per cent. of the latter.

Calf-kid.—Calf-kid is used for light upper-leather, and belongs to a different class from any yet described, being "tawed" instead of tanned. In this respect, and in most details of its manufacture, it resembles glove-kid.

The process is as follows. Selected calf-skins, dried or salted, are the raw material, and after a suitable softening in fresh water, are limed for 2–3 weeks, or till the hair goes easily. They are then unhaired and fleshed in the usual manner, pured with a bate of dogs' dung, scudded, and again cleansed with a bran drench. In Germany, the bran drench is used alone, and is composed of 33 lb. bran to 100 medium skins. Before use, the bran should, especially in summer, be well washed to free it from adhering meal. The temperature of the drench should not exceed 38° (100° F.), and the skins should remain in for 8–10 hours. Lactic acid is produced by fermentation; this removes lime, and is itself neutralized by the products of putrid fermentation which succeeds it.

The tanning is accomplished in a drum with a mixture of alum and salt; and after drying, the skins are again moistened, and worked in the drum with a mixture of oil, flour, and egg-yolk. In the German method, these two operations are combined. Eitner, who has written a series of articles on the process, gives 40 lb. flour, 20 lb. alum, 9 lb. salt, 250 eggs, or about $1\frac{1}{3}$ gal. of egg-yolk, $\frac{7}{8}$ pint ($\frac{1}{2}$ litre) of olive-oil, and 12–16 gal. water, as a suitable mixture. The skins are worked in a drum-tumbler (preferably a square one) for 20 minutes, then allowed to rest ten minutes, and this process is twice repeated. The temperature must not exceed 38° (100° F.), and it is said to be important that the drum should be ventilated by holes at the axis.

The skins are allowed to drain, are then rapidly dried at a temperature of 60°–71° (140°–160° F.), and, after "samming," or damping with cold water, are staked by drawing them to and fro over a blunt knife fixed on the top of a post. They are then wetted down and shaved, either with the moon-knife or ordinary curriers' shaving-knife, and sometimes receive a second dressing of oil, flour, and egg, to soften them still further.

Dyeing black is accomplished either by brushing on a table, or by "ridging" or folding, grain-side outwards, and drawing quickly through baths of the mordant and colour. To prepare them for the colour, stale urine is generally employed. A deeper colour, and one less liable to strike through the skin, is obtained by adding $\frac{1}{4}$ lb. bichromate of potash to 4 gal. of urine, or the following mixture may be substituted with advantage, viz. $\frac{1}{2}$ lb. Marseilles soap dissolved in boiling water, 5 or 6 egg-yolks added, and the whole made up to 4 gal. with water and $\frac{1}{4}$ lb. bichromate of potash. The colour used is infusion of logwood or its extract, or two-thirds logwood, which is best extracted by stale urine or old soak-liquor, with addition of a small quantity of soda (1 lb. to 25 lb. dye-wood). It is fixed and darkened by a wash of iron-liquor (1 of protosulphate of iron in 75 of cold water). After being again dried, the skins are grounded with the moon-knife, and rubbed over on the grain with a composition containing oil, wax, &c., and are finally ironed with a flat-iron, to give them a fine and smooth surface. Eitner gives a recipe for the gloss:—1 lb. gum arabic, $\frac{1}{2}$ lb. yellow wax, $\frac{1}{2}$ lb. beef-tallow, $\frac{3}{4}$ lb. Marseilles soap, 2 lb. strong logwood infusion, and 1 gal. water. The water is brought to a boil in an earthen pot, and then the soap, wax, gum, and tallow are added successively, each being stirred till dissolved before adding the next, and lastly the logwood. After boiling for an hour, it is allowed to completely cool, being incessantly stirred during the whole process.

Glove-kid.—This branch of leather manufacture is mainly carried on in Germany, Austria, and France. In Germany and Austria, lamb-skins are principally employed; in France, kid-skins. For fine gloves, the skins of very young animals only can be used. The commonest style of manufacture is as follows:—The soaking of the dried skins is effected in large wooden tubs (*Kufen*, *Bottichen*), and occupies on the average 3–4 days, according to the character of the soak-water, the size of the skins, and the time they have been stored. The skins, when thoroughly and uniformly softened, are unhaired, either by painting the flesh-side with a thin paste of lime, or in lime-pits. In unhairing by painting (*Schwöden*), the skins, after coating the flesh-side with lime, are folded together, so that the lime comes as little as possible into contact with the wool, and these bundles or "cushions" are placed in a tub, in which they are most frequently covered with water. After unhairing on the beam with a blunt knife, the skins must be limed for some days, in order that the leather may stretch well, a quality which the Germans denominate *Zug*. By this method of unhairing, the wool is preserved uninjured, but it is not suitable for the finer sorts of leather. The unhairing in lime-pits is done either with gas-lime (*Grünkalk*), or, as is now almost exclusively the practice, with the so called "poison-lime" (*Giftäscher*). This is prepared by mixing red arsenic (arsenic sulphide) with lime, while it is being slaked, and is at its hottest. The calcic sulphydrate (and perhaps sulpharsenite) thus formed hastens the unhairing, and gives the grain a higher gloss. Well-conducted establishments now avoid as much as possible the use of old limes, which produce a loose, porous leather, with a rough, dull grain. The limeing lasts on the average ten days, and is of the greatest importance. It is essential that the interfibrillary substance shall be dissolved, that the leather may have the quality known as *Stand*, that is to say, may be strongly stretched in either length or breadth without springing back. It also depends upon the limeing (and this is of special importance in the case of lamb-skins), whether the tissue of the fat-glands is well loosened, so that the fat, either as such, or as lime- or ammonia-soap, may be readily and completely worked out. Skins in which this is neglected can never be properly dyed.

When the hair (or wool) is well loosened, the skins are rinsed in water, and then unhaired on the beam with a blunt knife. The water employed in washing should not be much colder than the limes, or it will prevent the hair from coming away readily. The wool or hair is washed and dried for sale. The skins are thrown into water, to which a little lime-liquor has been added, to prevent precipitation of the lime in the skins by the free carbonic acid of the water, which would have the effect of making them rough-grained.

Next comes the first fleshing (*Vergleichen*) or "levelling." By this, the loose cellular tissue on the flesh-side is removed, together with the head, ears, and shanks, and the flanks are trimmed. The skins are then again thrown into water, softened with lime-liquor as above described, and then into a bate of dogs' dung. This is prepared by stirring up white and putrid dogs' dung with boiling water, and straining it through a sieve or wicker basket. The bate must be used tepid, and not too strong. The skins "fall" (lose their plumpness) in it rapidly, and become extremely soft and fine to the touch; and the fat-glands, remaining hairs, and other dirt, can now be very readily scudded out. So far no completely satisfactory substitute has been found for this somewhat disgusting mixture, but it has been noted that guano will produce similar effects. With regard to the mode of action of the dung bate, much has been speculated without proof, and exact analytical evidence is wanting; but, no doubt, a weak putrefactive action goes on, as may be deduced from the presence of *bacteria*; further, the ammonia and weak organic acids present in the putrefying dung are capable of acting on fat and lime; and finally, a direct mechanical effect seems to be produced, difficult to describe, but favourable to the succeeding manipulation. Too strong bates, or too long continuance in them, produces evident putrefactive effects on the skins.

When the skins come out of the bate, they are stretched and worked (*abgezogen*) on the flesh with a sharp knife, and any remaining subcutaneous tissue is removed. This constitutes the second fleshing. They are then rinsed in warm water, and beaten with clubs (*Stoss-keule*) in a tub, or worked in a tumbler-drum (*Walkfass*), in either case with a very little water only; and finally brought into a tank of water, not too cold, and kept in constant motion with a paddle-wheel.

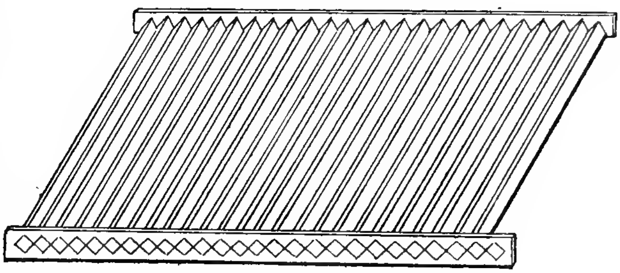
The skins are next cleansed on the grain-side by working on the beam with plates of vulcanite with wooden handles, so as to remove fat, lime- and ammonia-soaps, and other lime compounds, together with all remaining hair or wool. The skins are now a second time washed in the "paddle-tumbler." first in cold, and then in tepid water; and after allowing the water to drain from them, they are transferred to the bran-drench.

Bran-drench.—This is prepared by soaking wheaten-bran in cold water, diluting with warm water, and straining the extract through a fine hair-sieve. Sufficient of the liquid must be employed to well cover the skins, and the temperature may range from 10° (50° F.) to 20° (68° F.). These conditions are favourable to bacterial activity, which comes into play, and, on the one hand, evolves formic, acetic, lactic, and butyric acids, which dissolve any remaining traces of lime, and on the other, loosens and differentiates the hide tissue, so as to fit it to absorb the tawing solution (*Gare*). Much care is required in the management of the bran-drench, especially in summer, since the fermentation readily passes into actual putrefaction. The tawing-mixture is composed (like that employed in the fabrication of calf-kid, q. v.) of alum, salt, flour, and egg-yolks, in a quite thin paste. The skins are either trodden in it with the feet, or put into a tumbler-drum with it. Kathreiner pointed out, some years since (in vol. i. of 'Der Gerber'), that a mixture of olive-oil and glycerine might be partially substituted for the egg-yolks, in both the tanning and dyeing of glove-kid leather.

The tawed skins are now dried by hanging on poles, grain inwards. Rapid drying in well-ventilated, but only moderately-heated, rooms is essential to the manufacture of a satisfactory product.

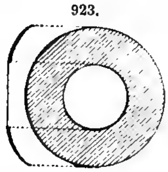
The dry leather is rapidly passed through tepid water, and after being hung for a very short time, to allow the water to drain off, is trodden tightly into chests, and allowed to remain in them for about 12 hours, so that the moisture may be uniformly distributed. It is then trodden on hurdles (*Horden*), composed of square bars of wood, joined corner to corner, so as to make a floor of sharply angular ridges, Fig. 922. The next operation is stretching over a circular knife, called the *Stollmond* (*stollen*, Eng. "staking"), shown in Fig. 923; then the leather is dried nearly completely, and staked again.

922.



Dyeing.—The dyeing of glove-kids is done in two ways: — *a.* The skins are plunged into the dye-bath (*Tunkfarben*). In this way, all light colours are ordinarily produced, such as *gris-perl* (pearl-grey), *paillé* (straw-yellow), *chamois* (reddish-yellow), silver-grey, aquamarine, &c. *b.* The skins are spread on an inclined or rounded table of stone or metal, and brushed over, on the grain side, first with a mordant (*Beitze*), then with the dye-liquor, and lastly with a solution of a mineral salt. The mordant serves to fix the colour on the surface of the skin, to prevent its striking through, to produce certain modifications of colour, and to enable any parts of the skin which yet contain fat to take the colour evenly with the rest. To satisfy these conditions, the composition of the mordants is very varied. Bichromate of potash, ammonia, potash, soda, and stale urine are among the most frequently employed, seldom separately, but usually in a mixture containing two or more.

923.



Dyestuffs of vegetable origin have always held the first place. These most in use are logwood (*Blauholz*), Brazil-wood (*Rothholz*), the two fustics —*Cuba Gelbholz* (*Morus tinctoria*) and *Ungarisches Gelbholz* (*Rhus cotinus*), several species of willow-bark and of berries, indigo-carmine, and indigo dissolved in sulphuric acid.

Aniline colours used alone remained in fashion for a short time only, but are now usefully employed as top-colours (*Ueberfarben*), viz. brushed in very dilute solution over vegetable colours. In this way, particularly tasteful shades of green, violet, and marine-blue may be produced.

After the mordant has been applied once or twice, and the colour 3–6 times, a wash (*Ueberstrich*) containing some metallic salt is generally applied, with the object either of bringing out the special tone required, or of making the colour more lively and permanent. The so-called "vitriols" are mostly employed: "white vitriol" (zinc sulphate), "blue vitriol" (copper sulphate), "green vitriol" (iron sulphate), and occasionally other salts.

Before dyeing, the greater part of the flour, salt, and alum must be removed from the skins by washing with tepid water; and therefore require a second feeding (*Nahrung*) of egg-yolk and salt. In the case of the skins which are dyed by plunging into the dye-vat (*Tunkfarben*), this is done after the dyeing is completed. In that of brush-dyeing, before the dyeing process.

After the dyeing, the skins, if dipped, are wrung out; if brush-dyed, sleeked out with a brass plate, to get rid of superfluous water. They are then dried in an airy room. Before staking (stretching), the skins are laid or hung in a damp cellar, or in moist saw-dust. They are staked twice: once damp, and once nearly dry.

Skins which are much damaged on the grain, or otherwise faulty, are smoothed with lump pumice on the flesh side, either by hand or machine. They are then dyed on this side, mostly by dipping, but occasionally with the brush, in which case, the method described is slightly modified.

Indebtedness is acknowledged to F. Kathreiner, of Worms, and David Richardson, of Newcastle, for much information on the production of light leathers.

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(See Skins; Tannin.) H. R. P.

LINEN MANUFACTURES (Fr., *Industrie toilière, linière*; Ger., *Leinenmanufactur*).

The spinning and weaving of flax is undoubtedly the second, if not the oldest, of the textile arts. Evidence of the truth of this statement abounds on every hand. The paintings in the tombs of Upper Egypt, in which the processes of manufacture, from the pulling of the flax to the weaving and finishing of the cloth, are vividly represented, taken in conjunction with the remarkable preservation of the cloths in which the ancient Egyptians enshrouded their embalmed dead, render its certainty beyond dispute. Every fact in connection with this subject, which has been brought to light, tends to show the very high degree of perfection to which these people had carried the industry. Whether they invented the art of weaving, or received it from a people older than themselves, it is useless now to inquire. Certain it is that, after Egypt had long been the emporium of manufactures and commerce, the art under notice gradually spread beyond its boundaries into neighbouring lands. The Israelites, on their departure from captivity, carried with them a knowledge of the industry which they had acquired during their sojourn by the Nile. Phœnicia possessed the art at a very early period, and Sidon, Tyre, and Carthage were successively great centres of commerce in "purple and fine linen." The cultivation and manufacture of flax became a considerable industry in ancient Greece and Rome. In these states, it first appears to have attained such dimensions as to become a separate handicraft or trade, though far from having become extinct as a domestic institution. In the former country, so high a degree of excellence was attained, that when the simplicity of the means the artisans possessed is borne in mind, the results achieved command the admiration of experts of the present day; and Spain, Gaul, and Germany doubtless received the art from these sources. During the period following the fall of Rome, the linen manufacture, along with other arts and industries, was nearly destroyed. The maritime and free cities of Italy were the first to accord renewed encouragement to the flax industry, and Bruges, Hamburg, and other towns became eminent centres. The Flemings at a very early period became flax manufacturers, and great numbers earned their subsistence by weaving, and disposing of their productions in France; under Baldwin III., and several subsequent rulers, the woollen and linen manufacturers of Flanders rose to great importance, and maintained their high rank until intestine quarrels and religious persecutions drove the craftsmen to foreign lands. From the 6th century down to the present day, Germany has possessed a manufacture and trade in linen goods of considerable extent and importance, while the raw material has been largely cultivated in its alluvial districts. The Netherlands for a long time manufactured, and otherwise traded with great benefit, in linen fabrics. Since its separation, Belgium has devoted great attention to the cultivation and manufacture of flax, and as regards the production of the raw material, now stands at the head of the industry. France for more than 1000 years has grown and manufactured flax, the fibre raised by the farmers being dressed, spun, and woven for domestic use long before the modern system of manufacture was originated; during the current century, the industry has made considerable progress, and though formerly spread over a large area of country, it is now mainly concentrated in particular localities, situated in the northern and western provinces: Flanders (French), Picardy, Isle of France, Normandy, Maine, and Brittany. Russia raises large quantities of flax, which is exported in the unmanufactured state; for centuries past, it has possessed a domestic manufacture, spread over its extensive dominions, and since machinery has been applied to it, the country has made fair though not great progress in adapting itself to the changed circumstances; formerly its linen manufactures, being composed of the better qualities of flax, stood high in various markets, but they have been supplanted to a great extent by the cheaper fabrics produced from jute and jute mixtures in Dundee. The states of N.-W. Europe—Denmark, Norway, and Sweden—possessed an industry in this article of ancient origin, but of only the smallest importance. Switzerland is prevented by geographical location, and unsuitable soil, from excelling in the production or manufacture of flax; but notwithstanding these disadvantages, it has succeeded in founding a considerable industry, the raw materials being imported from the surrounding countries, and the manufactured fabrics supplying the home market, and finding their way into Italy, Austria, and the Danubian States. The linen manufactures of other foreign countries are of the most insignificant character.

Flax and its manufacture have long been known in Great Britain and Ireland. The art of manufacturing the fibre seems to have been introduced by the Belgæ, and the existence of a manufactory of woollen and linen cloth at Venta Belgarum (Winchester) is recorded in the 'Notitia Imperii.' During the troubled period following the withdrawal of the Romans, the art rapidly fell into decay, and it was not until the Saxons had established their dominion that attention was again directed to the manufacture of wool and flax. Before the close of the 7th century, weaving had made great progress, and the Anglo-Saxon females had gained wide repute for their skill. Records show that the materials chiefly or solely used were wool and flax, fabrics manufactured from the latter fibre being worn as under-garments by all persons of moderate rank or wealth. In the interval between the 7th century and the Norman invasion, further progress was made; the Bayeaux Tapestry commemorating that event has for its foundation a linen fabric, 20 in. wide and 214 ft. long, the figures being worked in with dyed woollen yarns. Among the invaders, were many Flemish weavers, who were subsequently followed by others of their countrymen; and guilds or fraternities of these artsians were soon founded. In 1253, fine linen was first made in Wilts and Sussex; and in 1272, Irish linen was in use at Winchester. In Wales, the manufacture was established at an early date, records stating that, in the commencement of the 14th century, linen was a common article of wear. Fine linen was at this time imported from Rheims. The linen industry fluctuated greatly during the next three centuries, sometimes being stimulated into considerable activity and growth, and again left to neglect and decay. At the commencement of the 18th century, it had obtained a position of great importance, and those engaged therein, in conjunction with the woollen manufacturers, were sufficiently powerful to obtain the passing of many protective or prohibitive laws directed against foreign goods, especially the calicoes and muslins of India. The introduction of the cotton manufacture soon after this time had a depressing influence upon the linen trade. At first, cotton yarns were only used for weft; but after Arkwright's invention had been perfected, they were made strong enough to serve for warp purposes, and the growth of the cotton trade subsequently almost destroyed the linen manufacture, both spinners and weavers turning their attention to the new fibre, and engaging in the production of the new and popular fabrics. Since that time, in England it has been a decaying industry, and at present there is little of it surviving.

In Ireland, the course of the linen manufacture has been in a great measure parallel with that of this country. For a long period, the country was noted for the production of the raw material, much of which was exported to England in the fibre, and also in yarn; here it was woven into cloth, and to some extent returned again for sale. Towards the middle of the 17th century, linen manufacturing was thoroughly established in the island; Ireland had also at that time a considerable woollen trade, but this was discouraged for political reasons, and the linen trade was stimulated by every available means. From the beginning of the 18th century, its course has been one of steady progress, and, owing to the comparatively early adoption of machinery in the different processes, the present century has witnessed a great expansion.

In Scotland, linen manufacturing was established at a very early date, and was often encouraged by the Government. It also suffered the usual fluctuations incident to favouritism. The industry was spread over almost the whole of the country, and attained, owing to the introduction of Flemish and other skilful weavers, a high degree of excellence. More recently, when machinery became generally adopted, it concentrated in the localities which have since acquired repute for their excellent productions. Of late years, however, the linen trade has to some extent been overshadowed by the progress of the jute manufacture.

In all the countries ancient and modern over which the cultivation and manufacture of flax extended, the implements in use, until towards the close of the last century, were of the simplest kind. The excellence of ancient textiles was the result purely of skilful manipulation. It was not until the Greek and Roman periods that any real advance was made in the art of manufacturing linen. The method of spinning then adopted was to make a loose ball of the fibre, into which the distaff was inserted, the lower end being held under the arm in such a position as to allow of the fibre being conveniently drawn off by the fore-finger and thumb of the right hand. The spindle, on its lower extremity, had a whorl of wood or other material, by which it was kept steady, and its rotation was assisted. The upright loom seems to have been preferred. The *stamen* or warp was passed over a cross-beam or rail on the top of the loom, and kept in a state of tension by being divided into sections, with stones suspended from each. A set of lease-rods were used to separate it into equal portions, the threads alternating on each side, as in the modern method. The heddles were formed of threads, fastened at one end to a straight rod, and having at the other end a ring or loop, each containing a thread of the warp. The number of these varied according to the texture of the cloth. The weft was carried on a spindle or bobbin. In weaving, the shed was formed by drawing one or more leaves of the heddles forward at one time, and passing the pirn through the open shed. The tension upon the warp drew these back into their first position, when the next in order were drawn forward in a similar manner, the weft was again inserted, and the operation was repeated. Each thread of weft was passed to its position by the *pecten* or comb, which fulfilled the office of the modern reed. The teeth of the comb were inserted between the threads of the warp, and thus made to drive the pick of weft close to the preceding one, in order to obtain a firm cloth.

No important improvement took place in the means or processes employed until the invention of the hand spinning-wheel. The first step beyond the distaff and spindle, which had sufficed for the necessities of mankind through many centuries, was the invention of a rude frame for holding both these instruments, thus relieving the operator's hands for other duties. This arrangement, about the commencement of the 16th century, was much improved by having the spindle mounted for driving by a belt from a large wheel turned by hand. A treadle was soon after added for working it by foot. The form of the loom, too, had undergone a great change, having assumed one which allowed the warp to be arranged horizontally in the frame. The healds were modified so as to admit of being worked by foot-levers or treadles, and the batten or slay containing the reed was suspended inside the frame from the top, and made to oscillate upon centres. This enabled the weaver to drive home every pick of weft with greater facility, speed, and ease than by any previous arrangement, and tended greatly to increase the production. The shuttle was passed through the shed from hand to hand, as before, and when wide cloths were being made, two weavers were required to operate one loom. As linen and woollen were the only two fibres wrought to any important extent, both branches of the industry appropriated these improvements in nearly every country, as soon as the limited intercourse between them would allow.

The Saxon wheel, soon after introduced, was more perfect than the preceding. The spindle of this wheel was supplied with a bobbin, on which the thread was wound, and with a "flier" revolving at a greater speed than the bobbin, whereby the fibres were twisted as required. This constituted a great advance; and so perfect was its action that it has never been surpassed to this day. Its principle is still embodied in many of our preparing- and spinning-machines.

This wheel was a long time before it supplanted the more antique instruments, but during the 18th century, the latter finally disappeared. About 1764, it was further improved by the addition of another spindle. This was called the "two-handled wheel," and maintained its ground until the beginning of the present century. This, in its day, was a very efficient instrument. Its frame was mounted on three legs. To the right of the operator, was a spoked wheel, about 2 ft. in diam., on the axle of which was a crank carrying a connecting-rod, whose opposite extremity was attached to a treadle operated by foot. On the left, the two spindles were mounted in a part of the frame, which rose to a suitable altitude. The spindles were furnished with small whorls, grooved on their periphery, for the reception of the driving-bands. The large wheel was also hollowed around the rim for the same purpose. The driving-bands were composed of hard-twisted woollen or flax yarn, the selection depending upon the fibre for which the machine was being used; sometimes gut was the material. Each spindle had a flier for twisting the thread, which was wound upon a "bobbin," a thin wooden tube, fitting rather loosely upon the spindle. The flier revolved with great rapidity, the bobbin following more slowly, being held in check by the thread, and revolving only at a rate sufficient to take up the yarn as it was delivered by the spinner. The distaff was attached to the wheel in the most convenient position for permitting the fibres to be drawn off with facility by the hands of the worker, both being employed in drawing the material and forming the threads. These, in process of spinning, were from time to time shifted upon a series of bent wires, so as to fill the bobbins as evenly as the appliances would permit. The threads were moistened with saliva by the worker, to make the fibres more pliable and yielding to the torsion applied, and thus more readily form a solid thread. The filled bobbins were placed upon a pin held in the left hand, and their contents were wound upon a flax-reel, 120 rev. of which constitute a "cut." This quantity was tied together, and others were added until there was a sufficient number to form a hank, when it was removed. In spinning on both the one-thread and two-thread wheels, great expertness was attained by the best workers, and their yarn was remarkable for solidity, smoothness, roundness, and evenness.

The hand-wheel did not give way to its mechanical competitor until the close of last century; and before disappearing, had applied to it the mechanical traverse of the flier, for laying the threads in even layers upon the bobbin by automatic means, instead of passing them successively along the series of crooked guide-wires by hand.

The successes of Hargreaves, Arkwright, and Cartwright in the invention and application of machinery to the kindred industry of cotton-spinning, during the latter half of last century, soon suggested a similar course in relation to the flax manufacture. This was quickly followed, and very soon correspondingly favourable results were achieved, the new machinery superseding for ever the appliances which had sufficed for so long. The lead in this movement was taken by an optician and a clock-maker, named Kendrew and Porthouse, of Darlington. The former appears to have been the prime mover. An inspection of the Lancashire cotton machinery resulted in a patent being taken out in 1787, described as being for "a mill or machine upon new principles for spinning yarn from hemp, tow, flax, or wool." Several of these machines were fitted up and successfully worked for some years in a small mill situated on the Skerne, at Darlington. They soon attracted the attention of Scotch manufacturers, who erected some on the same principle, and paid a royalty to the inventors. But the progress made was not very great or satisfactory. The machinery was rude, and roughly finished, and the work was correspondingly difficult and inferior. It was many years before machine-spun yarns equalled the quality of those obtained from the hand-wheel. Experience dictated successive improvements and inventions, which so far perfected the yarns that in the early part of the present century they began to supersede hand-spun yarns, which finally disappeared. Many inventors contributed to this result, and their improvements will, to some extent, come under notice presently. The linen manufacture as now conducted requires large establishments, furnished with expensive machinery, and backed by considerable capital, to work with advantage. There is also needed a great amount of technical knowledge, which is called into requisition at every stage of the process, from the selection of the raw material to the time when it emerges from the manufacture in a finished state ready for the consumer. Without these essentials, there is considerable risk of failure.

Flax (see Fibrous Substances—*Linum usitatissimum*), after undergoing the treatment necessary to prepare it for the market (pp. 964–978), and passing into the hands of the manufacturer, is sent into the store of the spinning-mill, arranged in separate piles or lots, according to quality or growth, and ticketed with the number allotted to the grower from whom it has been purchased. The particulars of these lots are carefully taken down, and entered in the store-book for future reference. This is necessary in order to enable the selection for working to be made to the best advantage, because successive purchases made from one grower are found to be the most uniform in length, strength, and colour, having been grown upon the same soil, and from the same quality of seed, and retted in the same water. Similarity in these respects enables the first process, "roughing," to be performed more satisfactorily than if the fibre varied in its chief qualities. The first process being performed well does much towards assuring satisfactory results in the end.

Roughing.—"Roughing" is conducted as follows:—Scutchers make up the flax for market in bundles of 14 lb., constituting a "stone" of flax. Each stone contains 5–8 "stricks" or handfuls of finished flax, and each strick is composed of two "fingers," two of the small lots that have been treated at one operation in the scutching-process. The "rougher," having been supplied with his parcel of flax, about 2 cwt., takes one of the stones, and separates it into stricks and again into fingers. Holding one of the latter in his left hand, with the butt or root-end from him, he with his right hand separates as much flax from the bulk as he can conveniently hold between his fore-finger and thumb, being careful to select those fibres that have their ends level with each other. With a quick jerk of his right hand, he draws the selected fibres from the bulk, and swinging his arm around, brings them down upon the table in a semicircular form, with the convex side towards him. This operation is repeated, the rougher taking care to have all the pieces as nearly as possible of the same size, which is essential to the proper performance of the roughing, and being careful also to lay the pieces so as to form a straight row on his table. This is called "piecing out," and is continued until the rougher has made a pile of pieced-out flax sufficient to occupy him for an hour or more in "rough dressing." This he commences by grasping a "piece" near the "top-end"; leaving nearly the whole length before his hand, he jerks it behind him, and by drawing it suddenly back, thoroughly loosens it, and brings it down well spread upon the pins of the hackle, which is firmly bolted to the bench on which he is at work. Having gripped the piece near the top, as he proceeds to pull it through the hackle, all the short fibre is retained in the pins by the root-end, which is the object sought. He next takes the root-end of the piece between the finger and thumb of the left hand, and placing it over the corner pins of the hackle, draws it through with his right hand, leaving the weaker fibres with those previously in the hackle. Then, moving his hand down the piece a little towards the middle, he places it upon the portion in the hackle, in such a position that, when the latter is drawn through the pins, the ends of all the portions shall fall exactly level. Should the extremities be slightly irregular, he levels them by drawing out the projecting ends, and placing them in order. The operation is completed by the rougher next taking the top-end of the flax, and, by a quick turn, wrapping it around his right hand, and keeping the end that he is roughing well spread out between his finger and thumb, he throws the piece a second time over the hackle, draws it steadily through, and clears the remainder of the short fibres out of it. Again taking the root-end in his left hand, he laps it round the "touch-pin," a sharp, square, or triangular steel pin, fixed upright in a block of hard wood, fastened to his bench on the left of his hackle, and breaks off all the loose, short, and straggling fibres that remain, thereby securing a perfectly square root-end. The top-end is then, with one or two exceptions, treated in a similar manner, after which the piece is placed upon the heap of roughed flax, the rougher taking care, in withdrawing his hand, to leave in each a partial twist, so as to keep them distinct, for facilitating the succeeding operation.

Roughing is very expeditiously performed. In roughed flax, there are about 5–9 "pieces" in the lb., and in a day's work of 10½ hours, a good rougher will complete about 300 lb., or 10–14 cwt. a week. The flax as thus prepared is termed "lougs"; the portions broken off around the touch-pin, after being cleared from the tow, are weighed in with the longs, and called "shorts," being subsequently kept distinct. Roughers earn 15–20*s.* a week, according to their capability, being paid at the rate of about 1*s.* 9*d.* a cwt. High-class qualities of flax, having been carefully prepared for the market, generally need less dressing than other descriptions, and low qualities do not repay much expenditure upon them. The former include Belgian, Dutch, English, and French, whilst the latter are mostly composed of Russian, German, Italian, and some Irish sorts. The rate of pay for dressing these different sorts varies proportionately to the labour spent upon them. Irish flax requires most dressing, being as a rule carelessly prepared for the market.

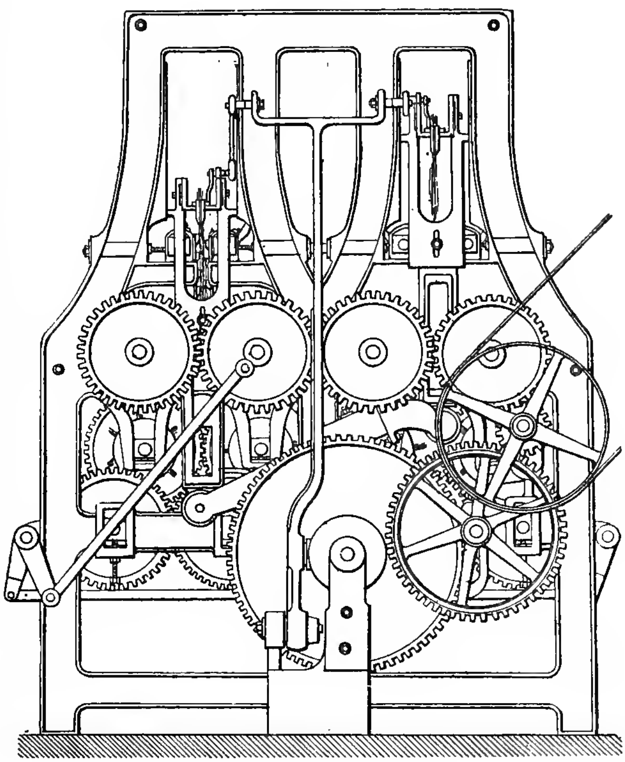
Machine-hackling.—After undergoing rough dressing, the material is brought forward to the next process, machine-hackling. Each fibre of flax, being composed of a number of finer filaments bound together by a natural gum, is capable of being chemically separated to its ultimate fibres. It is not often that this is done, however, and perhaps never for manufacturing purposes. The amount of splitting which the fibre undergoes in machine-hackling depends upon its quality, and the purpose for which it is destined. There are several varieties of machines constructed for accomplishing this object, all possessing particular merits, and being generally efficient.

The hackling-machines in a flax-mill should not be all alike in fineness, nor adapted for exactly similar work. Should the mill not possess more than three, one each should be fitted for coarse, medium, and fine work, because it is certain that, with the best care in purchasing the raw material, these three grades will come to the front in the necessary classification. The "parcels" from the "roughing-shop" having been allotted to appropriate machines, the attendant who serves the operatives in charge of the hackling-machine, generally a boy, gives them the shorts of each parcel to put through first, to serve as a distinguishing mark between that and the preceding parcel, which enables an accurate account to be taken of the weight of the longs obtained from each 2 cwt. The flax of each parcel, as the machining goes on, is made up into bundles of about 10 lb. each, termed "tipples," by a boy who attends a number of machines, and who is technically called a "tippler." His task is to go round and make up these tipples, and to answer the call of the hackler when his parcel is finished. The tipples, having all been put into a basket, are taken to the weighing-machine or scales, where the nett weight is ascertained; another boy at the same time brings the tow, the particulars of which are also taken, and entered upon a ticket. The weights being added together, the total should come to within a lb., or thereabout, of the weight of the parcel.

The feeding of the machine is performed as follows:—The filler—a boy—takes two pieces of flax from that received from the rougher, which he spreads upon a metallic plate, about 12 in. by 4, and which has a bolt called the "holder" fixed in the centre. A piece is spread on each side of this bolt, all except about 12 in. falling over the holder. A top plate is next placed upon the bolt, which is also a screw, and by means of a nut, the plate is firmly screwed down, and made as fast as if held in a vice. The faces of both plates are covered with corrugated indiarubber or cloth, in order to increase the security of the hold. The attendant boy, called a "filler," lifts the secured flax into the head or holder-channel of the machine, which is a "lifter," or rising and falling bar, having a vertical traverse of 12–18 in., or other required distance, according to the length of the flax. Inside the channel, is a rack, working upon a slide, which, by means of deflectors, takes the holders upon being placed in the machine, and, at each ascent of the head to the top of its vertical traverse, shifts the holder laterally a distance equal to its own length, so that, on its next descent, the flax in the holder which has been moved passes between the vertical sheets as before, but in front of a finer set of hackles. These sets of hackles are called "tools," and the quantity varies according to the size of the machine, and the requirement of the work. The Horner machine may have 6–12 tools; in this case, the breadth of the tool will vary from about 8½ to 11½ in., there being little difference in the frame of the machine, which is generally 11–12 ft. in length. According to the number of tools contained in the machine will be the lifts of the head to complete the lateral traverse of each holder, when it will be thrown out, with one half of the fibre it contains—the portion hanging down—completely hackled. The vertical traverse of the head is obtained by the action of a horizontal lever, working on a centre stud, set below and at right angles to the heads. At a short distance from the above stud, is a strong iron pin fixed in the side of the lever, having a runner encircling it, which is confined in a groove cast in the side of a large wheel, called the "wiper," and this, by its revolution, raises or lowers the runner in a manner corresponding to the direction of the groove. The fixed pin upon the lever being contained in the runner, the rocking motion is thus communicated to the lever, and by its means, the head-slides resting upon its extremities are alternately raised and lowered. On the outside of the wiper, is another groove, of a different shape from the former, by means of which the lateral traverse of the holders is effected. This groove has a runner also, which is connected with a vertical lever, that midway in its length has a V-bend, which is held in a given position by a stud-pin carried by a bracket upon the frame between the sheets. The opposite extremity of this lever is bifurcated, the arms being connected with rods working detents in the head-channel, which are adjusted so as to draw the holders when the head is at the top of its vertical traverse; the same movement carries the detents of the other head, which is at its lowest point, backwards to be ready for bringing forward another holder. The arrangement of the head is such that there is a holder for each detent, and one of the latter for every tool. The consequence is that, at every elevation of the head, and shift of the holders, one of the latter is thrown out at the end of its lateral traverse. This is lifted down by a boy, who is technically called a "changer," and laid flat upon a bed on the table, in such a manner as to cause the hackled portion of the flax to fall evenly over another holder, similarly placed to receive it, or rather sufficient of it to secure a firm grip as before; and to subject the unhackled part, when placed in the second head of the machine, to the certainty of being hackled or cut precisely as the first has been.

The sheets of a hackling-machine consist of endless leather straps, of about 5½ ft. circumference, passing over two rollers, the bottom one of which is the driver, and the top one merely a carrier. The former is 9 in. in diameter, and is furnished with iron bosses on its ends and centre, which have catches on their surface, bearing upon the straps and bars, and thereby causing the sheet to revolve. The bars just mentioned are of iron, the full length of the machine, and 1 in. broad by ¼ in. thick; they are secured to the straps at their extremities and centres by screws. The hackle-stocks are screwed to these bars, and thus form a revolving sheet of steel pins. On the inside of the end bosses, and on both sides of the centre, grooves or notches, for the reception of the stripper-rods, are cast. These rods are plain strips of tough, pliable wood, 1½ in. by ⅜ in. thick, and sufficiently long to reach from boss to boss. On the extremities, cast-iron ends are riveted. The rods, being pliable, are bent a little in order to get their ends into the grooves of the bosses; when inserted, they spring back again, and have a certain amount of play. As the roller revolves, they fall forward so as to come into contact with the points of the pins, which are thus stripped of the tow they have combed from the flax through which they have passed. This tow falls upon a "tow-catcher" in close proximity, which, when it has received each contribution, deposits it in a box below the machine. The top or carrier-rollers bearing the sheets are adjustable, by which means the pins in working can be set so as to "face up" to those of the corresponding sheet, or to intersect them, as may be deemed most desirable. This system of stripping by means of rods has been received with considerable favour, but experience has shown that in using some sorts of flax it is not perfect. There exudes upon the pins from these sorts a resinous oil, that causes the pins to get clogged with tow, from the failure of the rods to clear it away.

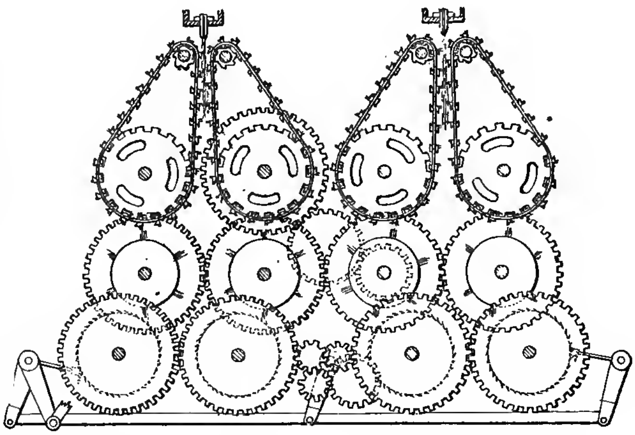
924.



The consequence is that many prefer the older system of the revolving brush and doffer, shown in side elevation and section in Figs. 924 and 925; but with these also there are difficulties, as they only cleanse one side of the pins. The accumulation of oil upon the latter has, however, been thoroughly obviated by an invention applicable to the stripper-rod system, by R. W. McDowell, Belfast, and which has been secured by Horner. This consists in the introduction of a revolving brush, capable of having the direction of its revolution reversed, by which means, it clears itself and cleans the back of the pins at the same time.

Flax which is hackled in the full length of its fibre is called "long line," and the machine is arranged in its details accordingly, being termed a "long-" or "cut-line" machine. For the finest yarns, however, it is necessary to cut off both ends of the fibre, in order to obtain the regular and even portion of the middle of the fibre, the ends varying greatly from each other and from the middle. The "middle" thus obtained is usually 12–18 in. long; from very long flax, it is sometimes desirable, in order to avoid waste, to take out two middles, which will each be 9–12 in. in length. These are called "short middles." At other times, only one end of the flax is cut off; when this is the case, they are called "long middles." The ends are sent to the carding-engine, and carded into tow. Less labour in roughing is bestowed upon flax which is intended for cutting, as it is simply drawn over the hackle to straighten the fibres, the "pieces" also being made much larger. This is known as "stacking." The flax is then carried to the breaking-machine, usually called the "cutter," which contains one or two sets of fluted iron rollers, and a circular knife revolving at 600–1000 rev. a minute. The fluted rollers carry the flax in and present it to the action of the cutter, holding it securely until it is cut through.

925.



The sheets should not be driven too quickly, as by so doing, danger is incurred of tearing and breaking the fibre instead of splitting it properly. As to what constitutes a proper speed there is a difference of opinion, but good authorities agree upon the following as affording satisfactory results: About 6 lifts of the head and 20 rev. of the sheet a minute, the finishing-tool containing 8 pins an in., and two rows for six-tool machine, for coarse long-line flax; 5 lifts of the head, 15 rev. sheet a minute, 14 pins an in., two rows for nine-tool machine, for medium long-line; 6 lifts of head, 20 rev. sheet, finishing-tool 30 pins an in., two rows for twelve-tool machine, for medium cut-line; 3 lifts of head, 10 rev. sheet, finishing-tool 50 pins an in., two rows for twelve-tool machine, for very fine cut-line.

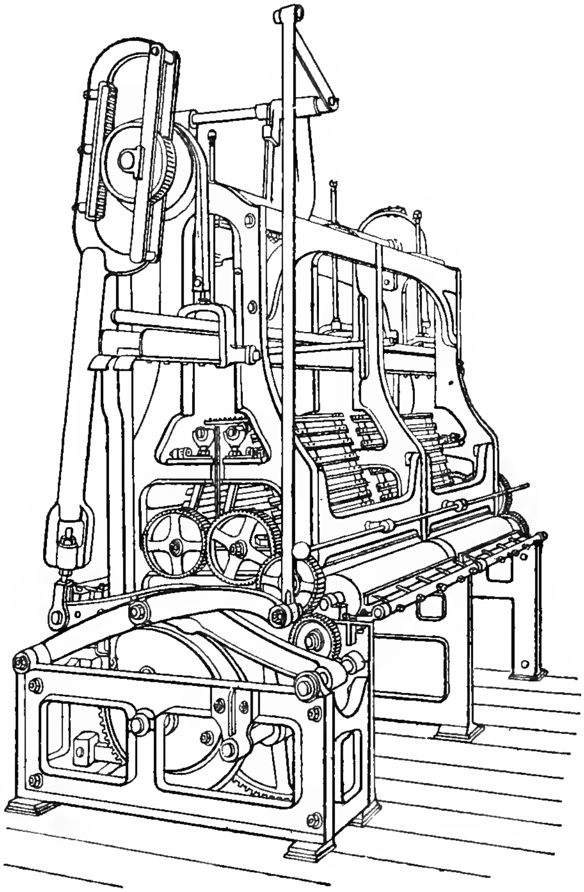
The hackling-machine is a costly article (250*l.*–300*l.*) in the first instance, and expensive to maintain, the wear and tear of the working parts being great, and their frequent renewal a necessity. Fig. 926 shows Cunningham's machine in perspective; it is made by the firm previously named, and is esteemed in the trade. The "manning" of the machine-room is a comparatively small charge, the labour employed being chiefly that of boys and youths, and consisting of tipplers, fillers, and changers, whose wages are 1*s.*–1*s.* 3*d.* a day.

Dressing and Sorting.—As the flax comes from the hackling-machine, it is held best for it to be drawn through a coarse hackle (a "ten"), broken, and next cleaned over a fine one called a "switch." Highly skilled and experienced men ought to be, and are usually, employed in this task as the assortment of the flax into its different qualities, performed by them, requires experience, intelligence, and quickness of perception to execute it satisfactorily. The coarser varieties of flax are put into the hands of apprentices, girls, and women, as their intrinsic value would not justify the employment of the more costly labour upon them. This is all done by hand. The old and laborious system of hand-dressing, which required a long training to acquire skill therein, has been so far superseded by machine-hackling that it is now rarely employed. One machine produces as much dressed flax as 20 hand-workers; four "roughers" are required to supply one machine, and about 6 or 7 sorters to dress the "longs."

When the piece has been properly levelled and dressed, it is ready to be transferred to the table, to the bunch in process of formation which in its various qualities it most resembles, where it is carefully placed in such a manner as not to disturb the order in which the fibres lie. But this is done only after it has been what is called "lapped," in which a portion of the end is thrown round the end of the piece in the form of a lap. The pieces are laid so as to overlap each other, but only in such a manner as to contribute to the building up of a square and firm bunch. Each bunch weighs about 20 lb., and is generally tied with four bands; but in cases where the finer qualities are being treated, they are sometimes carefully put into boxes before being received into the store, where the flax may have to remain weeks, months, and in exceptional cases even a year or two, during which time it ought to be preserved unruffled.

A careful assortment of the qualities of the flax is exceedingly important, as upon the skill with which this has been done, and the care with which it is subsequently preserved from becoming intermixed, depend satisfactory results in the spinning process. The points to be observed in sorting are fineness, length, strength, colour, and cleanliness; and these are required to be noted during the half-minute or so that a piece is in the hands of the operator undergoing dressing. It is exceedingly difficult to secure a perfect assortment of flax into its different qualities, because whatever principle is adopted as the basis, it is sure to fail in one point or other to give a good classification. If more than one system be employed, the number of sorts becomes unmanageable, and leads to confusion, whilst both warp and weft yarns are apt to be injured by the presence of fibre that ought to have been in the opposite class.

926.



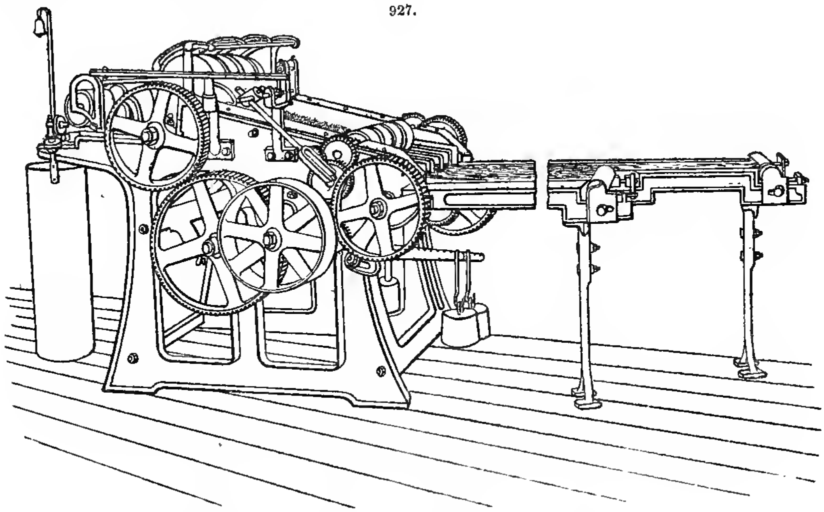
The most satisfactory arrangement of the various processes is to have the roughing, machining, and sorting in separate apartments, each under the care of an overlooker responsible for the proper performance of the work committed to his charge. The roughing-room should be in immediate proximity to the rough-flax store on one hand and to the machine-room on the other. The sorting-room should be provided with plenty of light, a northern aspect being the best, and efficient ventilation. It should also be near the machine-room on one side, and the dressed flax and tow-stores on the other. This arrangement entails less expense in handling, and less liability of spoiling the work or making waste through carelessness. This plan can, however, only be adopted in large establishments. In small ones, it is generally most economical to have these processes upon one floor, under the observation of a principal overlooker, but so arranged that the work shall proceed with the least interruption and handling, and in the most direct way.

Preparing.—On the efficiency and skill with which the "preparing" is performed, the best results almost entirely depend. Here the advantages of the preceding operations, however well managed, can be easily neutralized; whilst defective or negligent work at this stage cannot have its consequences eliminated subsequently. With practical knowledge and conscientious care at this point, from good material the very best results may be anticipated, whilst from an indifferent quality a product may be obtained that could not justly be expected.

The flax, dressed and sorted as previously described, is brought to the "spreading-frame," which is the first machine through which it passes in the preparation. Its function is analogous to that of the carding-engine in cotton manufacture, as the material in its passage through it is first converted into a sliver. It is a machine of about 10 ft. in length from back to front, and about 4–5 ft.

in width and height. A plain iron roller, called the "boss-roller," which may be 2–4 in. in diam., extends across the frame about $3\frac{1}{2}$ ft. above the floor, being supported by journals resting in bearings in the frame. In its front is a cast-iron plate with diagonal slits, called the "doubling-plate." These slits are equal in number to the rows of gills in each head of fallers. These gills and fallers are precisely similar in construction, and have the same function, as those described and illustrated in the article on Jute Manufacture, to which the reader is referred (see p. 1180–1). Upon the boss-roller, are pressing-rollers, composed of wood, and in shape corresponding to the bosses of the preceding roller. Two of these wood bosses are fixed upon one axle, and work in pairs. They are adjusted at the angle which will deliver the sliver to the doubling-plate in the best form. Upon the space between these bosses, are suspended hooks, to which springs adjustable by thumb-screws are attached, by which the force wherewith the presser-rollers bear upon the boss-roller can be graduated according to requirement. The back- or feed-rollers of the spread-board are set close behind the travelling gills, and at such a height as to allow the pins of the gills, when being lifted from the lower screws, to penetrate the fibre. Behind the feed-rollers, is a revolving leather apron; and between them, a conductor-plate. Fig. 927 represents the spreading-frame, as made by Fairbairn, Kennedy and Naylor, of Leeds.

927.



The operation is as follows: the attendant girl, called a "spreader," takes the pieces from the sorter's bunch, and divides them into as many portions as are consistent with the nature of the work in process—which may require light, medium, or heavy spreading, and then proceeds to lay them upon the revolving apron as evenly as possible, with the "top-end" nearest the feed-rollers, taking especial care not to toss the fibres, nor disturb their parallel arrangement. In this manner, the fibre is fed upon the revolving apron in an even and straight line down its length. Care is taken that each piece shall fall a little behind the preceding one, so that the feed thus formed may not enter the gills too heavy, and yield too thick a sliver. The flax, after being spread, is delivered by the revolving sheets into the conductors, thence passing through the feed-rollers to the gills, which travel slightly more rapidly than the feed-rollers revolve. The fibre is next delivered over brass guide-plates to the boss- and pressing-rollers, which have a much quicker revolution than the feed-rollers. By these, its foremost and longest portions are drawn quickly away in succession in a light, continuous, ribbon-like form, constituting the sliver. In this form, it is conducted to the doubling-plate, and passed through a diagonal slit under the plate, where it is joined by the others, except one from the same head, all passing together up through the last slit, where it unites with the outside sliver which has not been through a slit, and, in this combined form, the whole pass through the delivery-rollers and are deposited in long cylindrical cans, termed "sliver-cans." Upon the end of the delivery-roller, is fixed a small worm, which gears into a wheel, and this into another, called the "bell-wheel," one revolution of which rings a bell, indicating that a given length has been deposited in the can, which is then removed by the attendant, who immediately puts an empty one in its place. The tenuity of the sliver depends upon the lightness or thin spreading of the material upon the feed-aprons, and upon the draft of the boss-roller. These points are arranged according to requirement, and this having been accomplished, the weight of the sliver, or the number of yards per lb., can be perfectly controlled, being simply a matter of calculation.

The full cans from the spread-board are carefully weighed, a given number forming a set, which are to be subsequently doubled again into one sliver, for the purpose of eliminating any inequalities that may exist. In the next operation, the sliver from the spread-board passes to the first drawing- or "set-frame," so called from the cans containing the sliver being made into "sets" of a certain number, depending upon the number of rows of gills in the "head." These are usually 6 or 8, and as two slivers are put through each row, the number of cans required to form the set is 12 or 16. The set requires to be of a certain weight, and in order to obtain this with accuracy, the sliver-cans are made uniform in weight; this being known, they are weighed when full, and the nett weight of sliver in each is carefully marked upon the outside with chalk. The cans from each spread-board are marked with the number of the machine from which their contents have come, and are kept by themselves. When a set is required for one of the drawing-machines, the boy whose duty it is to provide it, selects from the stock of cans those whose weights will exactly make the total required. By this means, any irregularities that may exist in the sliver, owing to variation in feeding the machine, or other causes, are eliminated.

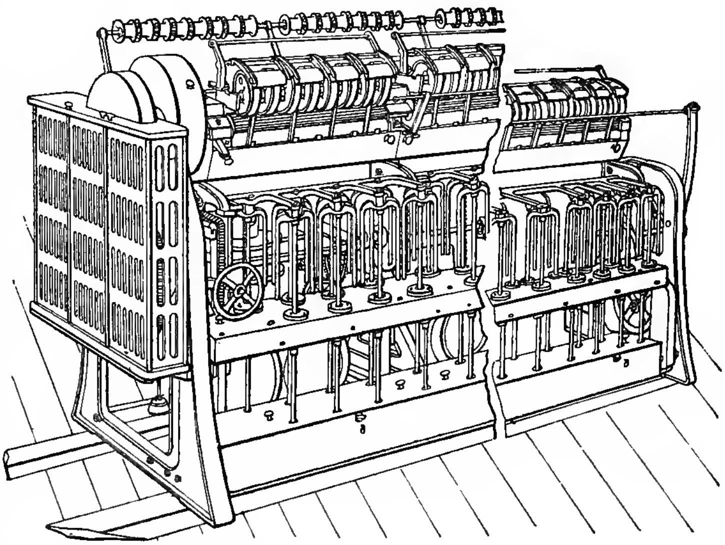
The drawing-frame is very similar in its construction to the spread-board, but is without the revolving apron or leathers, the place of these being supplied by rail and guide-pulleys, as the ribbon-like form of the sliver now requires. The feed-rollers and travelling gills are the same as in the preceding machine, except that the latter are arranged with their pins in a vertical position, whereas in the former, they were slightly inclined in the direction of their traverse. All the parts are finer and proportionately smaller, the work required from them not being so heavy as in the preceding machine.

The function of the drawing-, or 1st set-frame, is to double the sliver from the spread-board, further attenuate it by drawing, and enable the weights to be so regulated as to conduce most perfectly to the attainment of the desired end. In order that this may not be marred, close attention is required to all the details, it being especially requisite that care should be taken not to let any "single" pass through. "Single" is the term applied to the sliver, when, from breakage, or exhaustion of the contents of one can, the remaining sliver of the pair continues to pass on alone, so that on emerging at the front, it has only half the required substance and strength. Should this not be detected, it would seriously damage the yarn at the end. When discovered, it is pulled out of the can, or, if it has reached the roving-frame, and gone upon the bobbin, it is withdrawn from that. Those engaged in tending the machines can easily tell when the faulty portion has been drawn off, by the thickness of the sliver between their fingers. The "single" portion becomes waste, and is put into a receptacle provided for it. There are several causes which operate to produce single, besides the above, and in some cases, considerable damage to the gill-pins is also a consequence. Occasionally a fibre or two will lap around the pressing-rollers, and drag others with it, until in a very short time the whole sliver has been turned from its proper course, and wound round the roller, its fellow sliver going forward alone. Sometimes the lap becomes so thick that, when formed on the inside feed-roller, the gill-pins in rising penetrate it, the consequence being that they are strained or broken, which entails considerable loss, owing to the stoppage of the machine and the cost of repairs. Gills are frequently damaged from other causes, which cannot be detailed here. Single, if it has passed the roving-frame, and got upon the bobbin, may almost always be detected through the material upon the bobbin being much softer than the average, owing to its containing much less weight. There is generally attached to each machine an appliance whereby it can be stopped on the occurrence of any unusual strain upon the parts, and if maintained in good working order, this is usually sufficient to prevent the occurrence of much injury.

In each "system," or set of machines that work in succession to one another, there is the spread-board, and 1st, 2nd, and 3rd, and where a great amount of doubling is required, a 4th drawing-frame. In some cases, the last is omitted, and the sliver is instead put a second time through the 2nd, or other doubling-frame, as may be deemed suitable for the purpose. The latter plan, however, is only adopted when absolutely necessary, because it interferes with the orderly supply of sliver to the succeeding machines, the speed of which it is necessary to reduce, or otherwise allow them to stop. Other means are accelerating the speed of the drawing-frame, thus put to do double work; or increasing the draft; or a combination of these. None, however, is so satisfactory as the inclusion of a 4th drawing-frame. These last call for no detailed description, being merely repetitions of the others in every respect, except that the working parts are finer and smaller in proportion.

Roving.—When the material has passed the series of drawing-frames, in which it has been thoroughly opened, cleaned, doubled, and attenuated as sliver, without being twisted, it arrives at the last machine in the preparatory stage of its progress. This is the roving-frame, Fig. 928, a long rectangular machine, similar in its construction to the preceding, so far as concerns the possession of a series of "heads" of gills, traversed from back to front upon spiral screws, but differing in delivering the elongated sliver to revolving spindles, which twist and wind it upon the bobbins with which they are furnished. The roving-frame contains 4–7 heads, each having 8–12 rows of gills. The slivers from the last drawing-frame are passed singly—the doubling being finished—over the rows of gills, and are again further "drafted" in the process. The sliver has now become so attenuated that it is necessary to impart a little twist to it, so as to secure its coherence. This is accomplished by means of the spindle and flier, this machine being one of those belonging to the numerous group found in nearly all the textile industries, and known as "bobbin- and fly-frames." The mechanism of these having been illustrated and fully described in the article on Jute Manufactures (p. 1182, Fig. 869), the reader is referred thereto for further particulars. After having gone through the gills and delivery-rollers, the attenuated sliver passes downwards through the neck of the flier, next through a groove in the leg, and then through the eye to the barrel of the bobbin. Generally the arrangement is that the spindle shall "lead," and the bobbin "follow": that is, that the revolutions of the bobbin shall be so many less than those of the spindle, so as to enable it to wind up the roving as it is delivered from the rollers. When the spindles are filled with a set or "doff" of bobbins, as a full complement is called, the barrels are bare, and consequently at their least circumference, and will take up the rove at the slowest rate. In starting, therefore, they require to lag more behind their "leader" than at any other point. As the circumference of the barrel increases with every layer of rove deposited upon it, the rove would be taken up more quickly every time, and would consequently be first drafted much finer, and then broken, were the speeds of the flier and the bobbin constant at the proportionate rate at which work was commenced. But this result is obviated by the provision of an appliance by which the proportionate speeds are changed, the bobbin being accelerated as the circumference of its winding-surface enlarges by the addition of successive layers of roving. This is called the differential driving-gear, explained in the article on Jute, before referred to. Sometimes "cones" are employed to obtain the same result. When the latter are adopted, the upper cone is connected with the gearing of the frame, and its speed is constant. The driven cone is of the same shape as the driver, but is fixed in the reverse way: that is, the smallest diameter of one is set opposite the largest diameter of the other. The connection is by means of a strap, and this being traversed along the cones, gives a constantly varying rate of revolution to the driven cone, which is so adjusted as to accelerate the speed of the bobbin, until, when full, it very nearly equals that of the spindle. The belt is shifted on the cones about ¼ in., or other necessary distance, every time the traverse-rail in rising or falling arrives at the end of its course, and a fresh layer of rove has been placed upon the bobbin. After doffing the set of bobbins, and filling the frame anew, the differential driving-gear is readjusted, so as to commence again at correct speed.

928.



The temperature of the rooms in which preparing is carried on should be preserved as uniform as possible, not to fall below 15½° (60° F.), nor exceed 21° (70° F.). This is not difficult to accomplish in a well-found mill, and tends greatly to the production of satisfactory work. An excess of heat or cold, dryness or moisture, causes the sliver to lap round the rollers, the result being unsatisfactory work, diminished production, and increased waste. When, owing to atmospheric conditions, the air of the rooms is heavy with moisture, it should be warmed and dried by the introduction of steam into the warming pipes, regulated until normal conditions are restored. In the sharp, dry frosts of winter, or during the prevalence of dry east winds, the same tendency of the fibre to lap is often seen; in either case, the evil will be obviated by having a few jets in a steam-pipe and allowing the steam to blow into the room, when the moist particles are quickly absorbed by the dry atmosphere, and the fibre in process again becomes soft and pliable, following its proper course through the machinery. Where there is no provision for introducing steam in this manner, it will be convenient to sprinkle water upon the floor, in which case, hot water is best. Care must always be taken not to carry these proceedings to excess, and cause the atmosphere of the room to condense its moisture upon the machinery and walls, giving to everything a damp, clammy feel. Drafts or currents of air should also be carefully avoided, as provocative of the same mischief, whilst good ventilation should be provided. The rooms should also be furnished with sun-blinds to the windows, as excessive heat from direct sun-rays will also produce a similar effect.

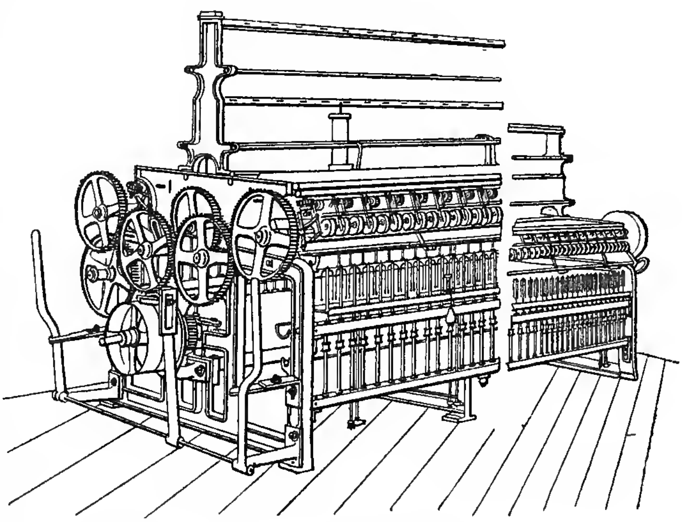
As in the management of all machinery, strict supervision should be maintained. Every part should be promptly supplied when broken or worn out, and the small essentials known as "mill furnishings," such as strapping, laces, banding, brushes, oilcans, oil, &c., whilst strictly dealt out, should never be denied in sufficient quantity. Though the aggregate charge resulting from this provision is considerable, economy in this would be at the cost of a more than corresponding depreciation arising from the extra wear and tear of the machinery, leaving out of consideration the inferior quality of the production. Thorough cleanliness should be insisted upon in every department. The machinery should be overhauled and cleansed at stated intervals. The reward for attention to these matters will be a large production, thereby diminishing the cost; a high quality, which will secure good prices in the market; a contented class of workpeople, earning good wages, and therefore not ready to quarrel with their employment; and last, but not least, a satisfactory balance-sheet at stock-taking.

Tow Preparation.—From the moment flax begins to undergo preparation for spinning and weaving, or any other divergent end, there is produced more or less "tow," or short broken fibre. This is principally obtained in the scutching, machining, and dressing processes, to which is generally added the sliver-waste produced in the more advanced processes. That obtained from scutch-mills has usually had the husk of the plant shaken from it, and is then sent to market as "scutching-tow," commanding only a few shillings a cwt. This is sold to coarse-tow spinners, who usually pass the material through a "shaker," by which it is more perfectly cleansed from the husk, after which, it is put through the "breaker-card." In other cases, it is preferred to get it rescutched over finer and lighter "handles" than those over which the flax was first put. The cost of performing this operation is about 4*s.* a cwt., whilst the produce obtained will not be more than $\frac{1}{4}$ of the quantity submitted to the process. Loss of weight and expense of cleaning bring up the cost to something over 1*l.* a cwt. Sometimes this class of tow is worked alone; in other cases, it is mixed with "milled tows," or those obtained from the processes of hackling, machining, and dressing in the flax-mill. The tow is first passed through a coarse card, and next through a finisher-card, after which it enters upon its course of preparation for being made into tow-yarn, which does not differ materially from that of line flax.

The "breaker-card" is a powerful engine with a large cast-iron cylinder, 3–5 ft. diam., and 4–8 ft. across the face. This is mounted upon a strong frame, and is almost surrounded by a series of smaller rollers of the same breadth, called "workers" and "strippers," all of which are covered or clothed with steel pins, of a size suited for the special character of the work they have to perform. A "feeding-sheet" or revolving apron is attached to the back, upon which the tow is evenly spread and slowly carried to the feed-rollers, by which it is delivered to the revolving cylinder. These rollers are about 3 in. diam., and have a surface movement of about 18–24 in. a minute. The direction of the revolution of the cylinder, at the point where it receives the tow, is downwards; and it consequently strikes the tow with great force in that direction. The pins with which it is clothed are generally about $\frac{7}{8}$ in. long, and are inclined in the direction of its revolution. These pins are set in "lags" or staves of wood, secured to the cylinder by screws. They are $\frac{3}{8}$–$\frac{5}{8}$ in. thick, 1 in. broad, and 24 in. long. The pins therefore protrude through them about $\frac{3}{8}$–$\frac{1}{4}$ in. The feed-rollers are also clothed with pins, those of the bottom one being slightly curved upward, as they present the tow to the pins of the cylinder, and therefore prevent the latter dragging in the material at too quick a rate. This resistance of the feed-roller secures a maximum of effective action, splitting and combing, on the part of the cylinder. It tends, however, to embed the fibre in its pins, and would, from this cause, soon destroy its efficiency, were provision not made to keep it clear. This is accomplished by the introduction of a third or "feed-stripper" roller, placed beneath, but sufficiently near for its pins, which are inclined towards the large cylinder, to strip the feed-roller by its greater speed. In its turn, it is stripped by the cylinder, whose surface velocity is again much greater. The cylinder, having received its full complement of tow, carries it forward to the "first worker," the second roller in the course of its revolution, which has about the same dimensions as the feed-stripper. This roller revolves at a slow rate, in a direction opposite to that of the cylinder, and as its pins are inclined so as to receive and retain the fibre from the cylinder, the latter is cleared, the material being split to a further extent by the action of the pins.

Revolving at a higher speed, and in close proximity to the first worker, is the first roller in the series which the cylinder passes after leaving the feed-rollers; this is the "first stripper," whose function is to strip the worker, and return the material to the cylinder. No splitting or cutting of the fibre takes place in this case, the duty of the stripper being merely to return the fibre from the worker to the cylinder. The number of workers and strippers is dependent upon the size of the cylinder, which will permit more or less to be arranged around its circumference. This again depends upon the requirement of the work, or what is called the "fineness of the card." When the tow has passed the series of workers and strippers, it is received by a large roller, called the "first doffer," clothed similarly to the workers, but not accompanied by a stripper-roller. It brings the tow to the front of the machine, at which position it is stripped from it, by the rapid oscillating stripper-knife in its front, in the form of a sheet; this is next divided into three portions, and each is passed between a pair of rollers, which calender and lay the fibre in the form of a sliver. Beneath the first doffer-roller, are one or two more of the same sort, having the same function, and stripped in the same manner, as the first. The slivers from all the doffers are received into a large can, and carried away to another machine, by which they are combined into the form of a lap, to fit them for the "second carding."

929.



The laps from the first carding are then placed in the second, or finisher-card at the back, in the position occupied by the feed-apron of the first machine, but which does not appear in this case. The finisher-card is in principle precisely like the first, differing merely in details. Its pins are finer and shorter, and its rollers more numerous and smaller, by which means, the tow is subjected to more treatment than in the first instance.

In the treatment of superior tows, a combined machine, called the "breaker- and finisher-card," is often employed, in which one operation suffices to do all that is required. In this instance, the tow is evenly fed upon the revolving apron, passes through, and is delivered in an even sheet, which is divided into a number of slivers, one for each of the front conductors. They are next passed through the conductors of the bottom doffer, over a polished cast-iron plate, called the "sliver-plate," and into the back conductors of a "rotary-card drawing-head," which is attached to the machine, and so-called because the traverse of the gills is accomplished by rather different means than the spiral shafts of the ordinary drawing-frame. The sliver then passes through a very coarse open gill on a short draft, which prepares it for the first drawing-frame. The rotary head has one, two, or three rows of gills, according to requirement. Altogether, it is regarded by many persons as a questionable improvement, and its application is far from being general. When it is absent, the sliver is carried direct to a drawing-frame, in which it is worked up into sets.

Tow-carding engines should be carefully set, so as to stand perfectly level. Proper lubrication ought never to be neglected, and the drums and driving-pulleys should be as large as convenient, in order to give the fullest purchase, and so secure the most even and economical driving, without which the sliver will suffer in quality, and make inferior yarn.

Spinning.—Spinning is the concluding process of this division. In it, the material which has come through the successive stages is converted into yarn, and forms in this condition a merchantable article. In many cases, flax-spinning establishments have weaving branches in connection with them, in which case, their production of yarn may be consumed upon the premises. In others, it is sent upon the market, and forms the supply which is drawn upon by establishments at which weaving only is carried on.

The spinning-machine, Fig. 929, like the roving-frame, is a "bobbin-and-fly" frame, and is made of such "pitch" or dimensions as the circumstances of individual spinners may lead them to select. They generally contain 200–300 spindles. In arranging the spinning-room, care should be exercised to secure a sufficiency of space, so that no part will be crowded, nor the necessary movements of the operatives impeded. Should the latter be the case, it is certain that some duties will be neglected, to the injury of the establishment. Light and ventilation ought to be provided to a full extent: the former to enable the spinners to see with ease whenever a thread has broken, or any other defect occurred; the latter, on account of the danger to the health of the operatives if they are permitted to work in foul air saturated with vapour arising from the great quantity of hot water employed in the wet process of flax-spinning.

A flax-spinning machine consists of a strong rectangular frame, about 3 ft. broad by a length proportionate to the number of spindles it contains. The latter are mounted in two rails, the lower one carrying the spindle-footsteps into which the base or foot of the spindle is inserted and revolves, the upper one containing the "bolster" or collar in which the "neck" of the spindle is enclosed, and by which it is maintained in a vertical position. Each spindle carries a flier on the top, and is furnished with a small pulley called a "wharve." Longitudinally through the centre of the machine, extends a tin cylinder; on the extremity of the shaft forming its axle, are fixed the driving-pulleys. Cotton driving-bands connect the cylinder and spindles, by which, motion is transmitted from one to the other. A traverse-rail, or "builder," having circular holes through which the spindles pass, is fitted to the machine in such a manner as to automatically rise and fall when the machine is at work. The bobbins are placed upon the spindles, and drop down until they rest upon the traverse-rail, which when at work carries them up and down to receive the successive layers of rove from the fliers. The fliers are next screwed upon the tops. The latter, having been several times already brought under the notice of the reader, need no further description. There is no independent driving power required for the bobbin, the drag of the thread being sufficient to pull the bobbin round; it lingers sufficiently behind, however, to take up the yarn as it comes from the rollers and is twisted by the revolving spindle. To retard the motion of the bobbin so much as is requisite to make it perform the function of winding on the thread with firmness, light bands are attached to the back of the traverse-rail behind the spindles, passed around the base of the bobbin, brought over the front of the traverse-rail, and allowed to hang down, having a small weight attached to the end. These are called "drag-bands." The friction or power exerted by these bands is varied by means of a comb upon the front of the traverse-rail. When the spinning is commenced, and the bobbins contain scarcely any yarn, they develop comparatively little centrifugal force, and therefore require little check upon them; as they fill, this force becomes greater, and the spinner has to advance the drag-band a groove or two upon the comb, so that it will increase its contact with the base of the bobbin, and exert a greater retarding power. The correct management of the drag-band is important in flax-spinning, as it is required to be accurately adjusted, to make good yarn and keep up the ends.

Within the past few years, a "spring self-acting drag-motion" has been introduced. It dispenses with the cord and weight, and, by a simple and ingenious arrangement, makes the dragging of the bobbin automatic, and keeps the necessary tension on each thread during the time the bobbins are being filled. The appliance consists of a peculiar angle-shaped metallic rod, arranged along the front of the traverse-rail or "builder." To this rod, are attached springs, one for each bobbio, the arms of which press against the bobbin, the pressure being regulated by means of a worm and ratchet-wheel. When the counts of yarn are changed, it is merely necessary to change the ratchet-wheel instead of all the drag-weights, as in the old method, which is an expensive system in both time and labour. The spinner is also relieved of all care of watching the individual bobbins, and is therefore at liberty to pay more perfect attention to the other portions of her work, or to take charge of an increased number of spindles.

The drawing-rollers of the spinning-frame are fluted, and composed or brass, in order to prevent oxidation through the presence of water necessary in the spinning process. The pressing-rollers are preferably of box, but several other woods are occasionally used.

The sliver-bobbins from the drawing-frame being placed in the "creel" or rack, the sliver is conducted from them into the hot-water trough, in which it is saturated, and then passes between the drawing- and pressing-rollers, by the action of which, the superfluous moisture is pressed out, and the sliver attenuated to the required extent; on emerging from the "nip" of the rollers, it receives the twist from the revolving spindles, and descends through the holes in the thread-plate, whence it passes to the flier, and is wound upon the bobbin in even layers by the rising and falling of the "builder" or traverse-rail. The bobbins having been filled, the fliers are unscrewed from the spindle-top; the set of full bobbins are "doffed" (removed) and replaced by another set of empty ones; the fliers are again put in their places, and spinning is recommenced.

Reeling, Drying, and Bundling are the subsequent processes necessary to complete the preparation of the yarn for the market.

"Reeling" is the operation of running the yarn off the spinning-bobbins upon reels of 90 in.

circumference, by which means, it is divided into measured lengths. It is a very simple operation, but its prompt performance is extremely important, owing to the fact that the yarn, having been "wet-spun," must be quickly cleared from the bobbins in order to be dried. Should this be neglected for a few days, it is probable that the yarn would be injured by mildew. The stock of bobbins required to keep the spinning-machines supplied is also so large that only few mills could keep their machinery at work more than three or four hours after the reeling process has been suspended. The bobbins when doffed by the spinner are put into boxes by the frame, and are fetched thence by children, who place them in "cages"—small boxes containing as many "pins" as there are spindles in one side of the spinning-frame, on which the bobbins are placed for transmission to the reeling-room.

Formerly the reels were worked by hand, as, owing to the very frequent stoppages, the application of power was difficult and unsatisfactory. Of late years, however, from the difficulty of finding an adequate supply of reelers, means have been devised to overcome these obstacles, and reels driven by power have come very generally into use.

In reeling, the chief care ought to be to keep up the threads, so that the hanks will not be short, as, being sold by measurement as well as weight, complaints would be received from the purchaser on this ground. The length is measured by the revolutions of the reel, which are indicated through a bell-wheel driven by a worm upon the axle of the reel. When the hanks are completed, of which there are 20–24 reeled at one time, each containing 3600 yd., the reeler doffs the frame by drawing out three wooden pins from the three spokes of one rail of the fly, which then drops down, and allows the yarn to become slack, and be easily stripped from the reel. Care must be exercised that they shall not be stained with oil in the stripping or other process, as it depreciates the value considerably, through the difficulty of clearing away the traces of this in bleaching or other subsequent treatment.

It is in the reel that the yarn is measured, and it will therefore be proper in this connection to introduce the yarn table which is used in the trade. The standard is 1 lb. of 16 oz. The particulars are as follows:—

Linen Yarn Table.

$2\frac{1}{2}$ yd.	(one rev. of reel)	=	1 thread
300 „	or 120 threads	=	1 lea or cut
3,600 „	„ 12 cuts	=	1 hank
60,000 „	„ $16\frac{2}{3}$ hanks	=	1 bundle
72,000 „	„ 20 „	=	1 reel
180,000 „	„ 50 „	=	1 3-bundle bunch
360,000 „	„ 100 „	=	1 6- „ „
720,000 „	„ 200 „	=	1 12- „ „

In speaking of the fineness of flax yarns, 1 lea-yarn would mean that there were 300 yd. in 1 lb., and 100 lea would imply $100 \times 300 = 30{,}000$ yd., and similarly of other numbers of leas. There is a system of "short-reel measurement," which is used mainly for convenience.

Flax yarns are generally dried over the boilers of the establishment, in apartments specially prepared to utilize the heat which is thrown off. The hanks are suspended upon drying-poles, which are made smooth, and painted, so that the yarn shall not be scratched and torn on splinters. The room in which the drying takes place requires to be well ventilated, so that the moist air can easily be drawn off. In some cases, it is desirable to use a "drying-machine," invented for the purpose, and which has been found very efficacious.

After being sufficiently dried, the yarn is next put up in bundles, and made into bunches of any desired size, containing 1–12 bundles, according to the lea, and the requirement of the manufacturer.

Weaving and its Preparation.—There is little to distinguish the weaving branch of the linen trade from that of the other textile industries (see Cotton Manufactures, Jute Manufactures). The yarn in the first instance, however, is carefully boiled and washed, by which, much of the natural gum upon the fibre is dissolved, and it is rendered more pliable. If the fabrics are intended to be white, the yarn at this stage is bleached (see Bleaching, p. 515), and if coloured, dyed. In both cases, it is dried after the process.

From the hank, it is next transferred to large bobbins in the winding-frame, a simple machine, not essentially different from similar ones described under other headings (see p. 768, Fig. 555). The bobbins are now transferred to the warping-mill or frame, which may be the old vertical reel-frame, or the more modern machine which puts the yarn upon a beam for the sizing-frame (see pp. 769–70, Figs. 556–7). In the sizing-frame, which is not materially different from that employed in the cotton trade (see pp. 770–7, Figs. 558–62), from which it has been adapted, the warp passes through a sizing-mixture, whose chief ingredient is Irish Moss (see Drugs, p. 814). It is dried by passing over steam-heated cylinders, contained in the same frame, and is delivered upon the loom-beam. Passing from here, it has the heddles attached in the usual manner—drawing-, tying-, or twisting-in, according to the description of the work. The warp is then ready for the next process.

Weft yarns have also to undergo a course of preparation, though shorter than the above. As it is identical with that described in Jute Manufactures (see p. 1185), it need not again be introduced.

The power-loom is now very extensively employed in weaving linen. For a considerable time, many difficulties were experienced in adapting it to this purpose, but, by perseverance, these were eventually overcome. They chiefly arose from the inelastic character of the yarn, which would not yield or stretch to the requisite distance to allow of the formation of a "shed," or opening of the warp for the passage of the shuttle by the operation of treading, without breaking large quantities of yarn. This was overcome by the invention of the oscillating carrier-beam, over which the warp passes on its way to the heddles. When the shed of the warp is closed, one of the two rollers composing this beam is raised by means of a cam upon the driving-shaft of the loom through a connecting-rod, so as to take up a portion of the warp. When the shed requires to be open, this roller is depressed, thus affording sufficient slack in the warp for a shed to be made by the tappets, without undue strain upon the yarn. This invention overcame the chief difficulty experienced, and has led to the introduction of the power-loom, and its successful operation, in the greatest portion of the trade in this country.

The power-loom employed in weaving light linens is almost identical with that of the cotton trade (see pp. 780–6, Figs. 566–570). Heavier fabrics require a correspondingly stronger loom, but this is nearly the only difference. Fabrics which differ from plain cloths necessitate the use of various attachments, such as twilling-motions, dobbies, jacquards, &c. The jacquard sustains an important part in the linen trade, being employed extensively for the production of damasks, table-cloths, and other ornamental linen fabrics. Of these, perhaps, it may be truly said that, by its aid, Belfast has produced the most perfect specimens of the textile art that have ever been fabricated.

Statistics.—The present condition of the linen manufacture is one of considerable depression, and its future is not regarded without anxiety by those to whom its prosperity is of the deepest interest. Cotton is the most dangerous rival it has to encounter, and the progress of the latter during the present century has to some extent been at the expense of linen. During the American civil war, and the consequent scarcity of cotton, linen fabrics were largely substituted, and the industry prospered greatly. With the return to normal conditions, and the prospect of a very low range of prices in the cotton trade, it is to be feared that the competition in the future will be still more severe, and to the disadvantage of the linen trade. But whatever may be the result of this, the products of the latter industry will always have a place, from the impossibility of a suitable substitute being found.

The following figures from the latest Returns upon the subject, and corresponding figures from the last preceding Returns, will be of interest.

FLAX FACTORIES IN GREAT BRITAIN AND IRELAND.

Countries.	No. of Factories.	Total No. of Spinning-spindles.	Total No. of Doubling-spindles.	Total No. of Power-looms.	Total No. of Persons employed.		
					Males.	Females.	Total.
England and Wales	101	190,808	28,439	4,081	4,812	10,176	14,988
Scotland	155	265,263	18,495	16,756	9,987	27,489	37,476
Ireland	144	808,695	18,048	19,611	17,036	39,306	56,342
Grand Total, 1879 ..	400	1,264,766	64,982	40,448	31,835	76,971	108,806
„ „ 1874 ..	449	1,473,800	81,335	41,980	37,931	90,528	128,459

In the above figures, no note is taken of the number of persons employed in cultivating the raw material, and handling it in the earliest stages; neither is there any cognizance of those engaged in the domestic branch of the industry, the Return covering only the establishments subject to inspection under the Factory Acts. A great portion of the decline exhibited in the five years is attributable to the decay of the English branch of the trade, which has retrograded fully 33 per cent. In Scotland, there is also a slight reduction; but in Ireland, there is scarcely any change.

Bibliography.—A. J. Warden, 'The Linen Trade' (1864); A. Renouard, 'Études sur le Travail des Lins' (Paris); 'Textile Manufacturer' (Manchester: 1874–); Flax Supply Association's Reports (Belfast: annual).

(See Cotton Manufactures; Fibrous Substances—*Linum usitatissimum;* Jute Manufactures; Lace.) R. M.

MANURES (Fr., *Engrais*; Ger., *Dünger*).

Every plant requires to be fed with certain substances, in order to attain perfection. The proportion of each substance needed by different plants varies considerably; but the substances themselves are the same in kind in almost every case, and consist principally of nitrogen, potash, phosphoric acid, lime, sulphur, soda, magnesia, chlorine, and silica. A productive soil contains all these elements in sufficient abundance, and will go on bearing crops incessantly, provided that all the plants which grow upon it be returned to it, either in a rotten natural condition, or as the excreta and remains of the animals feeding upon them. Further, it is well known that in so-called "new countries," it is possible to grow and remove crops from the same soil for many years in succession, without artificial aid, a fact which is due to the presence in the "virgin soil" of more than enough of the various or principal elements for immediate needs. But when this store has been exhausted by constant cropping, the plants become at first sickly, and, after a time, altogether refuse to grow. Then arises a necessity for enriching the soil by the addition of the ingredients in which it is wanting. This operation is known as "manuring"; while the materials thus supplied are called "manures." The "rotation" system of cropping, based upon the difference in proportion of the various elements required by certain crops, is very judicious; but it cannot be made to obviate the necessity for adopting artificial measures for maintaining the fertility of the soil. In the present condition of agricultural science, no attempt is made to supply a manure containing all the ingredients required by the crop to be grown, nor, except in rare instances, is an analysis made of the soil, in order to determine in what element it is deficient. The farming community are generally content to apply the article which the manufacturer chooses to send them, looking rather to its price than to its efficacy, and manifesting satisfaction according to the degree of its odour.

Manures may be generally divided into two kinds, natural and artificial.

Natural Manures.—Natural manures are farm-yard dung, sewage, seaweed, soot, nitrate of soda, and Stassfurt salts; these may be applied to the land without any previous preparation. Besides these, there are other natural products, of great value in agriculture, which, used in a raw state, are not in such a fit condition to be assimilated by the plant as after undergoing the treatment presently to be described. Principally, they are bones, fish, flesh, blood, and guanos. The preparation of "poudrette," or sewage treated with sulphuric acid, and dried, will be described hereafter.

Bones.—Though very slow in undergoing decomposition, bones are a most valuable manure, especially on light soils. They contain about 2–4 per cent. of nitrogen, and 50–60 per cent. of phosphates. They are seldom applied without having been first boiled to eliminate the fat, which may be done in ordinary coppers of large size. When it is desired to extract their gelatine, for glue-making and similar purposes, the boiling is effected under pressure (see Bones, p. 521). To hasten the fertilizing action of bones, they are almost always ground in a mill, after having become sufficiently dry from the boiling operation. The finer their state, the more rapidly will the crop be benefited by their application. One of the best forms of mill for reducing bones is that shewn in Fig. 930. This is a powerful and compact machine, with a cast-iron frame and foundation-plate, and when attached to a 10-H.P. steam-engine, or a water-wheel, it should crush and dress 15–20 tons daily. It weighs $7\frac{1}{4}$ tons, and the fly-wheel should make about 145 rev. a minute. It has two pairs of rollers, with cutters (made of cast-iron, and case-hardened) for crushing the bones, a revolving riddle for separating them into "rough," "half-inch," and "dust" or "quarter-inch," and a friction-sheave for preventing accidents to the cutters. Such a mill should cost approximately 250*l.*

930.

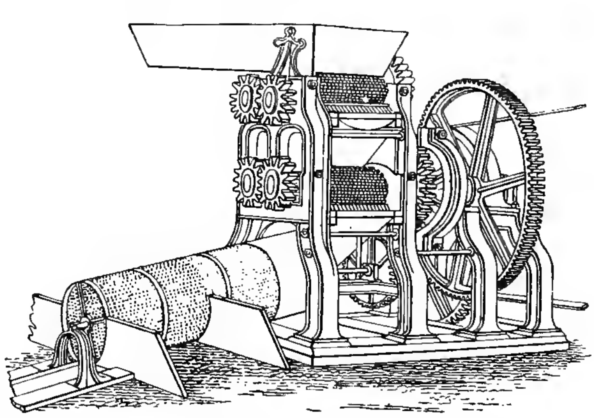
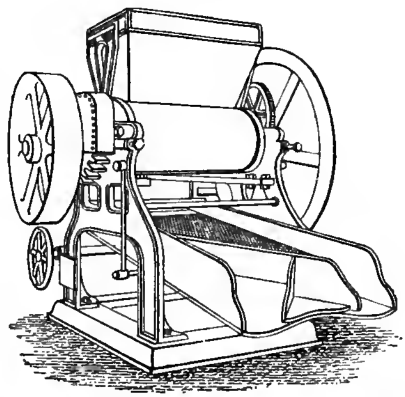


Fig. 931 shows what is known as a "dust bone-mill," consisting of a strong cast-iron frame, and two rollers furnished with steel cutters or saws, through which the bones, already ground by the mill just described, are passed, and thus reduced to dust. It requires 6-H.P.; weighs 26 cwt.; works at a speed of 240 rev. a minute; turns out 6 tons daily; and costs about 100*l.*

Occasionally, the ground bones are dissolved in sulphuric acid before use. This no doubt renders the phosphates more readily soluble, and available for the plant; but there is so much difficulty in drying the bones afterwards, that a large amount of free sulphuric acid exists in the mass, and destroys the sacks in which the manure is transported. There is also inconvenience in drilling-in the material with the seed, as is often done with dry manures. As an ingredient in other manures, however, e. g. "bone-superphosphates," &c., bones play an important part, and their presence in a superphosphate adds greatly to its value.

Fish.—Fish and fishery-offal are valuable fertilizers, rich both in phosphates and in nitrogen. In the Eastern Counties, and some other spots round the British coasts, they are sometimes applied in a raw state, when it is impossible to find a ready market for them as human food. They are often treated with sulphuric acid, in large leaden tanks, after having been pressed to extract the oil, which is, in itself, a valuable product, and whose presence would greatly neutralize the effect of the acid. In this country, very little care is bestowed on the preparation of fish-manures, and their quality varies suspiciously; but the Norwegians manufacture an excellent fish-guano, containing 25–30 per cent. of phosphate of lime, and over 7 per cent. of nitrogen. The guano-factories at Lerosen, Sanöen, and Lyngvœr produced 23,650 sacks (of 2 cwt.) of fish-guano in 1875, 23,061 in 1876, 22,561 in 1877, and 21,860 in 1878.

931.



The Americans are awaking to the value of fish-manures, and on many parts of the eastern coast of the United States, factories have been erected for the utilization of the shoals of menhaden, a fish of the herring family, which frequent those shores between April and November. In 1873, there were 62 factories at work on the coasts of New York and New England, catching at the rate of 1,193,100 barrels of fish, yielding 2,214,800 gal. of oil, and 36,299 tons of guano. Since then, the industry has much increased, particularly in N.-E. Long Island. The first step after catching the fish is the expression of its oil, which process will be described under Oils. The oil and moisture having been removed, the refuse fish is taken to the "scrap-house," and is known as "green scrap." In 24–48 hours, fermentation sets in, producing a darker shade, by the escape of ammonia; the material is then called "old scrap." In this state, it is transferred to a drying-room, where it is first subjected to a "picking" process, which consists in passing it through a cylinder armed with teeth revolving between set teeth, by which the whole mass is rendered uniformly fine. It is then dried, either in the sun, or by artificial heat. By the former plan, it is spread upon a sloping "platform," and constantly stirred by a wooden harrow, being finally gathered into a large heap, called the "cure," into which perforated pipes are inserted for conducting away any heat that may be developed. After about 4 turnings, it is cool enough for subsequent treatment. In wet weather, "platform curing" is replaced by artificial heat, which is a quicker process, but causes 10 per cent. more loss. The driers are revolving cylinders, with shelves running spirally through them. A fire is made at the front end; the hot air from this passes beneath the cylinder to the back end, and returns through the cylinder to the chimney. The drier is fed in front, and as it revolves, the scrap is carried up by the shelves to the top, whence it falls, to be taken up again in the same way. The archimedean arrangement of the shelves gradually works the material to the outlet of the cylinder. In a 25-ft. cylinder, revolving 8 times a minute, each charge takes about ½ hour to reach the back end, by which time its moisture will have been removed, and the material made ready for the "cure." If very wet, it may require 2–5 dryings. It is evident that the finest particles of the material will be carried off by the draught. Green scrap is mostly used for platform drying; old scrap, if very wet, is spread on the platform for 12–24 hours, before being put through the driers, or it would cake into balls. The dried scrap is ground and bolted in a special mill, consisting of two cylinders with cone-shaped bearing-faces, one making 2500 rev. a minute, the other 800. Analyses of dried fish-remains show 14 per cent. of phosphate of lime and magnesia, and 12 per cent. of nitrogen. Quantities of fish-"marc," or dried fish-refuse, are imported into this country for manufacture into nitrogenous manures.

Flesh.—Dried flesh forms a highly nitrogenous manure, and bids fair to assume a place in the market. It is principally derived from the refuse obtained in preparing Liebig's "extractum carnis," samples of which have shown 11–12 per cent. of nitrogen. In this country, horse-carcases are often dissolved in sulphuric acid, and applied as a manure; but their qualities are not superlative.

Blood.—The proportion of nitrogen contained in dry blood is very considerable, reaching 15 per cent. in thoroughly dried samples; but it is so difficult to remove even a portion only of the water, that its use is restricted to narrow limits, except as an ingredient added to manufactured manures.

Guano.—It is unnecessary to repeat the meaning of the word "guano," or a description of the material known by this name; but it is important to remark that the constitution of guanos is quite as varied as that of any other mineral phosphate. The nature of a guano seems to depend principally upon the climatic conditions under which it accumulates. The dry atmosphere of the Peruvian coast favours the formation of a nitrogenous guano; whereas similar deposits in moister climates lose all their ammonia, by decomposition and evaporation, and consist principally of phosphates insoluble in water; though, when removed before much decomposition has had time to ensue, they contain also a certain amount of nitrogen.

Phosphatic guanos cannot be used in a raw state, and are employed only in the same way as coprolites, or other mineral phosphates, in the manufacture of superphosphate. They will therefore be described under that head (see p. 1259).

By far the greatest proportion of the nitrogenous guanos, and certainly all the best of them, have come from Peru, or the islands on its coast. The most valuable has been the Chincha Islands variety, containing about 13½ per cent. of nitrogen, and the same amount of phosphoric acid. This was almost entirely used in a raw state, but the deposits have long since been exhausted. Following this, came other high-class kinds, such as Ballestas, containing 12½ per cent. nitrogen, and a similar proportion of phosphoric acid; Macabee, with 11 per cent. of nitrogen, and 12½ per cent. phosphoric acid; and Guanapi, yielding 10 per cent. of nitrogen, and 14¼ per cent. of phosphoric acid. But these also are fast disappearing, and are being replaced by still lower-class articles: such are Pabillon, having nearly 9 per cent. of nitrogen, and almost 14 per cent. of phosphoric acid; Independencia Bay, with scarcely 8 per cent. of nitrogen, and 10¼ per cent. of phosphoric acid; Huanillos, 7⅝ per cent. of nitrogen, but over 14 per cent. of phosphoric acid; Punta de Lobos, not reaching 6 per cent. of nitrogen, and containing nearly 18 per cent. of phosphoric acid; and some from the Lobos islands, giving little more than 3½ per cent. of nitrogen, while the phosphoric acid rises above 20 per cent. A very different species of Peruvian guano is the Angamos, which is freshly deposited, and obtainable only in small quantities. It contains almost 4 per cent. more nitrogen than even the Chincha Islands variety, with but 9 per cent. of phosphoric acid. The above figures distinctly indicate the extent to which guanos from the same country and climate differ in composition. The percentage of water varies also from 8 to 29 per cent. Most of these guanos contain a certain amount of all the elements essential in a good manure, besides the preponderating phosphoric acid and nitrogen. As much of the phosphoric acid present is combined with bases, in the form of phosphates which are insoluble in water, their effect upon the crop will be hastened by treating them with sulphuric acid, which possesses the property not only of rendering soluble much of the insoluble phosphate, but also of fixing the volatile carbonate of ammonium, and converting the uric acid present into ammonia. In applying crude guano to the soil, a considerable amount of ammonia will be evaporated and lost, unless the guano be completely covered with earth. This is prevented in a great measure by the treatment with sulphuric acid. Yet another advantage derived from dissolving the guano in sulphuric acid is that the great hygroscopic properties of the acid render the manure dry and powdery; this is especially advantageous when the sample of guano is very damp and sticky, as is generally the case. Very large quantities of guano are prepared in this way in Germany, and sold by analysis, on a basis of nitrogen equal to 9 per cent. of ammonia, and about 25 per cent. of phosphates, 20 of which are soluble.

The existence of bird-guano on the Jardinillos, a group of islands to the south of Cuba, has long been known, but only recently examined. Analyses from various portions give the following results:—Cayo Largo: N.-W., phosphoric acid, 24·02 per cent., = phosphate of lime, 52·43; W., phosphoric acid, 29·33, = phosphate of lime, 64·03; S. and S.-W., phosphoric acid, 28·98, = phosphate of lime, 63·27; Cayo Dios: (*a*) phosphoric acid, 28·83, = phosphate of lime, 62·94; (*b*) phosphoric acid, 26·53, = phosphate of lime, 57·92. The deposits are now to be worked for supplying the sugar and tobacco plantations, almost the whole of the phosphate being present in a soluble condition.

In many caves in Virginia and Texas, are found extensive deposits of bat-guano, in some instances amounting to several thousand tons. The deposits exhibit a dull-brown colour, and become finely pulverulent when dried in the air. They consist of the excrement of bats, more or less contaminated with soil, and their chemical composition places them almost on an equality with modern Peruvian guanos. Attempts to utilize them for the preparation of nitrate of potash, for gunpowder-making, have not been successful.

The climate of parts of the African continent also favours the preservation of guanos; but if the deposits are allowed to remain for any great length of time, they lose almost all their nitrogen. Thus, the now exhausted deposits from Ichabo and Saldanha Bay contained respectively but 6 per cent. and 1¼ per cent. of nitrogen; while the fresh accumulations yearly formed there, and collected immediately, yield as much as 12 per cent. and 9 per cent. of nitrogen respectively. The water present is also reduced: in the first case, from 27 per cent. to 17; and in the last, from 22 to 12. The thinness of the recent deposits, however, makes it difficult to collect the material in a condition free from foreign bodies, such as sand and stones.

Small parcels of nitrogenous guanos have been derived from many other spots; the quantity has, however, been insignificant, and the list may be concluded with two kinds from the islands of the Pacific Ocean. That known as "Baker's Island" contains nearly 35 per cent. of phosphoric acid; while "Jarvis Island" shows little over 20 per cent. of that element. In neither case, does the nitrogen exceed ½ per cent. These guanos have found a market in Germany, but are very little known in this country.

Artificial Manures.—The term "artificial" is applied to those manures which are never used save in a manufactured state. They may be conveniently divided into two classes, ammoniacal and phosphatic: the former represented by sulphate of ammonia; the latter, by the various kinds of superphosphates, nitrophosphates, bone-manures, turnip-manures, &c.

Sulphate of Ammonia.—In the distillation of coal for the production of illuminating-gas, the nitrogen is liberated as ammonia. This is retained in the water which is distilled over, and in the so-called "gas-liquor," from the scrubbers through which the gas is passed (see Ammonia, p. 246). The proportion of ammonia held in these liquids will naturally depend upon the character of the coal used. The ammonia thus recovered exists principally as carbonate, with smaller quantities of hydrosulphate, sulphate, hyposulphite, sulphocyanate, and chloride, of ammonium. This last salt in some cases represents 50 per cent. of the total amount of ammonia compounds procured in the water distilled with the gas, none but volatile salts being absorbed in the water descending through the scrubbers. Gas-liquor may be used directly as a liquid manure, provided it does not contain an appreciable amount of sulphocyanates (which are highly poisonous to vegetable growths), and that it be considerably diluted with water. It is far more common, however, to distil the ammonia from the liquor, and to collect it in sulphuric acid, as sulphate of ammonia. This salt is sold commercially on a guaranteed basis of about 24 per cent. of ammonia, or more than 93 per cent. of pure sulphate. When the proportion of nitrogen is very large, sulphocyanates may be suspected. Their presence may be detected by the formation of a blood-red colour on the addition of ferric chloride to an aqueous solution. If phosphates exist in the solution, the reaction can be observed only in the presence of hydrochloric acid.

The spent oxide of iron used for purifying gas also contains some ammonium salts, principally sulphate, with a little sulphocyanate. This may be washed out and utilized.

When the gas is purified by sawdust soddened with sulphuric acid, the purifier will contain, when dry, about 12 per cent. of nitrogen, which is equivalent to more than 50 per cent. of ammonium sulphate. It is not all present as sulphate, however, cyanides and sulphocyanates existing also; but it is said that the sulphocyanic acid evaporates by keeping the material in bulk for some time, and, being very volatile, it can certainly be easily expelled by hydrochloric or sulphuric acid in the presence of heat.

Commercial sulphate of ammonia is a white or pinkish-coloured crystalline mass. It may be readily applied in the form in which it is sold by the gas-companies, and other manufacturers of the article. It is also occasionally added to other fertilizers, in order to increase the percentage of nitrogen.

SUPERPHOSPHATES.—"Superphosphates," using the term in its widest sense, consist principally of phosphatic minerals treated with sulphuric acid, for the purpose of rendering the phosphates soluble in water, and therefore easily accessible to the plant. It is not by any means certain that the phosphates would not be rendered soluble in course of time, if applied to the soil without previous treatment with sulphuric acid; on the contrary, in some parts of Germany, are found deposits of mineral phosphates, which contain so much iron and lime in proportion to their phosphoric acid, that they cannot economically be used in making superphosphates, and these are applied to the land in a raw state. But the point aimed at is to supply material for the sustenance of the crop immediately to be grown, and it is small consolation to apply a dressing whose effect will not be seen for years. Therefore, except under such abnormal conditions as those stated, all mineral phosphates are dissolved in sulphuric acid, before application to the ground.

The many varieties of superphosphate are in accordance with the diversity of material used in their production. As all the mineral phosphates employed, and which form the bulk of this class of manure, undergo the same preparation, a description of the manufacture may be preceded by a notice of the most important species of this raw material.

Mineral Phosphates.—The value of a mineral phosphate may be adjudged in a great measure from its chemical composition. The first thing necessary is a large proportion of combined phosphoric acid, yielding, after manufacture, soluble tribasic phosphate of lime,—always the chief ingredient upon which the worth of a superphosphate is estimated. But it must not be taken for granted that the mineral containing the most phosphate of lime will yield the greatest proportion of soluble tribasic phosphate, for this is by no means certain. The presence of several other substances will greatly detract from the value of the sample. These are principally free oxide of iron, alumina, fluoride of calcium, silica, and carbonate of lime.

Free oxide of iron and alumina act detrimentally in two ways:—firstly, by absorbing and wasting a large amount of sulphuric acid; and secondly, because superphosphates made from minerals containing large proportions of these materials have a tendency to "go back" in standard, that is to say, that a portion of the soluble phosphate becomes, after a time, insoluble again. It may therefore happen that a mineral poor in phosphoric acid, and free from these compounds, will yield a manure of greater value than another mineral having more phosphoric acid, but contaminated with these deleterious ingredients. Iron existing as pyrites is not so mischievous, as it remains undissolved.

Fluoride of lime is objectionable chiefly as an absorbent and waster of sulphuric acid, while the gas evolved from it is highly unpleasant and unwholesome. The same may be said of chloride of lime. Their presence must also decrease the proportion of soluble phosphate.

Siliceous matters have no chemical effect upon the process either one way or another; but, by adding to the weight and bulk of material, they lower the proportion of soluble phosphate.

Carbonate of lime is objectionable, when in very large proportions, from causing a waste of acid, and reducing the proportion of soluble phosphate, as any other foreign body must do; but it possesses, on the other hand, a physical property which renders welcome its presence in moderate quantity, that is, that the carbonic acid liberated on its conversion to sulphate of lime remains in the mass for a time in a gaseous form, and thus produces in the finished manure a certain porosity or lightness, which is very desirable; and, at the same time, the sulphate of lime formed causes the manure to dry rapidly, which is one of the most important points to be attained in practice.

These remarks will be quite sufficient to indicate that, while taking the chemical analysis of a phosphate as a groundwork, it will be necessary to supplement this (supposing the analysis, of course, to warrant it) by actually trying the material with regard to the amount of acid it requires, and its physical and chemical conditions, when newly made, and after a lapse of time.

A more detailed description will now be given of the mineral phosphates principally employed in the manufacture, and of those waste products from other branches of industry which are now made to contribute towards the production of artificial manures.

Coprolites.—The name "coprolites" is given to a large class of mineral phosphates, existing as nodules and fossils, in strata of various geological ages, and scattered widely over the globe. They have been supposed to be fossil animal excreta, but it is at least doubtful whether that is the true origin of all coprolites.

The most valuable beds of the mineral in this country are in the Upper Greensand formation, lying chiefly in Cambridgeshire, and merging into Buckinghamshire. These are known as "Cambridge" coprolites, and formed at one time almost the only mineral phosphate employed in this country. They are of a greenish-grey tint, and are washed from a stratum not exceeding 1 ft. in depth. Hitherto, their standard of tribasic phosphate has been very constant; but deterioration is now often visible. They contain more carbonate of lime than the other coprolites, while the iron present is almost entirely as sulphide and silicate. The principal ingredients vary as follows:—Tribasic phosphate of lime, 54–60 per cent.; carbonate of lime, $11\frac{1}{2}$–$18\frac{1}{4}$; fluoride of lime, $1\frac{3}{4}$–$4\frac{1}{3}$; oxide of iron and alumina, $3\frac{1}{4}$–$5\frac{1}{4}$; insoluble siliceous matter, 6–$8\frac{3}{4}$.

Suffolk coprolites are another variety, raised in that and some adjoining counties, from beds adjacent to the London clay, in the Tertiary formation. That decomposed organic remains have at least been the origin of their phosphoric acid, can scarcely be questioned; but it is doubtful whether these coprolites are of the same character as the "Cambridge," and whether they have not rather been calcareous pebbles, metamorphosed by the action of phosphoric acid. They were the first coprolites used in this country, and monopolized the market till better varieties were discovered; but they are much inferior to Cambridge, in containing less phosphoric acid, and much more oxide of iron and alumina. Alone, they are not sufficiently good for making a superphosphate which shall yield at least 25 per cent. of soluble phosphate; but they may be used with richer phosphates, such as Cambridge coprolites, in the proportion of 3 parts of the former to 1 of the latter. They much resemble Cambridge coprolites in shape, but are very hard, with a smooth surface, and brownish-ferruginous tint. Their tribasic phosphate of lime averages about $52\frac{1}{2}$–$61\frac{1}{4}$ per cent.; carbonate of lime, 10–$17\frac{1}{2}$; fluoride of lime, $1\frac{1}{2}$–$4\frac{1}{3}$; iron and alumina, $4\frac{3}{4}$–$10\frac{1}{2}$; and insoluble matters, $9\frac{3}{4}$–$12\frac{1}{4}$.

At Potton, in Bedfordshire, coprolites are quarried from the Lower Greensand formation; on the whole, they are inferior in quality to the preceding. The larger nodules equal "Cambridge" in proportion of phosphoric acid, but contain more oxide of iron; the lesser nodules are of very poor quality. The colour is reddish. Their approximate composition is:—Tribasic phosphate of lime, 30–$54\frac{1}{3}$ per cent.; carbonate of lime, 5–8; fluoride of lime, 4; iron and alumina, 8–20; insoluble matters, 15–25. The nodule bed is intercalated in a deposit of coarse ferruginous sand, and is exceedingly variable in thickness. The sand extends to the north-east of Sandy Heath, by

Everton, Gamlingay, and Caxton, but the phosphatic bed has not been discovered in this direction. The extension of both the sandy and the phosphatic beds in a south-westerly direction is determined by the river Ivel. The beds reappear at Ampthill, where they are worked for the coprolites, and may also be traced in the neighbourhood of Woburn and Leighton.

Wicken coprolites are an inferior kind from Cambridgeshire, generally resembling the Suffolk variety, and composed approximately of:—Tribasic phosphate of lime, 36 per cent.; carbonate of lime, 10; fluoride of lime, 2; iron and alumina, 12; insoluble matters, 28. The phosphatic nodules are embedded in a sandy matrix, and are of two colours, light and dark: the former resemble those of Potton; the latter are characterized by a smooth exterior, and a smaller percentage of phosphate. The workings have been abandoned for some time.

Another Upper Greensand coprolite is raised in the neighbourhood of Boulogne, and sent over to this country, for use with higher class phosphates. It occurs in large grey nodules, with frequent organic débris, and is widely distributed along the north-eastern coast of France, from Havre to the Flemish border. Though poor in phosphoric acid, its impurities are principally non-deleterious, and therefore its phosphate is more easily available. Analyses by Voelcker of 5 samples of Boulogne coprolites gave respectively:—Tribasic phosphate of lime: 45·97, 46·43, 46·43, 45·19, 38·61 per cent.; carbonate of lime: 8·07, 11·93, 10·27, 8·95, 11·66; fluorine (3 samples): 2·08, 2·77, 4·96; oxide of iron: 2·89, 3·63, 3·54, 6·24, 3·52; alumina: 3·09, 3·66, 3·64, 5·39, 4·94; insoluble siliceous matters: 24·98, 23·56, 24·93, 26·16, 28·45. France possesses two other important deposits of coprolites, known as the Ardennes and the Bellegarde beds. The former are of greater importance than the Boulogne coprolites, and are largely and successfully used in French agriculture, as a simple finely-ground powder. The annual production of these beds was estimated at 25,000 tons in 1872, and has very materially increased since. The Bellegarde coprolites may possibly exercise some local influence, but the low proportion of phosphoric acid in the material will prevent its wider application.

Coprolites are also said to be abundant in Germany, and to occur sparsely in Canada. Russian coprolites are, perhaps, rather better known, but they are of very poor character, giving:—Tribasic phosphate of lime, 33–48 per cent.; carbonate of lime, 5½; fluoride of lime, 3½; iron and alumina, 6; insoluble matters, 30¼–43.

Apatite.—Apatite is a definite crystalline mineral, and is the purest phosphate met with in an inorganic state. There are two varieties, known as "fluor-apatite" and "chlor-apatite," according as the lime not existing as phosphate is combined with fluorine or chlorine. Sometimes both forms are present. These minerals are found in veins, in primitive formations and volcanic rocks, principally in Scandinavia and Canada, but also in Bavaria, Bohemia, Saxony, and Switzerland, as well as in New York and New Jersey, in America. As they contain from 75 to over 90 per cent. of tribasic calcium phosphate, they are a valuable source of phosphoric acid, but a well-conditioned superphosphate can hardly be made from them alone. They answer admirably, however, in conjunction with phosphates containing less phosphoric acid and more carbonate of lime. They are very hard, and of vitreous appearance, with a colour varying from yellowish to greenish-white.

The vein of chlor-apatite, which was discovered some years since on the southern coast of Norway, has been worked on a considerable scale by the Bamble Phosphate Co., and others. The expense of preparing the rock for market by hand-trimming is great. The present annual production barely reaches a few thousand tons; while the extent of the deposit was estimated at 75,000 tons. Sometimes the mineral yields as much as 90 per cent. of phosphoric acid in bulk, but generally it does not exceed about 75 per cent. It consists essentially of:—Tribasic phosphate of lime, 75–90¾ per cent.; chloride of lime, 1½–4¼; iron and alumina, 2–3; siliceous matters, 1½–11½. Some samples also contain about 1½ per cent. of fluoride of calcium.

The Canadian variety is imported to a greater extent than the foregoing. It is a fluor-apatite, sometimes containing also carbonate of lime, which is said never to be the case with the Scandinavian mineral. Analyses show:—Tribasic phosphate of lime, 65–91 per cent.; fluoride of lime, 7½; chloride of lime, ¾; siliceous matters, 1–10½. The deposits consist of pockets or bunches, of crystalline structure, embedded in granite, gneiss, and mica-slate. Their occurrence in widely separated pockets, the cost of excavation and hand-trimming from the accompanying rock, and the great expense of transportation, combine to limit their consumption. The production hitherto has not been much above 10,000 tons annually, even if it has always exceeded 5000 tons. New England and Great Britain absorb almost the whole quantity raised.

Phosphorite.—The mineral known as "phosphorite" is a fluor-apatite, contaminated with quartz, and differing from all other phosphates in being pyro-phosphorescent. It is found principally in Spain and Portugal, and especially in the Spanish province of Estramadura (whence its common name of "Estramadura phosphate"); also at Arnberg, in Bavaria. It is a hard, yellow-tinted, crystalline body, moderately free from iron and alumina, and often wanting altogether in carbonate of lime. It yields a high class superphosphate, from 30 to 33 per cent. of its phosphate being rendered soluble; but the lack of carbonate of lime makes it non-porous, and difficult to get into a powdery condition. It is imported largely from Spain. Samples from cargoes indicate the following variations in its composition:—Tribasic phosphate of lime, 53–86 per cent.; carbonate of lime, 0–10½; fluoride of lime, 1–3½; iron and alumina, 1¼–4; insoluble matters, 4–21. Logrosan and Caceres are the two principal localities where the mineral is found in Spain. At the former place, are several distinct veins of phosphorite. The rock is blasted out, and the large pieces are cleaned by hand and hammer, and then assorted into high and low grades. The pieces of trimmed rock average 3–4 in. in thickness. The shipment necessitates great trouble and expense. The mineral is transported in heavy waggons, drawn by mules or oxen, and carrying 2–2½ tons, to the railway at Villanueva de la Serena. The cost of transport and handling till the phosphate is put on board at Lisbon amounts to almost 40*s.* a ton, and the expenses reach 60*s.* by the time it is landed in England. A railway to Villanueva would greatly reduce the cost, and would permit the delivery of enormous quantities of the material, to the exclusion of Carolina and other low-grade phosphates. This phosphorite may be depended on as yielding 75–85 per cent. of bone phosphate of lime, it can be raised and laid down at the mine's mouth for 12*s.* a ton, and it exists in enormous quantity. The construction of a railway or tramway as indicated would probably enable it almost to monopolize the markets of Europe.

On the other hand, the Caceres mines are more important at present, and form the chief competitors with Carolina phosphate in the English market. From 1866 to October 1875, the principal company at Caceres had furnished about 125,000 tons, receiving 8–14*s.* a ton, according to quality, for the rock at the mines. The cost of transport to Lisbon amounts to about 32*s.* a ton. Analyses of the mineral show bone phosphate of lime averaging 60–65 per cent. The total recent production has been about 25,000 tons yearly. Most of it comes to England, France consuming only a few thousand tons, and Spain itself none at all.

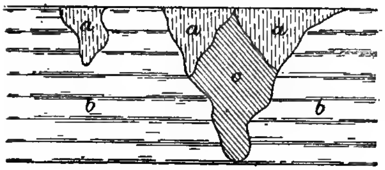
Phosphates.—Under the head of "phosphates," are included the remaining known phosphatic minerals, save a few non-nitrogenous guanos, which, however, resemble the Peruvian guano in little besides name. The best known phosphates are those occurring in pockets or patches in limestone formations in France (Bordeaux), Germany (Nassau), and Carolina; less important are the Russian and Bukowina varieties; while immense quantities are derived from the West Indian islands of Sombrero, Navassa, Maracaibo, St. Martin's, Curaçao, Oruba, and Pedro Keys. Besides the preceding, which are all phosphates of lime, there are two varieties of phosphate of alumina, known as Redonda and Alta Vela.

The French phosphate is raised in the departments of Lot and Tarn-et-Garonne, and is shipped to this country in large quantities from Bordeaux. It exists in fissures and cavities in the limestone, varying much in size and shape, whose whereabouts is generally indicated by outcropping threads of the mineral. It seems to be an aqueous deposit, and is sometimes found at but a short depth beneath the surface, in thin layers, underlying alluvial soils, which also contain a large proportion of phosphates, associated with iron and other impurities. This surface layer is unfit for manufacture, but is used on the spot in a raw condition. The appearance, quality, and texture of the mineral vary considerably. The richest specimens are hard, of white colour, and break with an earthy fracture. The bulk of it is harder and more compact, of a dark-yellow or brown tint, containing about 70 per cent. of phosphate; while some that is raised is of still poorer quality, dark-agate coloured, of waxy lustre, and seamed with veins of oxide of iron. This last has no important commercial value. The beds are principally in English hands. The best sorts, containing 70–80 per cent. of phosphate, and very free from oxide of iron and alumina, form superior manures; but as the phosphate decreases, the iron, &c., increase, so that the low grades are worthless for manufacturing purposes. The standard of the commercial article varies as follows:—Tribasic phosphate of lime, 50–80 per cent.; carbonate of lime, 8–15½; iron, alumina, fluorides, &c., 4–13; siliceous matters, 2½–19.

The phosphorites of the south occur in the three departments of Tarn-et-Garonne, Lot, and Aveyron. Fig. 932 shows a geological section of the bed as met with at Caylus (Tarn-et-Garonne): *a*, red clay; *b*, Jurassic limestone; *c*, phosphorites. These phosphorites are enclosed in cavities, resulting from the upheaval of the Jurassic formation, and are supposed to have been produced by the infiltration of phosphated water, and the subsequent evaporation of the water. The mode of occurrence of the phosphatic nodules of the *Tun* series, worked at Lezennes, in the department of Nord, is shown in Fig. 933: *a*, Tertiary sands; *b*, chalk; *c*, freestone; *d*, phosphates of the *Tun* series, in green chalk; *e*, chalk and flints. The phosphate beds at Mans, in Maine, occur as shown in Fig. 934: *a*, yellow sand in inclined beds; *b*, sand and sandstone blocks; *c*, foliaceous clay; *d*, sand and sandstone blocks, with nodules of phosphate; *e*, yellow sandstone. In the Ardennes, Orne, Eure-et-Loire, and Perche, phosphatic beds are found in the *Gaize*. A geological section of that of Céton (Orne) is shown in Fig. 935: *a*, siliceous clay; *b*, chalk containing pecten and asper fossils; *c*, *Gaize*, beds of nodules; *d*, astarte limestone. Nodular phosphates in the Gault are abundant in the departments of Ardennes, Pas-de-Calais, Meuse Aube, Haute-Marne, Yonne, Marne, Isère, Doubs, Haute-Saône, and Alpes-Maritimes. At

Wessant (Pas-de-Calais), they present a section as shown in Fig. 936: *a*, disturbed ground; *b*, small phosphatic bed; *c*, Gault limestone; *d*, bed of phosphatic nodules; *e*, green sand; *f*, green sandstone; *g*, pebbles; *h*, river. The phosphate of lime of the Lower Oolite occurs at St. Vigor (Calvados) as shown in Fig. 937: *a*, disturbed ground; *b*, white oolite; *c*, ferruginous oolite; *d*, beds of phosphatic nodules; *e*, bed of phosphate of lime; *f*, millstone grit; *g*, bed of

932.



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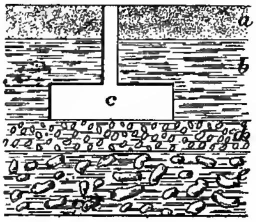

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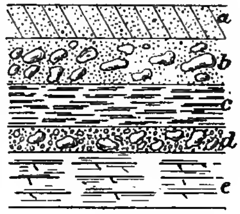

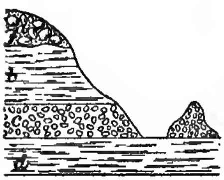

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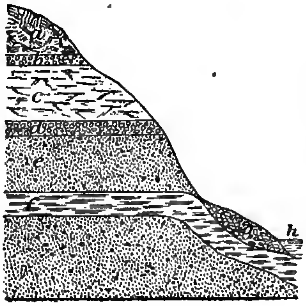

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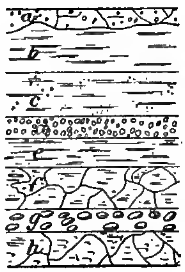

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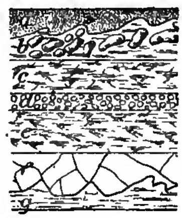


938.

flints; *h*, millstone grit. At Poillé (Sarthe), the nodular phosphates of the Lias present the section indicated in Fig. 938: *a*, Tertiary sands; *b*, siliceous clay; *c*, marl, and Upper Lias limestone; *d*, phosphate bed; *e*, marl, and Middle Lias limestone; *f*, Middle Lias conglomerate; *g*, Carboniferous limestone.

No new deposits have lately been discovered in these regions, despite continued and careful prospecting; and an impression prevails that the better part, both in quality and quantity, has already been sent to market. The production has reached 20,000 tons a year.

The German or Nassau phosphate occurs in a manner very similar to the last-named, near the rivers Lahn and Dill, in the Rhine basin. It is also equally variable in composition and aspect; sometimes it breaks with an earthy fracture, and is of yellow hue; again it will occur as a phosphatic concrete, cemented by ferruginous matter; and the crystalline form is not unknown. The best sorts are fairly free from iron, and make a good dry superphosphate; but they set extremely hard. For a time, they were abundantly used here, but the supply is now trifling. The lower qualities, like those of the Bordeaux mineral, are useless for manure-making, and for identical reasons. They are similarly employed in a raw state on the spot. The better classes have a varying constitution, as:—Tribasic phosphate of lime, 58–71 per cent.; carbonate of lime, 4½–8; iron and alumina, 4½–15; insoluble matters, 2½–12. It possesses a distinctive peculiarity in the presence of appreciable quantities of iodine, which is often driven off in violet vapours, on the addition of sulphuric acid.

South Carolina or Charlestown phosphate is very similar in composition to the best coprolites, but differs widely from them in appearance. It is found in the calcareous formation of the Charlestown basin, partly underlying the city, and occupying an area amounting altogether to perhaps 50–60 square miles. The deposits are distinguished as "land" and "river," each having its own peculiarities. The mineral occurs in rough nodules, perforated by boring molluscs, and associated with marine and terrestrial animal fossils, in thick strata of clay and sand, the cavities in the phosphate being mechanically filled with these substances, from which they can be cleansed by washing. The phosphate appears to be a converted Eocene marl, and is very uniform in composition. The river phosphate is of dark-grey colour, and is obtained by dredging in the Bull, Soosaw, and Stono river-beds. It is much the harder of the two varieties, and is difficult to grind; but is very superior for superphosphate-making. Though not containing so much phosphoric acid as the best Cambridge coprolites, it is distinctly preferable to them, on account of its much lower percentage of carbonate of lime consuming less acid; also by reason of the pyritous nature of nearly all the iron, and from its possessing physical characters which enable the acid to act on it with much better effect. It has replaced Cambridge coprolites to a great extent in this country. Its composition is represented as follows:—Tribasic phosphate of lime, 54–58 per cent.; carbonate of lime, 12¾–14; fluoride of lime, 1–2½; iron and alumina, 3½; insoluble matters, 13½–15. It is now often dried in hot-air flues before exportation, and is then called "calcined phosphate," yielding:—Tribasic phosphate of lime, 57½–59 per cent.; carbonate of lime, 11¾; siliceous matters, 12¾. The land phosphate is inferior to the other in most respects, and is consumed almost entirely in home markets. It has a yellowish colour, and is softer, and more easily ground; but more difficulty and expenditure are entailed in cleansing it than is needed with the river kind, which can be washed at the same moment that it is dredged up. For this reason also, combined with the presence of its iron as oxide, it yields a lower grade of soluble phosphate, and is consequently less valuable. The mean of eleven estimations gives:—Tribasic phosphate of lime, 53½ per cent.; carbonate of lime, 8¾; iron and alumina, 7¼; siliceous matters, 14.

Russia is said to possess some 12,000 square miles of phosphate-producing country, but analysis indicates nothing higher than 33 per cent. of tribasic phosphate. In the Bukowina, also, there are some deposits, declared to be rich on the average. The Russian phosphate occurs generally in the strata of the Cretaceous formation; it is also found in the Jurassic, Tertiary, and even Silurian. An examination into its commercial value led to the conclusion that, where the phosphate is accessible, its quality is too low to admit of more than local utilization; while the richer nodules, disseminated as they are throughout a compact formation, cannot be mined profitably. Only one attempt has been made at local agricultural utilization of these vast deposits: that ended in failure.

Of the large class of "rock-" or "crust-" guanos from the coral islands of the Caribbean Sea many are called "guanos," without any regard to their origin, which in some cases remains in obscurity. Seeing that they contain no trace of nitrogen, the term "phosphate" seems more appropriate.

The most important and valuable variety is named after the island of Sombrero, on which it is found. The islet, which is only about 2½ miles long, ¾ mile wide, and 20–30 ft. above the level of the sea, may almost be said to be composed of phosphatic materials; and the fragments of bones, found in the rock, have led to the supposition that the remains of turtles and other marine animals may have collected in the coral, while it was yet a shoal, and that bird-droppings assisted in cementing the mass together. The phosphate varies in colour, and is sometimes porous, at other times dense. It is at present worked below the waves, and probably the coral foundation on which it rests is now almost reached, as the mineral contains much more carbonate of lime, with less of iron and alumina, than formerly. Dissolved alone, it makes a very superior superphosphate, of light-yellow hue. It contains:—Tribasic phosphate of lime, 69–76 per cent.; carbonate of lime, 12–17; iron and alumina, 4–10; insoluble matters, 1–2.

Navassa phosphate exists in the form of pisolitic grains, of bright-red colour, cemented into hard masses, in the rock-cavities of the island whence it is named. It contains only a moderate amount of carbonate of lime, but its proportion of iron, and still more of alumina, is so great that it is impossible to make a superior superphosphate from it alone; moreover, the toughness and stickiness of the material during manufacture, and the hardness with which it ultimately sets, are additional drawbacks. Its large proportion of phosphate makes it useful for admixture with poorer materials. Its principal component parts are:—Tribasic phosphate of lime, 55–70 per cent.; carbonate of lime, 4–6; fluoride of lime, 0–2; iron and alumina, 23–28; insoluble matters, 3¼–5.

Maracaibo or Monk's Island produced a very superior phosphate, which was principally used in manufacturing the so-called "phospho-guano," but which is now exhausted, or nearly so.

St. Martin's Island, of the same group, now yields a valuable article, but which sometimes contains a large proportion of carbonate of lime. It varies thus:—Tribasic phosphate of lime, 52¾–76½ per cent.; carbonate of lime, 15–32¼; iron and alumina, 2¾–4½.

The island of Curaçao furnishes a valuable phosphate of lime, in an unmineralized and finely divided state, which may be applied in its natural state, or employed to manufacture very superior superphosphates, as much as 38 per cent. of soluble tribasic phosphates having been got out of a damaged sample showing only 65 per cent. of tribasic phosphate before treatment. The possibility of attaining such a high standard, even from a comparatively inferior sample, is due to the fact that none of the phosphate appears to be contaminated to any extent with iron and alumina, and that carbonate of lime and siliceous matters are almost equally conspicuous by their absence. The proportion of tribasic phosphate of lime rises as high as 80 per cent., and averages about 70.

Another of the Leeward Islands, called Oruba, yields a tolerably rich phosphate, but it is apt to be strongly contaminated with iron and alumina. It chief ingredients are:—Tribasic phosphate of lime, 63¼–76¼ per cent.; carbonate of lime, 2¼–15¼; iron and alumina, 14½–26½.

Redonda and Alta Vela Islands produce phosphates in which the lime has been entirely, or nearly so, replaced by alumina; these are, therefore, quite valueless for manuring purposes.

There remain but the phosphatic guanos to be mentioned. The best of these is procured from Mejillones, on the Bolivian coast, and is employed in manufacturing the compound known as "biphosphated guano." Besides about 71 per cent. of tribasic phosphate of lime, it has nearly 1 per cent. of nitrogen, with less than 2 per cent. each of carbonate of lime and siliceous matters, and scarcely any iron and alumina.

Browse Island guano is closely similar to Mejillones, but somewhat superior. It is imported in a fine powder, free from lumps and stones, and ready for treatment with sulphuric acid, without any grinding or other preparation. It contains about 1½ per cent. of ammonia, and yields a superphosphate up to 40 per cent. soluble; at the same time, it contains no fluorine, very little iron and alumina, and only a convenient proportion of carbonate of lime.

Malden Island guano, as well as that from Howland and Starbuck Islands, all of the same archipelago, have been principally used in Germany, for the preparation of high-class superphosphates. The first-named contains nearly ½ per cent. of nitrogen, besides tribasic phosphate of lime, about 73½ per cent.; carbonate of lime, 12½; ferric oxide, 1.

The following is a comparative statement of the percentages of phosphoric acid in the various natural phosphates and in the superphosphates made from them:—

Commercial Phosphates: Localities.	Percentage of Phosphoric Acid in the Natural Phosphates.	Percentage of Phosphoric Acid in the Superphosphates made from them.
Rio Grande—Bone-ash	39·84	13·98
Mejillones—Guano	33·23	18·58
Phœnix Islands—Rock-guano	39·08	17·18
Sombrero—Rock-guano	37·51	16·90
Curaçao—Rock-guano	32·52	15·80
Swan Island—Rock-guano	..	13·83
Navassa—Rock-guano	33·18	11·42
Elrogue—Rock-guano	32·00	Wet.
Redonda—Rock-guano	40·19	Wet.
Cambridgeshire—Coprolites	26·47	10·09
Cambridgeshire—Coprolites	25·95	10·02
Ardennes—Coprolites	20·71	7·60
Grandprè—Coprolites	17·13	5·34
Varennes—Coprolites	21·91	5·14
Bellegarde—Coprolites	23·37	8·36
Bordeaux—Phosphate	38·64	14·98
Bordeaux—Phosphate	21·46	5·04
German—Phosphate (best)	34·88	16·61
German—Phosphate (inferior)	17·56	8·08
Peine—Coprolites	14·38	5·82
Horde—Black band (phosphate)	19·48	1·46
Russia—Government of Orel (phosphate)	18·35	Wet.
Odegaarden—Apatite	37·66	15·41
Spain—Phosphorite (best)	38·05	14·04
Spain—Phosphorite (inferior)	20·15	9·20
Logrosan—Phosphorite (yellow)	37·55	16·20
Logrosan—Phosphorite (rosy)	42·17	18·10
Zarza la Mayor—Phosphorite	36·26	15·49
Caceres—Abundancia mine	27·00	13·62
Caceres—Estrella mine (white)	29·09	14·72
Caceres—Esmeralda (rosy)	37·38	15·94
Canada—Apatite	39·80	19·59
Carolina phosphates—		
Cooper River—Land deposit	..	10·70
Ashley River " "	.	12·30
Ashley River " "	..	9·68
Between Ashley and Rantowles—Land deposit	..	15·53
Between Ashley and Rantowles— " "	..	11·17
Wando River—River deposit	..	10·30
Stono River " "	..	12·54
Edisto River—Land deposit	..	11·79
Edisto River " "	..	9·95
Edisto River " "	..	10·43
Ashepoo River " "	..	12·51
Ashepoo River " "	..	14·55
Ashepoo River " "	..	11·67
Bull River—River deposit	..	12·73
Soosaw River " "	..	14·16
Beaufort River " "	..	10·14

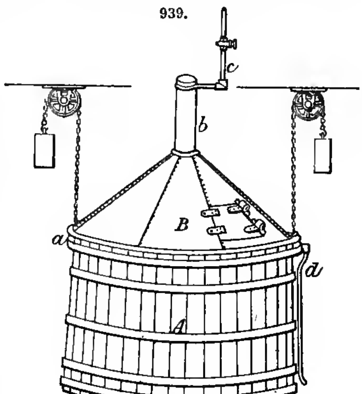
Bone-ash.—Bone-ash is another useful product, containing 60–80 per cent. of phosphates. It consists of calcined bones, contaminated with more or less of foreign substances. Their nitrogen is driven off by the calcining, and is generally wasted. Bone-ash is imported mostly from S. America, also from the Baltic and Black Sea ports. It is rarely or never applied in its imported state, but is generally ground in mills, such as are used for reducing mineral phosphates, described further on. In a finely comminuted state, it is employed in producing the better class superphosphates, or "bone-manures."

Shoddy.—Woollen refuse and hair, generally known in the market as "shoddy," are essentially nitrogenous manures. Pure dry wool or hair contains about 17 per cent. of nitrogen, but the commercial article commonly varies between 6 and 8 per cent. When applied in a crude form, it decomposes very slowly, and its benefit is observed for several seasons. Treatment with sulphuric acid hastens its absorption; and it is often employed in the manufacture of other manures, solely as a source of nitrogen.

Animal Charcoal.—This is a phosphatic material, consisting of the ash produced by burning bones in close vessels (see p. 453). It is used in sugar-refineries, and other works, for purifying purposes, and when no longer efficacious in this respect, it finds a market with manure-manufacturers. The amount of phosphates contained in it may vary from 50 to more than 80 per cent., according to the purpose for which it has been employed. Before being used as a manure, its phosphates are always rendered soluble by treatment with sulphuric acid; generally it forms only an ingredient of superphosphates.

Sugar-scum.—The term "sugar-scum" is applied to a compound obtained from sugar-refineries, containing not only the solid impurities of raw sugar, but also occasionally the coagulable constituents of blood used in the refining process, as well as bone-char, when the char-dust is utilized by mixing it with the solution of sugar in the "blow-up" pan (see Sugar). Analyses of a series of sugar-scums in actual use by manure-manufacturers reveal great variety of composition:—(1) Phosphate of lime, 11·75 per cent.; ammonia, 1·18. (2) Phosphates, 26·00; ammonia, 3·4. (3) Phosphate of lime, 6·16. (4) Phosphate of lime, 3·14; nitrogen, 1·22 = ammonia, 1·48 (equal, in dry scum, to nitrogen, 2·88 = ammonia, 3·49). (5) Phosphate of lime, 10·8; nitrogen, 0·98 = ammonia, 1·19. (6) Phosphoric acid, 7·14; nitrogen, 1·36 = ammonia, 1·65 (equal, in dry scum, to nitrogen, 1·83 = ammonia, 2·22). (7) An analysis of the dried contents of the filter-bags at a sugar-refinery where no blood is used gave:—Moisture, 3·5; organic matter, 41·6 (containing 17·8 sugar, and 0·5 nitrogen); ferric oxide, 0·72; alumina, none; phosphoric acid, 2·03; lime, 22·5; magnesia, 1·83; sulphuric acid, 6·82; chlorine, none; carbonic acid, 11·3; insoluble residue, 7·76; alkalies and loss, 1·94. Comparative analyses of samples taken respectively from (*a*) the filter-bags of a refinery where no blood is used, and from (*b*) those of another (belonging to the same firm) where several pails of blood are added to each charge of the "blow-up" pans, gave the following results:—Moisture, *a* 48·58, *b* 46·95; organic matters, *a* 20·82, *b* 29·55; mineral matters, *a* 30·60, *b* 23·50. The mineral matter contained—phosphoric acid, *a* 4·03, *b* 2·24; and the organic matter—nitrogen, *a* 0·48, *b* 0·89 = ammonia, *a* 0·59, *b* 1·09. Comparing these results with those of analyses (4), (6), and (7) above, the quantity of nitrogen appears very much lower. The inference to be drawn from this is that scum from refineries where neither blood nor char-dust is used would probably be of little value to the manure manufacturer. That procured from one sugar-works is said to contain 18–20 per cent. of phosphate of lime. The exhausted bone-black from sugar-refineries contains about 58 per cent. of triphosphate of lime and magnesia, and 8·8 of carbonate of lime.

939.

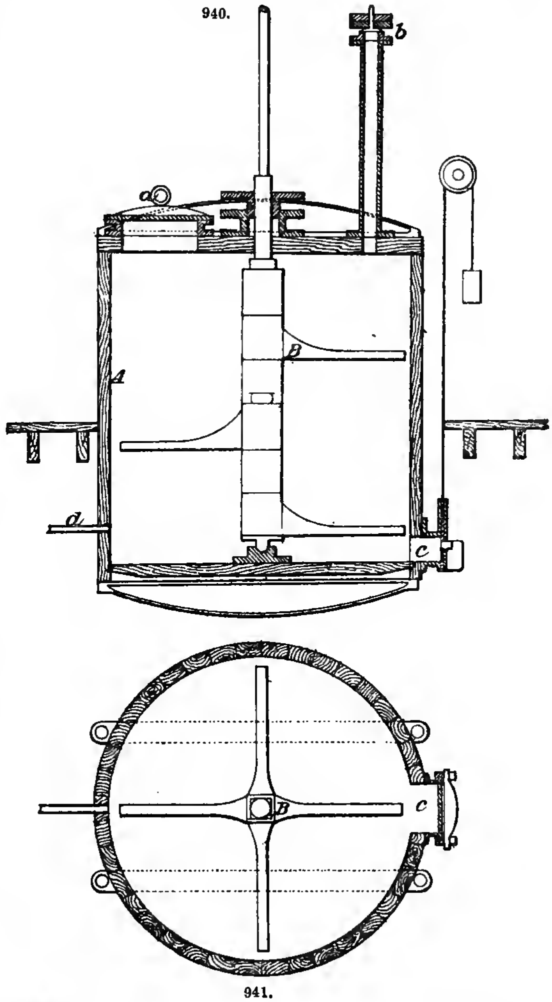


Scutch.—The term "scutch" is applied to the refuse from glue-works. It is usually treated with heat and sulphuric acid, to separate any fat it may contain, before being used for the manufacture of manure. Sometimes this is conducted in open or partially closed vessels by the aid of free steam; as the fat separates, it is skimmed off, and when all of it is removed, the residue is run off into a tray, to cool and consolidate. In some works, it is run into trenches dug in the earth, and after several months, is dug out, and dried in kilns or brick flues; at others, it is collected in a heap, and left to dry by spontaneous heating.

The chief point to be attended to is to deal with the scutch as early as possible after its removal from the glue-pan. An excellent apparatus for inoffensively extracting the fat from scutch is shown in Fig. 939. The scutch, mixed with acid, is heated by free steam in a large pan A, provided with a rim *a*, containing water, into which dips the edge of a conical cover B, so as to form a water-lute when the cover is let down. A short length of pipe *b*, closed at the top, rises from the apex of the cover, and is surrounded by a ring of perforated pipe *c*, from which cold water constantly flows over the outside of the cover, into the grooved rim of the pan, whence a waste-pipe *d* carries it away. By this means, the steam within is condensed, and runs down the inside of the cover into the rim. The fat is ladled out, and the residue is run off into a covered tank outside the works to cool.

Another form of apparatus is shown in Figs. 940, 941. The scutch and sulphuric acid are introduced into a close cylindrical leaden vessel A, encased in wood, and charged at the upper part through a circular opening *a*, about 18 in. wide, which is closed while working, by an iron cover screwed down. Within is a stirrer B, the shaft of which passes through the centre of the top of the vessel. When the cylinder has been charged and closed, steam at about 105° (220° F.) is admitted for 2 hours at *d*. Very little vapour escapes by the safety-valve *b*, and its odour is not perceptible outside the works. At the end of 2 hours, the steam is shut off, and the material is left to settle till next day. The fat is then ladled out through the charging-door, and the residue is run off through an opening *c*, about 14 in. wide by 5 in. deep, near the bottom of the vessel. Another method in use is as follows. The scutch, quite fresh from the pans, whence it is brought in closed vessels, is put into a tub with water and sulphuric acid; steam is injected to separate the fat, which is taken off, and the scutch is enclosed in coarse bags, and strongly pressed in a hydraulic press, to which steam is admitted. The fat flows off from the bottom of the press, and is collected and refined by remelting by steam-heat. The pressed scutch has no odour, and can be kept under shelter, without heating or becoming offensive.

940.



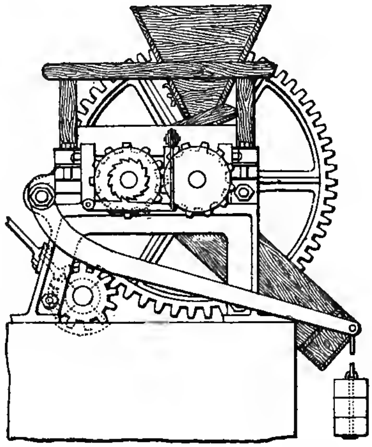
941.

Manufacture of Artificial Manures.—The next consideration is the means adopted for preparing raw materials for use as artificial fertilizers. It has been already remarked, that the greater part of the phosphate of lime existing in mineral phosphates is in a state that defies solution in ordinary water, and that, in order to render that phosphate soluble in water, and immediately available for the plant, it is dissolved by the action of sulphuric acid. The decomposition of the mineral would occupy such a great length of time, however, if the acid were to be applied to the unbroken nodules, that they are universally reduced to a fine state before being mixed with the acid.

Crushing.—The first process in the preparation of the mineral is that of reducing it to such a consistency as to admit of its being fed regularly into the mills which grind it to powder. This may be effected by the "crusher," shown in Fig. 942, consisting of a pair of chilled cast-iron rollers. Sometimes two pairs are arranged in the same machine, the lower ones being set somewhat closer than the upper. The mill may be fed with material about the size of road-metal. It is usually worked in conjunction with the grinding-stones, and is then driven from the same lay-shaft, to which the pinion and disengaging-clutch are attached, as shown. The method of driving may, however, be made suitable for any required position. Pressure is applied to the rollers by means of weighted levers, which may be varied according to the nature of the material under operation. These crushers are manufactured by E. R. and F. Turner, of Ipswich, in two sizes: the smaller, capable of crushing about 2 tons an hour, requires about 3 H.-P.; the larger needs double that power to reduce about 5 tons an hour. In some cases, so-called "edge-runner" mills are used, instead of the specially constructed crusher.

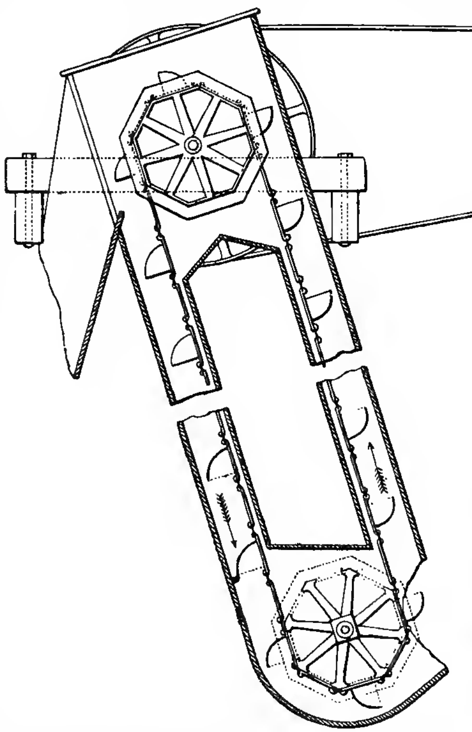
Grinding.—The material issuing from the crusher is taken by elevators, or by other suitable means, to be fed as required into the hoppers on the grinding-mill. These do not differ materially from an ordinary flour-mill. The bed-stones should be firmly secured in cast-iron coned pans, fitted with adjustment-screws; and the driving-wheels on the lay-shaft should be geared with hard and well-seasoned wooden cogs. These wheels may be made in halves, for facilitating the renewal of the cogs by means of a duplicate wheel. They work with iron pinions on the stone spindles.

942.

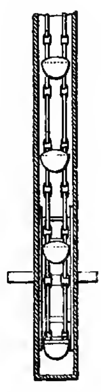


The stones are usually best French burrs, and are 4 ft. 6 in. in diameter. Each mill requires about 6 horse nominal engine power to reduce 10 cwt. an hour of the material from the crusher to a fine powder. It is very important that the phosphate shall be reduced to an exceedingly fine powder, especially when the mineral is very hard, as otherwise the acid will not have a fair opportunity of acting upon it, and consequently the proportion of soluble phosphate produced will be less than it might be. This fact has been demonstrated by experiments: of some samples of ground phosphates, fulfilling in all respects exactly similar conditions, it was found that the sample which had been ground to the finest powder gave 25¾ per cent. of soluble phosphates; while it was impossible to get far beyond 22½ per cent. with that which had been passed through a "38-wire" sieve. The material cannot, in fact, be rendered too fine; and a good plan is to regrind all that does not run through the hand as an impalpable dust, like flour, or the very best Portland cement. It should be caught from the mill in a sieve, and be constantly tested.

943.



944.



Mixing.—The dry materials to be employed in the composition of the manure, whether ground mineral phosphate, crushed bones, shoddy, scutch, &c., are raised to the "mixer" by some such apparatus as that shown in Fig. 943. This is a chain elevator, made by Turner, of Ipswich, and is found to answer exceedingly well. The charge of dry materials is shot down at the foot of the elevator, to be raised by the buckets, and deposited by them, in a constant and regular stream, into the hopper with which the top of the mixer is fitted. The elevator shown in the figure will deliver about 4–5 tons an hour; but they may be made with 9-in. buckets, to raise 8 tons in the same time. For ground materials alone, which yield readily to the buckets, ordinary pulleys with indiarubber belting may be used, instead of the octagonal pulleys and iron chain; but the latter repay their extra cost by longer wear.

Fig. 944 shows a front view of the buckets, with a portion of the casing removed. The requisite parts are two octagonal pulleys, cost about 2*l.*; double wrought-iron chain, about 1*s.* a foot; plate-iron buckets, with steel mouth-pieces, each 2*s.* 9*d.*; and bolts and nuts for ditto, about 1*s.* 3*d.* a doz. As the pitch of the chain is $8\frac{1}{4}$ in., and every alternate link carries a bucket, there will be one bucket required for every $16\frac{1}{2}$ in. of chain, and 2 bolts and nuts to each bucket. The elevator drum should travel at about 20 rev. a minute.

945.

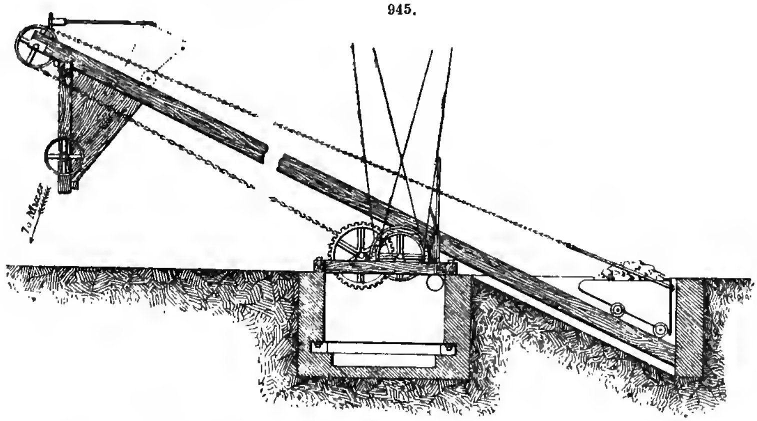
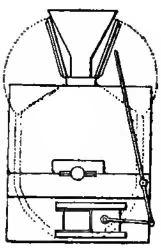
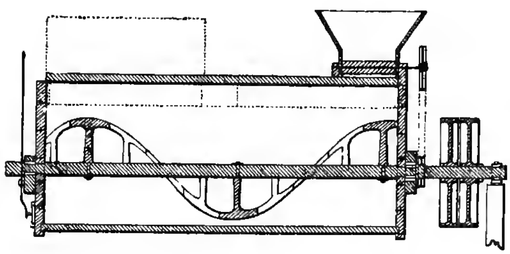


Fig. 945 shows another form of elevator for dry materials, which may be conveniently used when the latter have to be brought from a considerable distance; but as it is much more expensive than the preceding form, it is only adopted when circumstances compel it. The truck is filled with 4 cwt. of the ground material at the foot of the inclined plane, up which it is drawn by the chain. On reaching the top, the wheel is caught by a stop on the rail, and the contents of the truck are tipped into the hopper. The truck should make an ascent once in every three minutes.

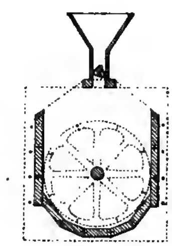
946.



947.



948.



The "mixer," shown in end view, and longitudinal and cross sections, in Figs. 946, 947, and 948, is also of Turner's construction. It consists of a stout wooden case of 3-in. deal, strengthened by longitudinal tie-rods of $\frac{5}{8} \times \frac{3}{4}$ in. round iron. The boards are all planed, and ploughed and tongued; the tongues are 1 in. $\times$ $\frac{1}{4}$ in., and are placed in the centre of the thickness of the boards. The top of the case consists principally of one board 9 in. wide, to which are hung four doors or covers, two on either side. The durability of the case is increased by lining it with "14-lb." lead, at an extra cost of about 20*l.* Iron cases have been tried, but have proved less durable than wood. Through the case, passes an octagonal shaft or spindle of cast-iron, into which cast-iron stirrers are wedged helically along its length. The price of such a machine, with feed-roll, hopper, and driving-pulleys, will be about 50*l.*; and its weight, say 35 cwt. The driving-strap should be 5 in. wide; and the speed, 80 rev. a minute. The power required is about 4 H.-P.

The action of the machine may be made continuous or intermittent. In the latter case, it is charged about once in every 3–5 minutes with 4–5 cwt. of ground materials, and the proper proportion of acid; it will then turn out about 8–10 tons of manure an hour. By the time that the compound reaches the exit of the mixer, it should have become very uniformly mixed. The smaller sized mixer will make about $1\frac{1}{2}$–2 tons an hour, and needs little more than 1 H.-P. It is of primary import that the acid used be of one constant degree of strength, or as near thereto as is practicable, and that the quantity used in each charge or mixing be accurately proportioned to the needs of the raw material. Chamber acid, which is ordinarily made at about 115° Tw., is perhaps the best suited for the purpose, as it is sufficiently strong, and is, at the same time, uot so strong as to need the addition of water. When the manure-manufacturer also makes his own acid, it may be conveniently run from the chambers; but as it would be very difficult to regulate minutely the delivery of a certain quantity of acid from so large a vessel as the leaden chamber, it is preferable to let the acid run first into a lead-lined tank, holding about 10 cwt. of acid, placed near the mixer, and at a height of about 4 ft. from the floor. A floating gauge-glass will readily indicate the height of the acid; and at the side, may be fixed a leaden rule, graduated into divisions, each representing 10 lb. of acid. The tank communicates with the mixer by a 3-in. leaden pipe, fitted with an earthenware tap; by these means, and by observing the index, the attendant can regulate to a nicety the exact quantity of acid to a given weight of dry material. When the mixing is conducted intermittently, it is well to take care that, after a mixing has been let out, and the exit door has been closed, the flow of acid into the mixer shall be in advance of the dry materials, rather than allow the latter to precede the former, as, in this case, a hard, dry mass may accumulate at the mouth of the mixer, and create much trouble.

Figs. 949 and 950 show a complete arrangement of manure-making apparatus:—*a* is the mixer, which is supplied with dry stuff by the elevators *b*, and with sulphuric acid by the pipe *c* (having a plug at *d*) from the cistern *e*, which is filled from the chamber by the pipe *f*; *g* is the pit or "den," into which the manure is delivered by the mixer; and *h* is the platform for the man who regulates the supply of acid, and opens and closes the delivery-hole of the mixer, by means of the sliding door, worked by a lever, as shown in Fig. 946.

The following are practical notes on the quantity of concentrated sulphuric acid (say 168° Tw.) required by different kinds of phosphatic materials:—1 ton Cambridge coprolites, 60 per cent. phosphate, requires about 14½ cwt.; 1 ton Suffolk coprolites, 50 per cent. phosphate, 15 cwt.; 1 ton Spanish phosphorite, 68–70 per cent. phosphate, 14¾ cwt.; 1 ton Navassa phosphate, 73 per cent. phosphate, 14¾ cwt.; 1 ton of a mixture of two parts Cambridge coprolites, and 1 part bone, 14 cwt.; 1 ton of a mixture of 2 parts bone-ash (70 per cent.), and 1 part ½-in. bone and bone-dust, 13 cwt. When "chamber acid" is used instead of oil of vitriol, an increased quantity of acid, varying in inverse proportion to its strength, will be required. The following table shows the number of pounds of chamber acid, according to its density, required for 1 ton of Cambridge coprolites; opposite the quantities, are stated the corresponding depths of acid in inches and tenths, as measured from a cistern having the dimensions 6 ft. × 4 ft.:—

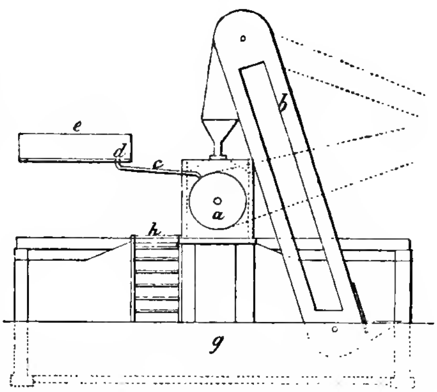
Strength of acid.	Quantity required.	Depth in Cistern.	Strength of Acid.	Quantity required.	Depth in Cistern.
° Tw.	lb.	inches.	° Tw.	lb.	inches.
100	2005	10·7	113	1922	9·8
101	1999	10·7	114	1916	9·75
102	1992	10·6	115	1911	9·7
103	1986	10·5	116	1904	9·65
104	1979	10·4	117	1898	9·6
105	1972	10·35	118	1892	9·55
106	1966	10·3	119	1886	9·5
107	1960	10·25	120	1880	9·45
108	1954	10·2	121	1874	9·4
109	1948	10·1	122	1868	9·3
110	1941	10·05	123	1863	9·25
111	1935	10·0	124	1857	9·2
112	1928	9·9	125	1851	9·1

The effect of the chemical action of the acid on the phosphate is the generation of considerable heat, which is of great service in rendering the manufactured article thoroughly dry, so that it can be reduced to a moderately fine powder. For the purpose of conserving the heat, it is common to make the mixer-pit of very large size, capable of holding as much as 100 tons at one time; and it is found that much greater proportions of soluble phosphate, and altogether vastly superior manure, can be got by mixing these large quantities, than by treating little batches.

Mention has already been made of the ill effeot exercised by ferric oxide and alumina, in causing the manure to "go back" in quality. Some experiments made were thought to show that the evil could be remedied by mixing such phosphates in small quantities, so that the heat of the mass should be far less considerable. But it was soon found that, besides producing a manure of very inferior physical qualities, the plan only had the effect of postponing the deterioration in chemical qualities, and did not in any degree prevent it. In workiug with phosphates whose "setting" power is good, depth is not essential in the den; but in all other cases, it is absolutely necessary, and better results are obtained in proportion as the shape of the den approaches more nearly that of a cube (omitting the corners). One manufacturer, of great experience in using German phosphorites, prefers a den of large area, so that the manure may run out thin, and cool quickly, and he thinks that this considerably lessens the liability of some manures to "go back." On the other hand, this idea is contradicted by the experiments just alluded to, and, in running the manure out very thin, there is always great risk of destroying the uniformity of the mass, particularly when bones form an ingredient of the manure.

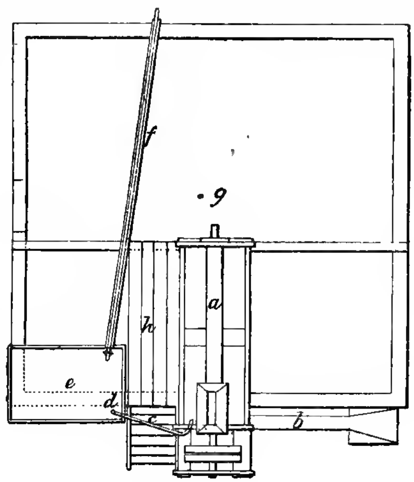
In cases where difficulty is experienced in obtaining a manure that will dry well, a small proportion of gypsum may be conveniently added, as a drier, if the phosphates used are of such high quality as to bear that admixture, and at the same time to yield at least 25 per cent. of soluble tribasic phosphate of lime.

949.



The production of so-called "turnip-manures" and "dissolved bones" is achieved by the addition to the dry materials, before mixing, of such nitrogenous or ammoniacal matters as have already been mentioned. When bones are used, they are generally introduced in fragments of the size known as "half-inch"; in this form, they are so slowly acted upon by the acid that they remain in specks throughout the mass, plainly visible to the eye of the suspecting farmer.

Screening.—After allowing the manure to heat for 24–36 hours, it is dug out, and put through a machine for reducing it to a pulverulent form. The best machine for this purpose is that known as Carr's disintegrator. The material in passing through the machine is subjected to percussion from the bars of the cages which compose the latter, and which revolve in alternate directions at a high rate of speed. A casing or hood is necessary to prevent the scattering of the material, from the centrifugal force it acquires whilst under operation. The power required to drive the machine varies from 8-H.P. upwards, according to its speed, the quantity delivered, and the nature of the material. It is scarcely necessary to add that only a thoroughly dry manure can be disintegrated in this machine, nor indeed in any other, except with the greatest trouble.



950.

Finally, the manure is weighed into gunny bags, holding 2 cwt. each; the mouths of these are sewn up with coarse twine; and, in this condition, the manure is conveyed to the land where it is to be used. The bags are seldom fit for re-use, and are more commonly charged for in the price of the manure, remaining the farmer's property. The destruction of the bags by the action of the free sulphuric acid in the manure, and the consequent occasional waste of their contents, may be much reduced by passing the bags through a mixture composed of 15 per cent. chloride of barium, 10 per cent. chalk, 5 per cent. glue, 5 per cent. glycerine, and 65 per cent. water, squeezing them between wooden rollers, and drying them. For transport abroad, manures are generally packed in barrels.

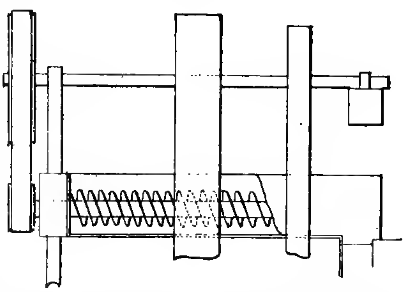
Poudrette.—The French word "poudrette" is applied to a preparation of sewage, or rather night-soil, with sulphuric acid. The acid is generally added to the excrement in the pails used to transport it to the works, and the whole is then tipped into a Milburn's desiccator, from which, when it has suffered sufficient evaporation, it is removed to a drying-floor heated by flues beneath. It is subsequently passed through a disintegrator, preparatory to being packed for sale. Sometimes a much more complicated system is pursued. The pails are first emptied upon a strainer, constructed to allow all liquid and fine suspended matter to flow through, while retaining the solid fæces, &c. The filtrate is pumped into an elevated tank, for the supply of a boiler capable of dealing with 550 gal. of liquid matter at a charge, and provided with a stirrer, to prevent incrustation. The boiler being charged, 80 lb. of dolomite (magnesian limestone) is added, and the whole is distilled by a fire below. The ammonia distilled off is conducted into an ordinary saturator, such as is used in making sulphate of ammonia (see Alkalies—Ammonia), containing brown sulphuric acid. The fœtid vapours evolved in the saturator are carried through a worm-pipe in the supply tank, partly for condensation, and partly to warm the contents of the tank before running them into the boiler. The condensed vapour is run off into the drains. The sulphate of ammonia thus made is evaporated in a shallow, open, leaden vessel, on the top of the saturator, and as it crystallizes, is drawn out and set to drain. Only $\frac{5}{8}$ of the ammonia is boiled off. The residue in the boiler, when this proportion has been collected, is run off by a valve at the bottom, and is stirred up with superphosphate in large wooden vats. The product is then dried, either by ordinary means or by pressure. The solid matters originally separated by the straining are mixed in a mortar-mill with the superphosphate and soot or waste charcoal.

To prevent nuisance arising from this manufacture, the whole process must be conducted within a closed building. The interior of the desiccator should communicate with a blower, creating an in-draught, sufficient to prevent the escape of effluvia through the crevices of the cover, or while charging the machine. Flues must be provided, so that the blower shall drive the vapours through the fires used for heating the drying-floor, before they escape into the chimney of the works.

Prevention of Nuisance.—In the process of manufacturing artificial manures, such as superphosphate, nitrophosphate, bone-manure, &c., very offensive and injurious vapours are abundantly evolved; consequently, a knowledge of how to prevent these vapours from becoming a nuisance to the neighbourhood is of vital importance to those engaged in the industry, particularly in a densely-populated country like England. Only a few of the largest firms have hitherto given much attention to the subject; but future legislation on the noxious vapours question will probably enforce upon all the precautions willingly adopted by a few.

The objectionable odours are generated chiefly in the apartments where the manure is mixed, and where it is received after mixing to set and cool—in other words, in the "mixer" and the "den." It is therefore essential that these should be made practically airtight, so that the gases may be kept under control. The first point is to prevent the vapours generated within the mixer from escaping through the hopper by which the solid materials are fed into the mixer. This is most efficiently accomplished by substituting the arrangement shown in Fig. 951 for the ordinary feed-hopper. It consists of a horizontal wooden box, kept completely and constantly full of materials, which are carried into the mixer by means of the archimedean screw working within the box. It can only be used when the mixing is continuous.

951.

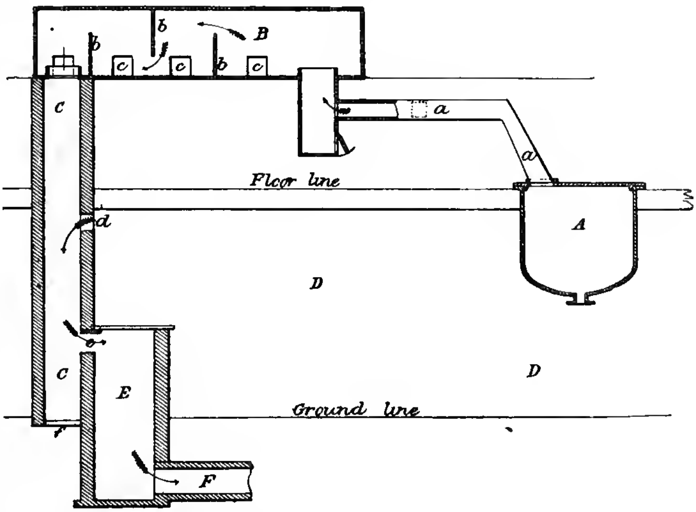


The manure, on flowing from the mixer, falls into the den, which is a close chamber, constructed of brickwork walls (best lined with cement plaster), and with a paved floor. In the walls of the den, are suitable wide openings for removing the manure when set; these are firmly closed by stout wooden doors during the mixing. The den is also securely roofed over, either permanently or temporarily, in such a way as to include the outlet from the mixer. When the manure is to be dug out of the den, the latter is ventilated by removing the roof, if temporary, or by opening windows provided for that purpose, if it be a permanent covering. As the vapours generated during the mixing of the manure, and immediately after its outlet from the mixer, are those chiefly to be dealt with, attention is mostly confined to means of drawing them away and rendering them innocuous.

No very complete analysis has yet been made of the constituents of the gases evolved in the manufacture of artificial manures. In the case of ordinary superphosphate, fluoride of silicon is formed by the action of the sulphuric acid upon the silica and fluoride of calcium contained in the said phosphates. The fluoride of silicon, in the presence of condensing watery vapour, is resolved at once into hydrated silica and hydrofluosilicic acid, thus—$3SiF_4 + 4H_2O = SiO_2, 2H_2O + 2(2HF, SiF_4)$. Dr. Adams has also conclusively proved the vapours to contain arsenic, from the arsenical sulphuric acid used, most of the acid employed for manure-making being derived from pyrites. Without doubt, some of the arsenic is evolved as arseniuretted hydrogen, from the action of the acid upon the iron portions of the interior of the mixer; but the greater part is probably in the form of chloride of arsenic. The proportion of the latter will be commensurate with the amount of chlorides decomposed in the mixing, and, estimated as arsenious acid, varies from 2 to 10 oz., and even more, for each ton of manure made. When organic matters are added to the raw constituents of the manure, additional offensive vapours are generated, of very various characters. When much salt is present, the production of hydrochloric acid vapour will be great. The odours from manure-works are carried considerable distances, extending sometimes to over 4 miles.

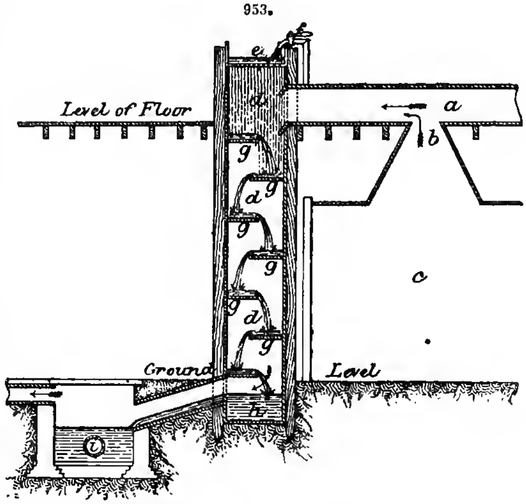
Of the offensive vapours given off during mixing, some are condensed by cold, some dissolve in (or are decomposed by) water, and the remainder are destructible by fire. The application of these agents — cold, water, and fire — resolves itself into long flues, water-towers or "scrubbers," and furnaces, usually assisted by motive power, such as that produced by the draught of a tall chimney, or by a fan.

952.



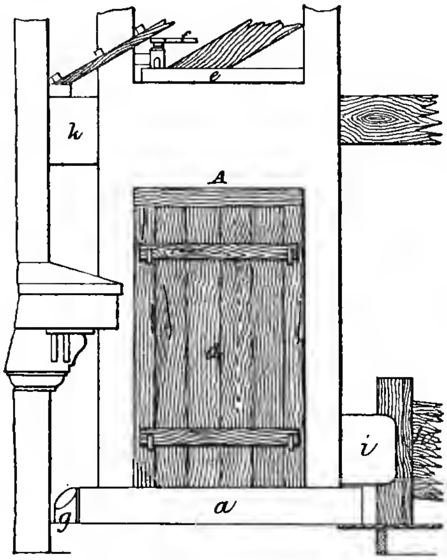
In simple superphosphate-making, a long flue seems to answer every purpose, and has been successfully adopted in some of the largest works. Its object is, by cooling, to promote condensation of the steam, and consequent deposition of the hydrofluosilicic acid, and other matters, before arrival at the chimney, by which they would otherwise escape into the atmosphere. In these flue deposits, is found a notable quantity of arsenic. An illustration of a thoroughly efficient arrangement is given in elevation in Fig. 952. The mixer A is connected by a short flue *a*, 12 in. square, with a wooden chamber B, about 18 ft. long, and 3½–4 ft. wide and deep, divided at equal intervals by partitions *b*, springing alternately from top and bottom. At the bottom of each partition thus formed, is a door *c*, by which the deposit is periodically removed. The chamber B opens into the top of a square brick tower C, about 14 ft. 6 in. high, and 2 ft. 7 in. in diameter, receiving at *d* the vapours arising from the pit or den D. In the tower C, more silica is deposited. Adjoining C at the bottom, is a shorter tower E, with a communication between the two at *e*, about 4 ft. above the bottom of the former. The deposit accumulated in C is thus prevented from choking the passage, and is removed by a door at *f*. From E, the vapours traverse an underground flue F, 150 ft. long, terminating in a chimney. The chief deposition takes place in B and C, the former being cleaned out twice a week, and the latter once a month. Beyond the first 15 yd. of the flue, the deposit is scarcely appreciable, and the flue is only cleaned out once a year. At the works where this plan is in operation, the manure made averages 100 tons a week, about half the raw phosphate being bones. At another works, making 300 tons a week, and employing nearly all mineral phosphates, the total flue is 440 ft. long.

953.



A second method, adopted successfully in some works, is to condense the vapours by the direct application of cold water. This is effected either by a shower or cascade, or by means of a "scrubber," i. e. a tower partly filled with material over which liquid is made to fall. A most efficient example of the shower or cascade arrangement is shown in Fig. 953. From one end of the mixer, an opening, the entire width of the mixer, and about 15 in. deep, communicates with a wooden channel *a*, into which emerges a similar connection *b* from the den *c*. At about 3 yd. from the mixer, the channel *a* communicates with the upper part of a water-tower *d*, where the vapours

954.



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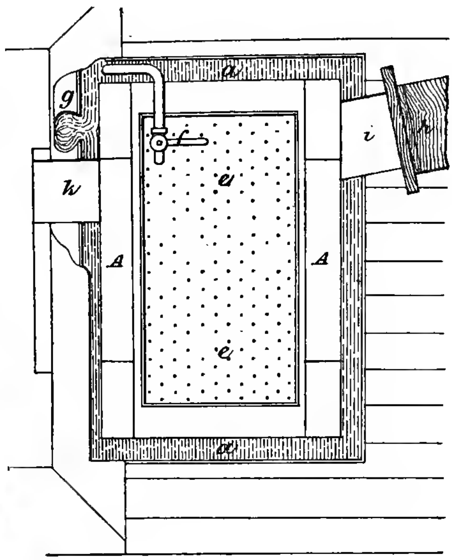
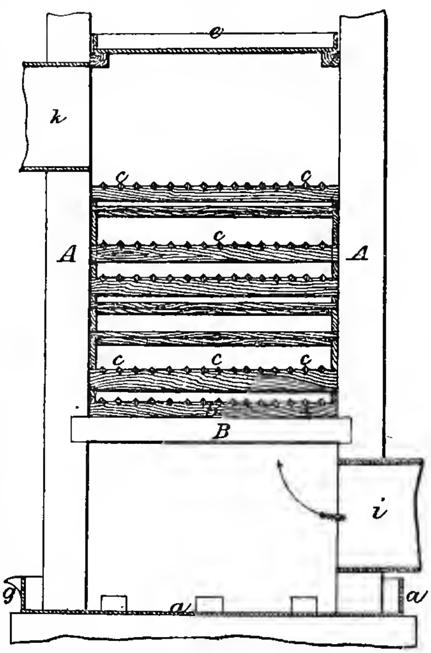


meet with a shower. The tower is of wood, 3 ft. square, and 18 ft. high. At the top, is a tank *e*, with a perforated zinc bottom, fed by a 3-in. tap *f*. Within the tower, a series of wooden shelves *g* spring alternately from opposite sides, with flanges to determine the flow of water towards their centres. At the bottom of the tower, is a cistern *h*, whence the water flows over a ridge into the drain *i*. The unabsorbed vapour is drawn off by a fan, and conducted into the boiler-fires of the works. With an abundant water-supply, nothing is more effective than this plan.

The "scrubber" system is, however, in more general use. Its arrangement is shown in elevation, plan, and vertical section, in Figs. 954, 955, and 956. Leading from the mixers and the dens, are square wooden flues, terminating in a fan, which draws the vapours from the mixers and dens, and forces them into the condenser. This latter consists of a brick chamber A, standing in a strong leaden tray *a*. A range of lead-covered iron bars B is built into the brickwork, and supports the two first racks *b*, which are notched to receive the loose square wooden bars *c*. The racks are so disposed that the alternate sets of bars *c* are at right angles to each other. Upon each row of bars, are laid packing-pieces, to carry the next set of racks, and this is repeated to the top. The whole of these racks may be removed for cleaning, and replaced through the door *d*. At the top of the tower, is a perforated leaden tray *e*, supplied with water by a tap *f*. The water falls in a shower upon the intercepting bars within the

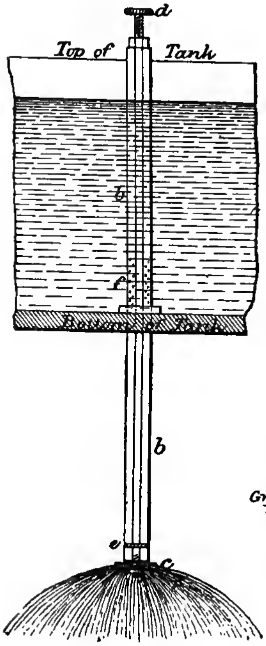
956.



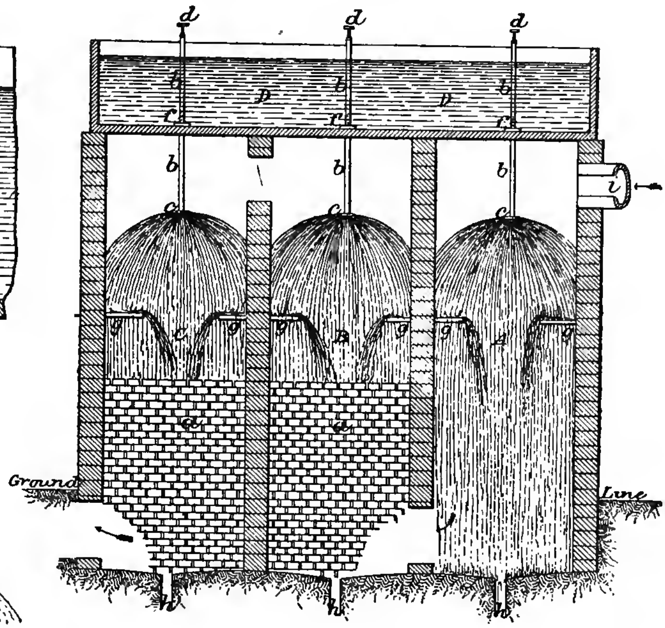
condenser, and passes between them to the bottom of the condenser, whence it overflows at *g* into a drain. The vapours from the mixers and dens enter the condenser near the bottom, and beneath the bars B, by means of the wooden flue and pipe *h i*; and, after passing the condenser, escape near the top, by a short flue *k*, leading to the chimney of the works. The efficiency of this arrangement seems to depend less upon the flow of water, than upon the obstruction offered to the passage of the vapours, affording time for the decomposition of the fluoride, and the arrest of the products of the decomposition; but the water undoubtedly renders valuable assistance. The escaping vapours show no trace of fluorine compounds; but still contain an appreciable quantity of arsenic.

A still more effective form of scrubber is shown in Fig. 957. The condenser consists of three vertical chambers of brickwork A B C; the first contains nothing, but the second and third are packed in their lower portion with perforated bricks *a*, laid evenly, but not too closely. Above the

958.



957.



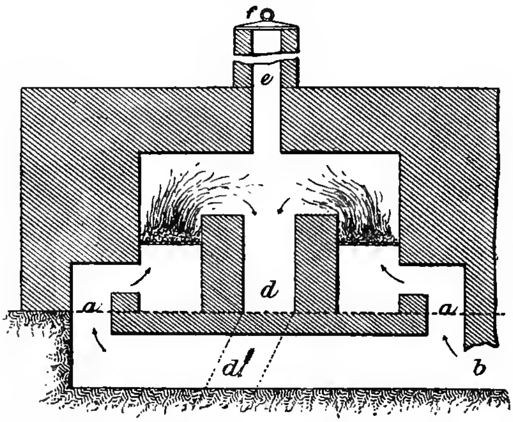
three chambers, is a capacious cistern D, for supplying water to the condenser. From this cistern, the water flows by pipes *b* into each of the three chambers. There is an excellent arrangement for distributing the water, which is shown in detail in Fig. 958. The bottom of the pipe *b* is open, but capable of being closed partially or completely by means of a plate or button *c*, which can be raised and lowered by a screw-rod *d*, worked from above, and guided into a central position at *e*. When the plate *c* is slightly lowered, the water, entering the pipe *b* from the tank D by the perforations at *f*, flows out in a thin sheet resembling an open umbrella, and falls down through the chambers, being determined by the shelves *g* towards the centre of the chambers; then, passing through and between the perforated bricks *a*, escapes by the drain-pipes *h*. The vapours from the mixers and dens enter the upper part of the first chamber A by means of a 12-in. pipe *i*, then pass below, as shown by the arrow, into the second chamber B, and, after passing through the bricks, enter the third chamber C, above the sheet of water, with and among the spray from which they descend through the bricks, and escape by the flue, some 50 ft. long, which conducts them to the furnaces shown in Fig. 959.

These furnaces are in duplicate, and provided with dampers at *a*, so that the vapours may be directed into either at will, on their entering from the condenser by the flue *b*. After passing through the fires *c*, the vapours descend by the flue *d*, and pass away to the chimney of the works. As a means of testing to what extent the vapours are deodorized, a small chimney *e* is provided; by closing the damper placed at the floor-line in the flue *d*, and removing the luted cap *f*, the vapours may be smelt. This combined arrangement of condenser and fire is perfectly efficient, and when kept in working order, the escaping vapours give no trace of arsenic, or other deleterious substance.

The result of these observations is to show that, in the case of manure made from ordinary mineral phosphates, the prevention of nuisance is efficiently ensured by affording the time, space, and other conditions necessary for the decomposition of the vapours, and the deposition of the condensed products; but that where animal and vegetable substances are used in the manure, not only must these precautions be rigidly observed, but complete success can only be obtained by passing the vapours through fire, to destroy their organic constituents. By the adoption of these combined measures, the operation of making the manure may be rendered absolutely innocuous and inodorous.

There remains to deal with the odours which arise during the subsequent operations of digging-out and screening the manure. It has been suggested that, by leaving the manure for a much longer time in the den, so that the imprisoned gases might have an opportunity to condense, all smell would be avoided; but this is a condition which would be practically impossible in many works, and onerous in all. The only practical solution of the difficulty seems to be by enclosing the den, and the apartment where the screening takes place, and to draw off all the vapours set free in these apartments, by means of a fan, passing them through a condenser and a furnace, as already described.

959.



General Considerations.—The importance of artificial manures in modern agriculture cannot be overrated, by far the greatest proportion of the vegetable products of all civilized countries at least being grown by their aid. It would be difficult to assign any distinct locality where this branch of chemical manufacture is carried on. The universal distribution of the agricultural industry furnishes sufficient reason for this. Perhaps it is most largely conducted in the immediate neighbourhoods where the raw materials are mined or quarried, and it is safe to assume that every sulphuric acid manufacturer is more or less engaged in making artificial manures; at the same time, there are a great number of smaller capitalists, who buy the raw materials, both mineral and acid, and supply local needs. The manufacture is a creation of the last 25 years, and is always spreading; it will no doubt continue to grow until some better means is found for economizing that great natural fertiliser—Sewage. The sum of money invested in the manufacture must amount to several millions. When the manure-manufacturer does not make his own sulphuric acid, the capital required is very small, as compared with other manufactures. Moreover it may be conducted on any scale, large or small. Legislation concerning the conduct of the manufacture is in a transition state; but probably next session will find manure-factories under the Noxious Vapours Act, which is not likely, however, to impose any restriction upon the trade, save the prevention of nuisance, which may be easily accomplished. The commercial prices of the manufactured articles vary so much that it is not easy to fix upon a general figure. They are usually sold on a basis of containing a certain proportion of the actively fertilizing principles—the soluble phosphate of lime, the insoluble phosphate of lime, the potash, and the nitrogen (as ammonia), being the elements which enter into the estimation. The values set upon these ingredients are approximately as follows:—Soluble phosphate in bone manures, 4*s.* 6*d.* per unit per cent.; soluble phosphate in mineral superphosphates, 4*s.*; precipitated phosphate, 3*s.* 6*d.*; insoluble phosphate, as bone, or from guano, 2*s.* 6*d.*; insoluble mineral phosphate, up to 7 per cent., 1*s.*; potash sulphate, 3*s.* 6*d.*; ammonia, 20*s.*; insoluble phosphate in good "dissolved bones" (when precipitated phosphate is not reckoned), 2*s.* 9*d.* This scale is adopted by Alfred Sibson, F.C.S., of 23, St. Mary-Axe, who is well known as an analyst of manures and feeding-stuffs. As between manufacturer and consumer, it is probably the most equitable of any. It assumes that the manures are sold under the conditions usually prevailing in agricultural districts, the article being in dry, powdery condition, supplied in bags, and carriage paid, and credit being given. The two prices for bone phosphate and mineral phosphate are not generally recognized by analysts; but the justice of the plan is evident, from the greater cost to the manufacturer of phosphate in the form of bones, and the greater expense in their manipulation. Many chemists, also, do not estimate the "precipitated" phosphate, or soluble phosphate which, by long keeping, has reverted to an insoluble condition, an occurrence frequently experienced, especially with bone-manures; yet the unfairness of not admitting the distinction is manifest. The greatest proportion of the artificial manures sold in this country pass first through the hands of commission agents, before reaching the actual consumers, the farmers.

Imports and Exports.—Our imports of bones of animals and fish for manurial purposes, in 1879, were:—From the Argentine Republic, 26,929 tons, 149,541*l.*; British E. Indies, 6678 tons, 38,567*l.*; Turkey, 5828 tons, 32,845*l.*; Russia, 5123 tons, 31,315*l.*; Brazil, 3989 tons, 23,156*l.*; Uruguay, 3394 tons, 18,794*l.*; Italy, 1981 tons, 11,691*l.*; Chili, 1877 tons, 10,458*l.*; other countries, 8439 tons, 49,405*l.*; total, 64,238 tons, 365,772*l.*

Our imports of guano in the same year were:—From Peru, 44,325 tons, 480,927*l.*; Islands in the Pacific other than Fiji, 10,938 tons, 48,832*l.*; Bolivia, 7232 tons, 44,937*l.*; Australia, 4054 tons, 18,644*l.*; W. coast of Africa, not particularly designated, 3517 tons, 45,421*l.*; China, 1472 tons, 15,500*l.*; Patagonia, 1412 tons, 7498*l.*; Chili, 1150 tons, 13,800*l.*; Uruguay, 596 tons, 4682*l.*; other countries, 2859 tons, 24,207*l.*; total, 77,015 tons, 704,448*l.*

Our imports of unenumerated manures in the same year were:—From the United States, 109,378 tons, 293,302*l.*; Germany, 38,659 tons, 112,213*l.*; France, 18,411 tons, 34,421*l.*; Portugal, 10,593 tons, 37,219*l.*; Dutch W. Indies, 9144 tons, 52,501*l.*; British N. America, 8129 tons, 29,917*l.*; Belgium, 6726 tons, 15,927*l.*; British W. Indies, 5478 tons, 26,714*l.*; Hayti and St. Domingo, 2190 tons, 6747*l.*; other countries, 6636 tons, 32,496*l.*; total, 215,344 tons, 641,457*l.*

The values of our exports of unenumerated manures in 1879 were:—To Germany, 542,860*l.*; France, 121,300*l.*; British Guiana, 79,530*l.*; foreign W. Indies, 54,928*l.*; Russia, 48,370*l.*; Sweden and Norway, 45,330*l.*; Denmark, 22,860*l.*; Belgium, 20,865*l.*; Channel Islands, 19,693*l.*; Holland, 18,850*l.*; British W. Indies, 15,370*l.*; Spain and Canaries, 12,188*l.*; Mauritius, 10,200*l.*; other countries, 25,716*l.*; total, 1,024,832*l.*

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(See Acids—Sulphuric; Assaying; Bones; Cements—Glue; Leather.)

MATCHES (Fr., *Allumettes*; Ger., *Zündholzchen*).

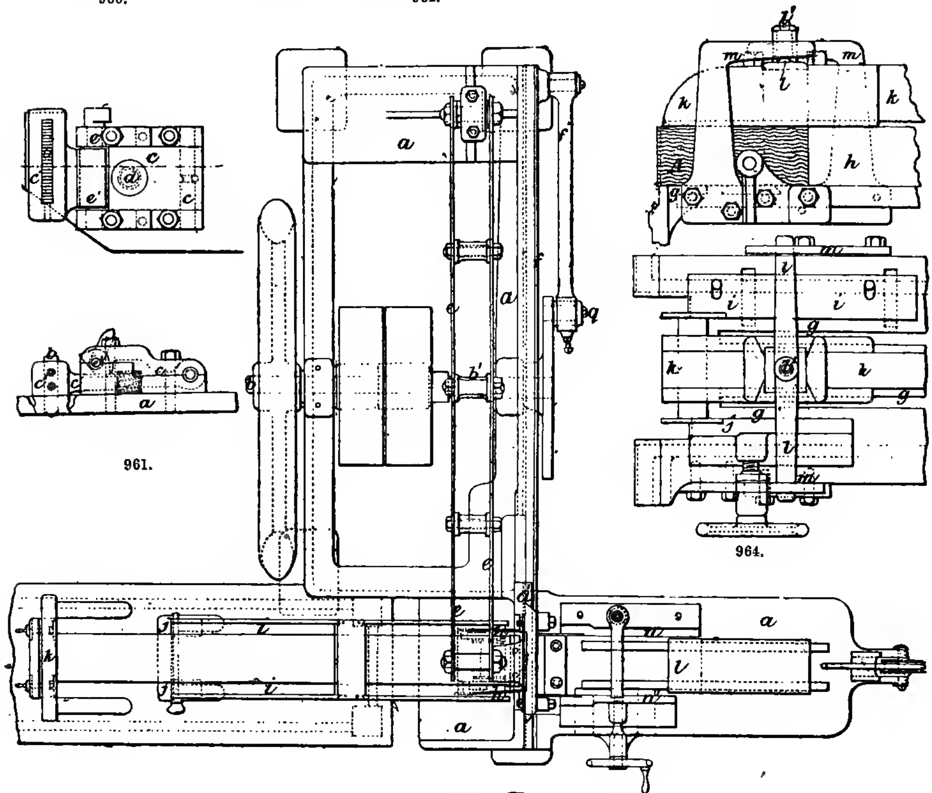
The manufacture of matches for lighting purposes is principally divided into three great branches, comprising the ordinary wooden match or "lucifer"; "vesuvians," which are principally used in the open air by smokers; and "vestas," in which a thin wax taper is substituted for the wood.

Splints and Splint-cutting.—The timber for match-making comes chiefly from Sweden and Canada, and is usually very straight-grained pine or aspen; it is sawn into 12-ft. lengths, 3 in. thick by 11 in. wide, and subdivided into blocks 5 in. long, representing two matches. If the timber is worked up in the neighbourhood of its growth, it can be cut into splints in the green state; but if it has been dried, it must be afterwards steamed for about 20 minutes. It is then passed through the splint-cutting machine, which cuts the whole into splints of the required size, only the last flake of the wood being wasted.

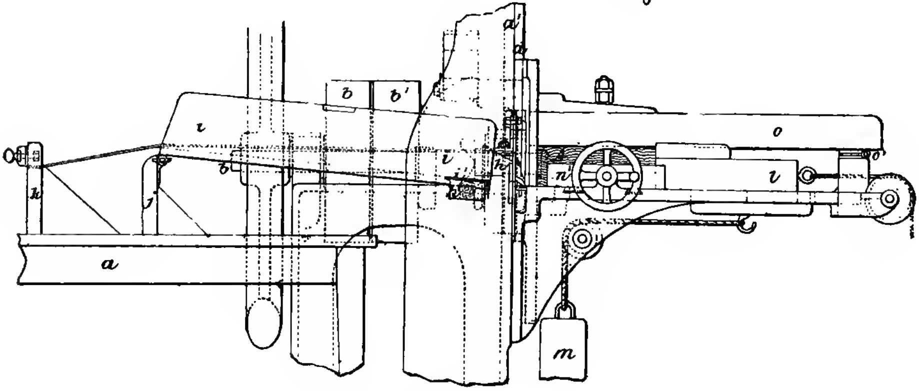
In the old method, the 5-in. blocks were cut by a vertical cutter into flakes having the exact thickness of a match; a number of these were placed together, turned at right angles to the former cut, and divided into splints. From time to time, machines have been introduced to cut the splints at one operation. One of the earliest (1859) was that of F. Tillett, in which a set of reciprocating lances grooved the block to be cut into splints, whilst a knife arranged at right angles sliced off the grooved portions. An improved machine of this type is used in Canada, and has been introduced in England by Pace and Howard. It is shown in Figs. 960 965: *a* is the framing of the machine; *b*, the driving-shaft, driven by a belt passing around pulleys on it. Fixed to *b*, are a crank *b′* and a crank-disc; *c* is the slicing-knife, fixed to the slide *d*, which works up and down in vertical guides, and receives its motion from the crank *b′*. On a standard *a′*, is jointed one end of a lever *e*, the opposite end being connected by a link to *d*. The centre of *e* is attached to one end of a link *p*, the other being operated by the crank *b′*, thereby giving the required motions to the slicing-knife. The slide *f* moves to and fro in horizontal guides, and is fastened at one end of a connecting-rod *f′*, carried by the crank-pin *q*. In this slide, is mounted a box *g*, in which the lancets *g′* are fixed. As the splints are cut, they pass through an opening in the slide *d*, and through a spout *h*. Fixed to it, a pair of rollers *h′* work between guides *i′* fixed to *i*, which, at its other end, is hinged to the standard *j*. The upper side of the spout and trough are covered by an indiarubber band *i″*, fixed to the slide *d* and standard *k*, through an opening by which the splints pass out of the trough and over the table. By these means, the splints, as they are cut, are kept in correct position, and are delivered on the table at the lower end of *i*. The block of wood A is placed upon the table, pressed towards the slicing-knife *c* by the block *l*, and held in position between guides *n n′*.

The arrangement of the holder for the lancets, and the devices for keeping the wood in position whilst being cut, having been found somewhat inefficient, Pace has devised modifications of these details. Figs. 962 and 966 show elevation and plan of the tool-holder, and Figs. 963, 964, side elevation and plan of the devices for steadying the match-wood. In Figs. 960, 961, *a* is a portion of the slide carrying the lancets *b*, mounted in a holder *c'*, formed on a lever *c*, which turns upon an axis carried by the slide; this lever *c* is acted upon in one direction by a spring to carry the lancets out of action, whilst an incline *e'*, mounted on an axis, acts reversely to carry the lancets into position for work; *e'* is operated by a tail-piece, which strikes against the framing of the machine, and thereby causes the lancets to come into or out of position for work as required;

960. 962. 963.



961. 964.

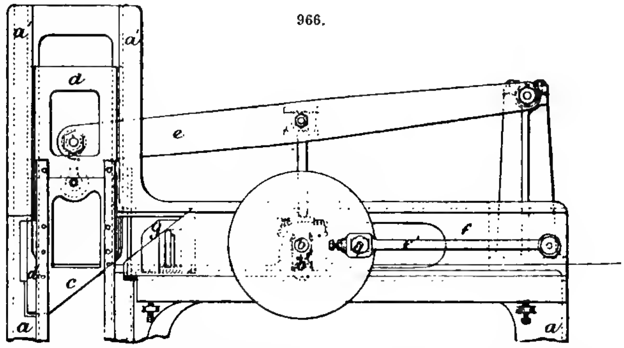


965.

while A, Figs. 963, 964, is the block of wood to be cut into splints. This last is supported on the table *g*, and is pressed forward by the pushing-block *h*. The block is guided at its sides by the fixed guide *i* and adjustable guide *j*, and, at the top, by the holding-down lever *k*; but instead of acting upon the holding-down lever *k*, by means of a locking-latch mounted on an axis of motion at one side of the block of wood, as in Figs. 962, 965, a much longer locking-lever *l* is employed, mounted on an axis *l'*, carried by the holding-down lever *k*, and each end of which comes under inclined catches *m*, fixed to the frame of the machine on each side of the block, and as far therefrom as practicable. By these means, A is held firmly, and the lancets are prevented from following the grain of the wood, and thus made to act with precision.

In Sweden, the splints are usually made from aspen, cut in logs of 12–22 in. diameter. The wood is worked as soon as possible after being felled; if seasoned, it has to be steeped in water. The logs are cut by a cross-cut saw into pieces of 14 in., each containing seven lengths of matches, the bark being removed immediately afterwards by hand labour. The pieces are next chucked in a spear-lathe, making 15–20 rev. a minute, where they are reduced to shavings by a planing tool acting simultaneously over the whole length. The thickness of these shavings is equal to the required thickness of the matches. Fixed to the same rest as the planing tool, but slightly above it, are eight cutters, which divide the shaving into seven equal breadths, whereof each corresponds to the length of one match. These shavings are freed from knots, and cut into lengths of about 6 ft., from which the matches are produced by a machine similar to a guillotine paper-cutter; this operates upon two packs at once, each consisting of 90 shavings, and, when properly fed and making 120 strokes a minute, cuts matches at the rate of a million to each working hour.

966.



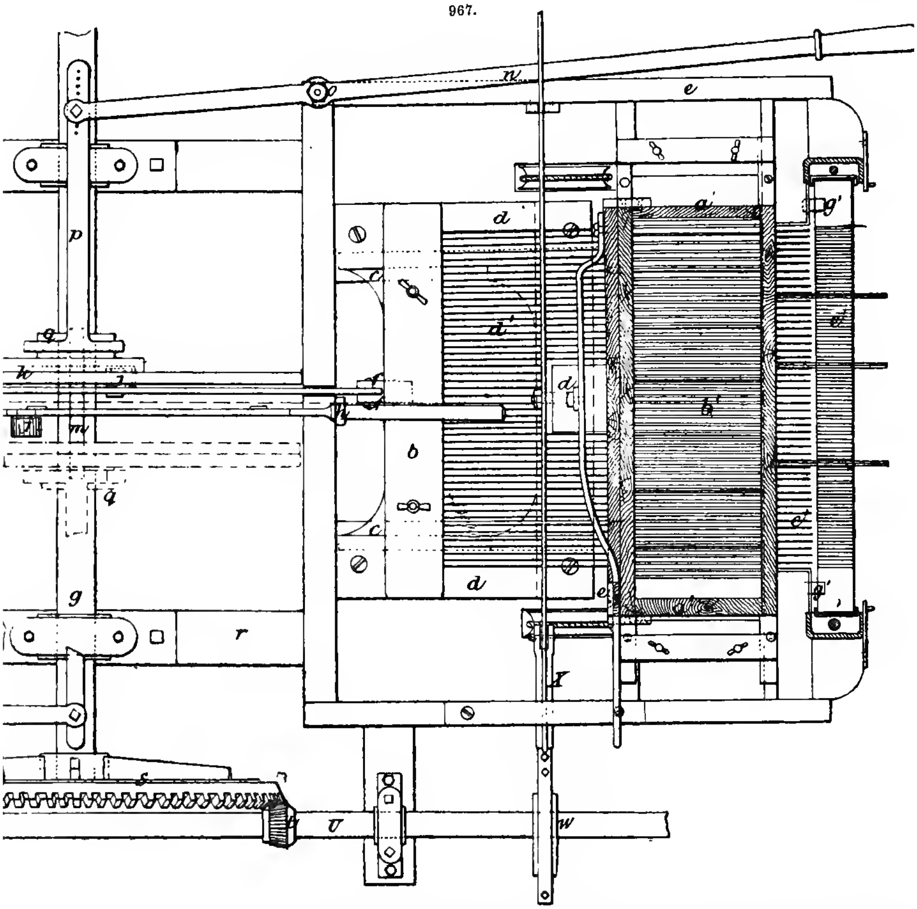
At this stage, the Swedish splints are dried by being passed through two wire-gauze cylinders, about 10 ft. in length and 30 in. diameter, making 30 rev. a minute, and placed one above the other within a brick stove heated by chips and waste. The dried slips are next freed from splinters by being placed on a grid, with openings of suitable width to effect the separation. This grid receives a rapid vibratory motion, in a direction across its openings, by a crank-shaft. Its surface is partitioned, by strips of zinc in the same direction, into compartments a little wider than the length of a match; so that the slips are not only freed from splinters by rubbing against each other and against the bars of the grid, but are also laid parallel in these compartments.

Filling and Dipping.—The splints are then collected into bundles and dried, which takes a longer or shorter time, according to the state of the atmosphere. The next process is to place them in the dipping-frames; the bundles are packed and looked over for "flakes"—imperfect splints, which would interfere with the action of the machine, and must be removed. The general plan was to dip the bundles (before arranging them in the frame) into paraffin. The objectionable feature is that each match does not receive its fair share of paraffin; this is in a great measure obviated by dipping in the frame, or by applying a hot plate to the end of the bundle, which dries the tops of the splints, and enables them to absorb the paraffin with rapidity. Both plans are in use.

The dipping-frame consists of wooden laths, 1 in. by ¼ in. section, and 28 in. long, having a hole at each end, and moving freely upon two round iron bars fixed in a somewhat stronger lath. Between each two of these laths, 50 splints are ranged, equidistant from each other, and projecting equally beyond the surface of the frame. This is done by means of a filling-machine, consisting mainly of a cast-iron table, fitted with 50 parallel grooves, of a depth equal to the intended projection of the cuttings beyond the surface of the frame.

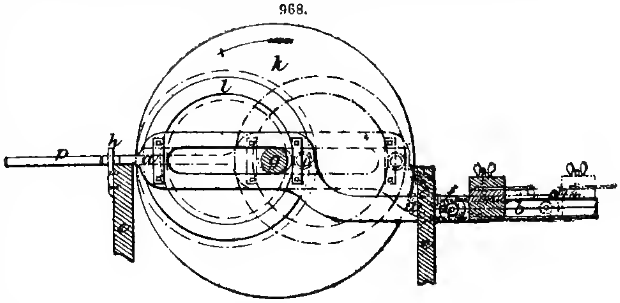
Filling-machines are commonly worked by hand, the frame being held in front, the box containing the splints being shaken by hand, whilst the wires which project the splints from the grooves into the filling-frame are worked by levers from a treadle. Fig. 967 represents a plan of an ordinary filling-machine, with certain additions devised by L. Mount, for enabling a number of machines to be operated simultaneously. Here one machine only is in work, but the Fig. indicates the method in which the two machines, back to back, are driven from the same shaft *g*; and Fig. 968 shows the manner in which the bevelled slide is drawn backwards and forwards, and the length of stroke given by the movement to the stud and roller, and consequently the connecting-rod, by the rotation of the cam; *a* is the connecting-rod, secured to the slide *b*, which is bevelled at its ends *c*, and works in V-grooves in the cast-iron piece *d*, screwed to the frame of the machine *e*. The connecting-rod *a* is secured to the slide *b* by being passed between two tongue-pieces *f* and a bolt. It is made in two parts, fastened together by a strip of metal, and is slotted as in Fig. 968, so that it slides easily over the shaft *g*. Its outer end, shaped in a turned rod, works in the bearings *h*. The connecting-rod is provided with a stud *i*, encircled by a friction-roller *j*; *k* is the cam, with a groove *l* on its face. It is carried round on the shaft *g* by a key *m*, entering a similar sized cavity in the inner periphery of the cam, large enough to allow the cam being operated by the hand-lever *n*, pivoted at *o*, so as to slide along the shaft and out of the way of the friction-roller *j*; *p* is the fork, entering a groove in the boss *q* of the cam, and connected with the hand-lever; *r* are the bearings, placed between the backs of two machines, and on which the shaft *g* is supported; *s* is a bevel-wheel, in gear

967.



with a pinion *t* on the shaft U; there are bearings to support this shaft; *w* is a boss, set eccentric on the shaft U, and which, by means of the fixings and attachments *d*, gives a rapid to and fro motion to the hopper *a′* containing the splints. This has the effect of shaking them down into the grooves *b′*, made in the bed-plate forming the bottom of the box *a′*; *c′* are the vertical plates, through which the splints issuing from the machine are separately pushed by the wires *d′* into the grooves of the dipping-frame *e′*. This frame *e′* is set upon the ascending and descending frame, which is controlled in its working by a counterbalance weight. The frame *e′* is prevented from being pulled up by the weight by means of the counterbalance catches *g′*. Motion is imparted to the shaft *w* by means of a belt from a main shaft. This communicates motion through the pinion *t* to the bevel-wheel S and shaft *g*; which latter, by means of its fixed key *m*, carries around the cam *k*, the

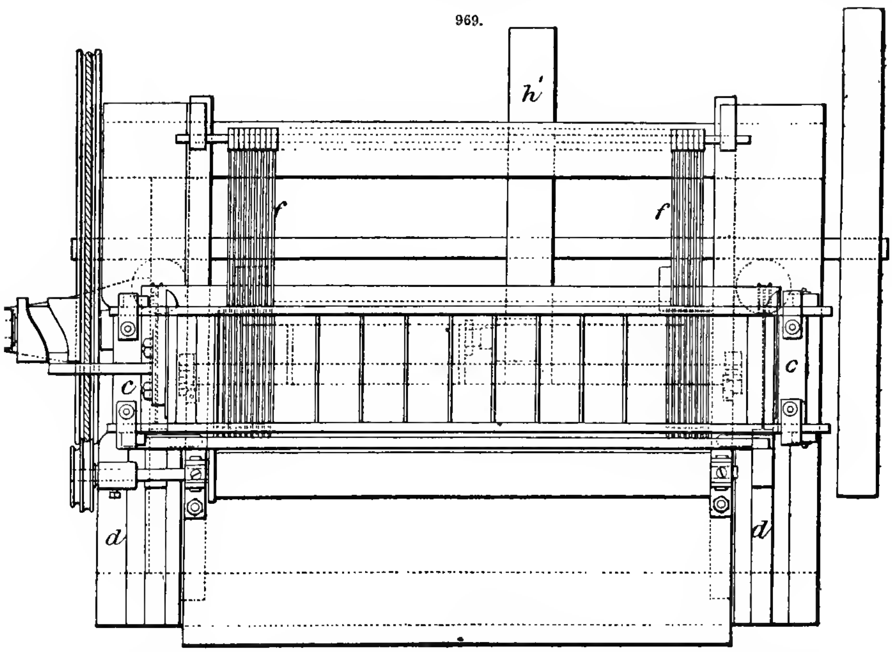
968.



hand-lever *n* having first been moved so as to allow the groove of the cam to admit the friction-roller *j*. The motion is imparted thereto and to the connecting-rod *a* and slide *b*, which last is pushed backwards and forwards; the wires d', entering the grooves b' of the bed-plate, push out the splints, which are caused to fall by the shaking or to-and-fro motion imparted to the hopper, between the plates c' and on to the fold of the dipping-frame; another grooved fold is then put on the same, and the operation is continued until the dipping-frame is filled, when it is taken away and a fresh one is supplied. The rotation of the shaft *u* carries with it the fixed eccentric boss *w*; this is connected with the jawed connecting-rod *x*, and this latter to the bar x'. The motion is imparted from this to the pieces *y*, and to the hopper. The lower of these pieces is fixed to the rod x', and the upper one is attached to the iron band x'' of the hopper. They are held together, when required, by means of the drop pivoted bit y'', worked by the rod *z*. An additional groove is formed at either end of the bed-plate, so that if more than the proper number of splints should fall into the grooves b', they will be kept from being pushed out of the box, and thus overcrowding the dipping-frame and wearing out the brush. The shafts *g u* and the rod X' can be continued or lengthened, so as to accommodate and work any convenient number of machines.

The filled frames are conveyed away to be dipped. They are placed on a flat table, and levelled by taps upon a piece of board. Matches were formerly all tipped with sulphur to convey the flame; but this is now done only when, for economy's sake, the sweepings of the factory are re-dipped, and these are sold as inferior goods. If not already paraffined, first one side and then the other is immersed and withdrawn from the paraffin-bath; they are then passed on to the dipping-room. The apparatus here consists of a steam-jacketed iron pan, containing the igniting composition, and a hollow iron table, also kept hot by steam, upon which a sufficient quantity of the composition is from time to time ladled to supply the requirements of the work; this is spread in the necessary thickness, and to cover a space somewhat larger than the dipping-frame. The splints projecting from one side of the frame are applied to the composition for a moment, and, in the case of common matches, are removed, reversed, and applied at once to the other side; but with good matches, after one side is dipped, the frame is suspended, and dipped end downwards for some 15–20 minutes, being slid between light iron supports provided for this purpose at the sides

969.



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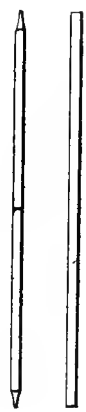


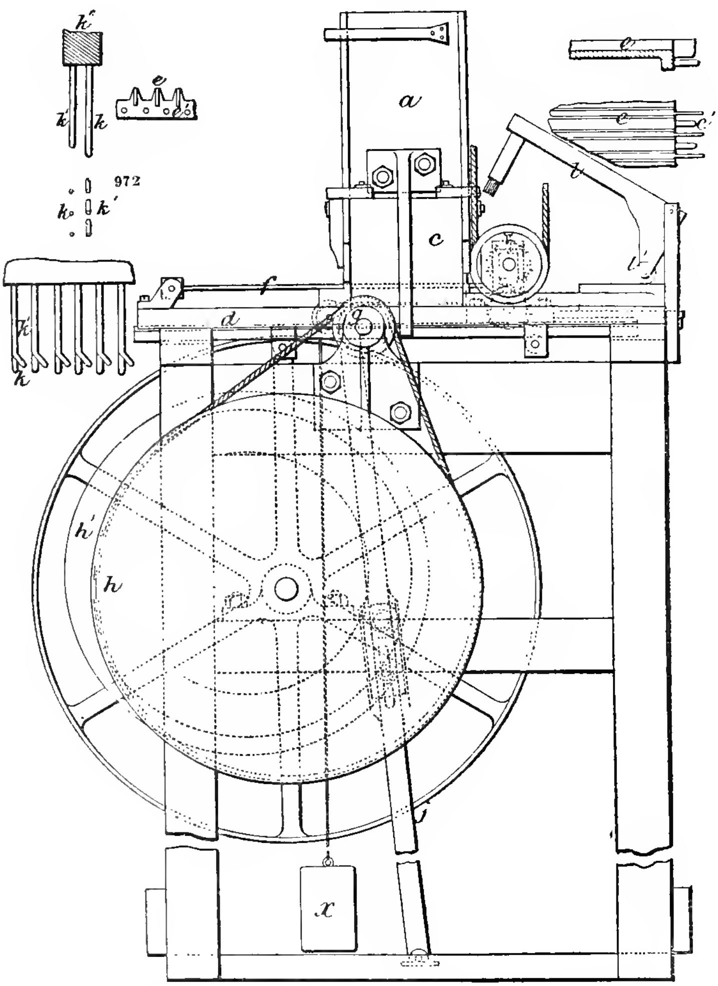
of the dipping-room; the composition thus assumes a more sightly form, and the top of the match is well rounded, the other side of the splint being completed in precisely the same way when the first is dry.

The matches are finished by being removed in the frames to a drying-room, where, after remaining for a short time, they are ready for cutting and packing into boxes.

The matches, when dry, are laid in heaps, cut down, and put into boxes by the handful. The boxes, when filled, are placed in frames called "ducks," holding three to four gross, and passed through iron doors into the packing-room, where they are put into packages, glued up, and labelled.

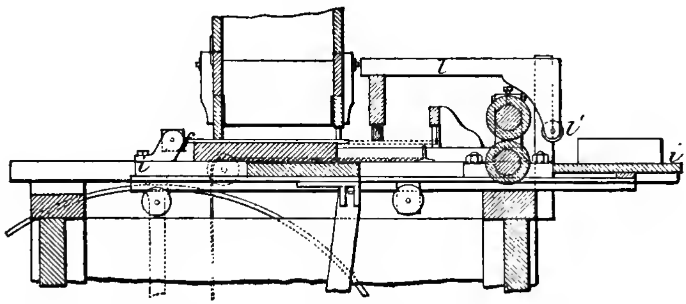
It has been supposed to be advantageous to point the ends of splints before dipping, and to effect this economically, Pace has devised the machine shown in Figs. 969 to 976. In manufacturing pointed splints, he first sorts them, so as to get rid of all short or otherwise imperfect ones. For this purpose, machinery such as that represented in end view Fig. 973, vertical section Fig. 975, plan Fig. 969, and side view Fig. 976, is employed. The splints are placed in a reciprocating box *a*, provided with projections, working on guide-bars *b*. The box *a* is prevented

971. 973. 974.



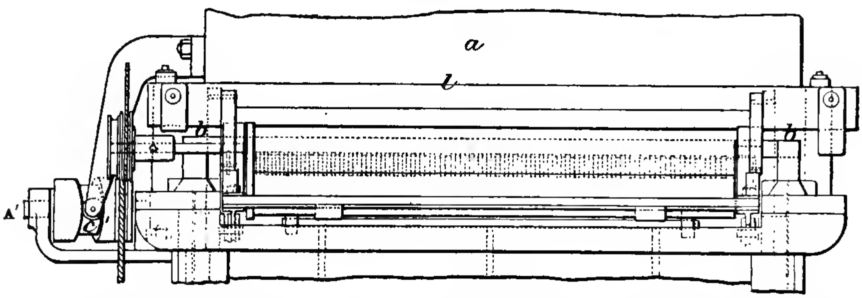
rising from *b*, by guide *s*, fixed to standards *c*, carried by the table *d* of the machine, and adjusted sideways by guides *a''*. The box *a* is provided with divisions, and the bottom is formed by a fixed plate *e*, provided with grooves *e'* to receive the splints. A series of wires and rods *f* mounted on a rod *f'* act in combination to push the splints out in a manner similar to the filling-machine, Fig. 967. An arm A' has on its end a roller C', running in the groove of a cam *g*, provided with axes working in bearings fixed to a bracket. This cam receives motion by means of a belt passing partly around a grooved pulley on one end of *g*, and partly around a grooved wheel *h* on the driving-shaft. By these means, an endwise reciprocating motion is given to the box *a*, in order to agitate the splints. The rod *f'*, with the pushing-wires, is carried by brackets fixed to a table *i*, which has a reciprocating motion derived from a lever *j* mounted on the frame, and provided with a pulley, working in the groove of a cam *h'* fixed on the driving-axis. The grooves *e* (Fig. 974) extend a short distance beyond the front of *a*, and, at their ends, the bottoms are removed, and replaced by short pins *e'*, occupying only a portion of the width. In connection with *e*, are sliding supports, Figs. 971, 972, 975, consisting of straight wires *k* and bent wires *k'*, the latter turned at their points, so that these partially cross the spaces between the wires *k*. Both *k* and *k'* are fixed in a bar *k,"* joined to the slides, which move to and fro in grooves, formed in the table *d*; they are forced

975.



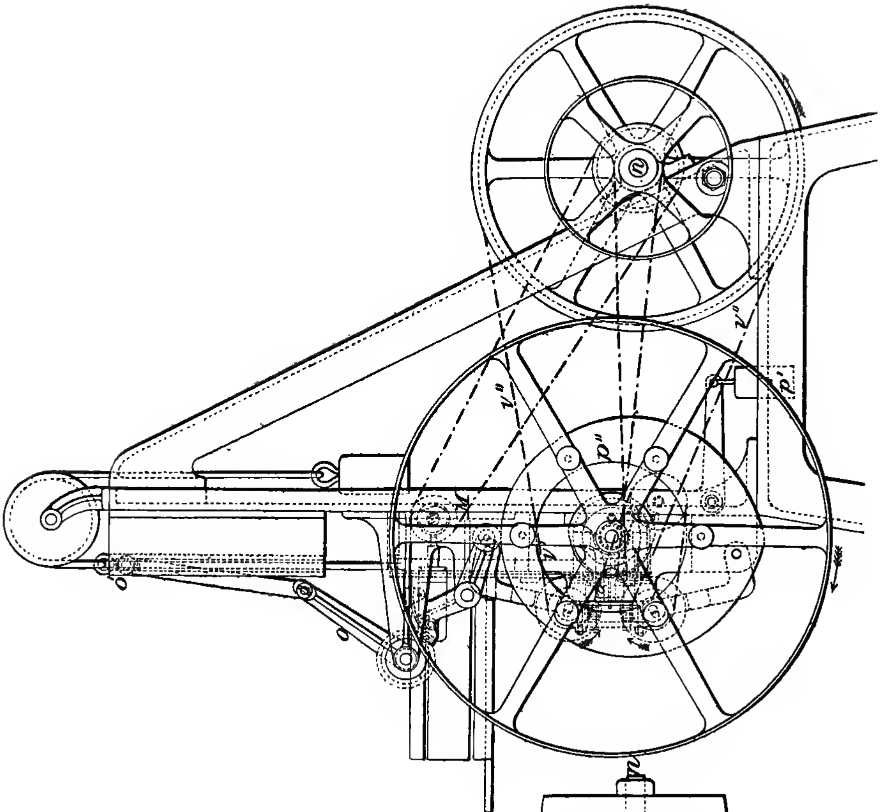
in the one direction by weights *x*, and in the other, by pushers *i''*, which also act upon projecting plates *k''* fixed to the slides. Thus the reciprocating supports *k k'*, the travelling bed *i*, and the pushers *f* travel together in the one direction until the travelling supports *k k'* arrive at the box *a*, when the travelling bed *i* and pushers *f* continue their motion a short distance, and the motion of the travelling supports *k k'* is stopped for a time; then, on the return journey of the pushers *f*, the latter travel for a short distance alone; and finally, the pushers and the travelling supports *k k'* move together for the remainder of the distance.

976.

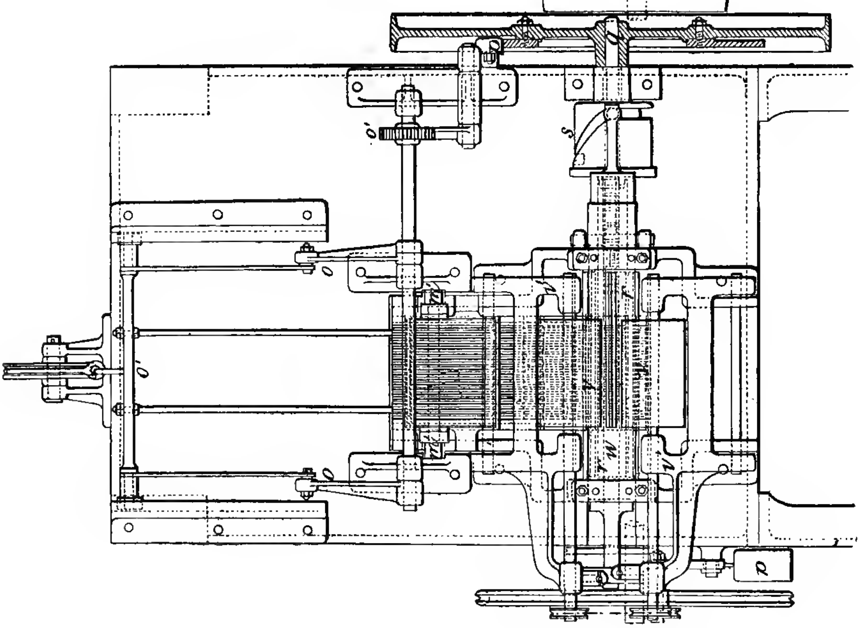


As the splints are pushed out from *e*, and fall on to *e'*, a brush *l* descends, and brushes aside the faulty splints. This brush is fixed to a lever *l'*, mounted on to a fixed axis. The tail of the lever *l'* is acted upon by a projection, fixed on the travelling bed *i*, so that, as the projection approaches the box *a*, it acts upon the tail-piece *l'*, and raises the brush *l* to permit the required motion of the sliding supports *k k'* to ensure the proper drawing off of the selected splints. These drawing-off rollers are covered with indiarubber, mounted in bearings, and rotated by a strap from an intermediate wheel, motion being communicated from one roller to the other by toothed-wheels. Thus any short or faulty splints will fall down, whilst the good splints will remain supported by *e'* and *k k'*; in the return motion of the travelling bed *i*, the splints will be taken by the delivery-rollers.

The splints, sorted in this manner, are fed into a box *m* forming part of the pointing-machine, a plan of which is represented, with the pointing-rollers removed, in Fig. 977, a front view in Fig. 979, and an end view in Fig. 978. Fig. 982 is a vertical section of parts on the line A B of Fig. 977. The bottom of the box *m* is formed by a fixed grooved plate, and is provided with V-pieces *m'*, sliding in guides; to these pieces, is fixed a cross-bar, having at its centre a roller which works within the groove of a cam M, mounted on a cross-shaft turned by a strap, which passes partly around a groove formed on the boss of the cam M, and partly round a pulley fixed on the driving-shaft. The splints are placed in the box in a vertical position, and are pressed towards the bottom by wires, which work in slots formed in the sides of the box *m*, and are acted upon by springs. The splints are, by means of wires, carried by a reciprocating-bar, pushed from beneath the box along continuations of the grooves, and in their course from beneath the box *m*, are first acted upon by



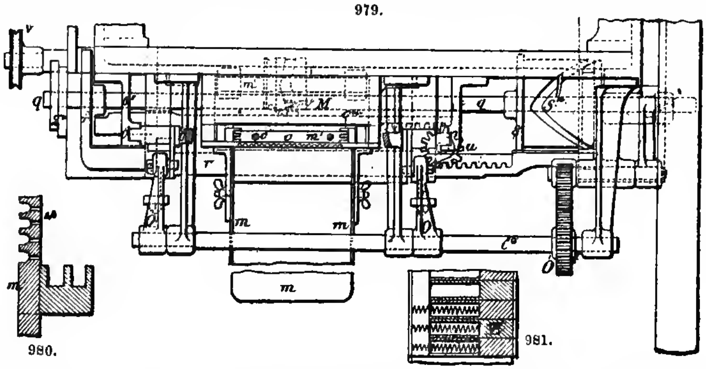
978.



977.

spring-pistons E, Fig. 981, to retain them in the grooves, and then, before they have left these pistons E, pressure is applied to them for a similar purpose by a series of springs carried by a fixed bar. The spring-pistons also prevent more than one splint passing from a groove at each

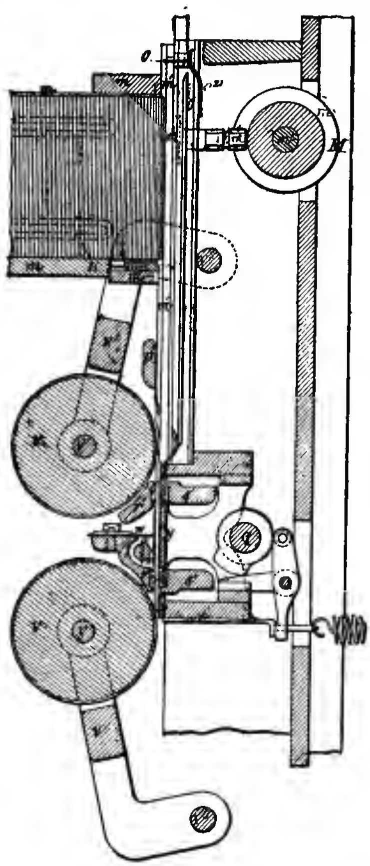
979.



980. 981.

action of the wires. The bar o is fixed to the lower ends of rods, which, at their other ends, are fixed to a cross-bar O′, whose ends work within channels formed in the frame of the machine. This cross-bar is connected with levers O, fixed on a shaft, which bears a toothed-wheel o', receiving motion from a toothed segment formed on a lever, whose bearing is connected with a second lever, provided at its end with a roller p, resting on the periphery of a cam p''. This cam p'' is fixed to the arms of a wheel on one end of the main driving-shaft q. A weight hanging from one end of a cord passes over a pulley, is connected at its other end with the cross-bar O′, which it raises, at the same time keeping the roller up to its cam p''.

982.



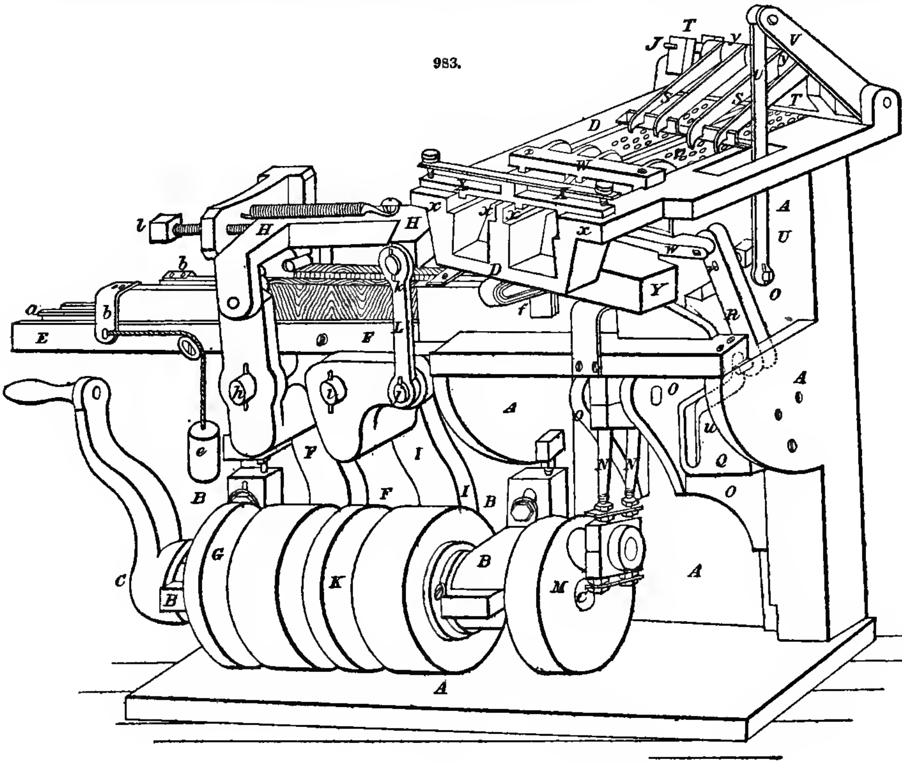
In the further descent of the splints, they fall between reciprocating rubbers, and are correctly adjusted by a catch-plate, which is simultaneously pushed forward to receive the lower ends of the splints. The rubbers are fixed in frames r s', which slide a short distance away from the splints, so as to leave a free space for their descent. The frame r is acted upon at each end by cams s'' on the main shaft, to remove the rubbers from the splints, and by springs to press them inwards.

From one end of the frame r, projects a stud, provided with a roller, working in the groove of a cam s'', and the frames r' s' have toothed racks taking into the teeth of a pinion u; thus as motion in the one direction is given to the second frame r', a similar motion, but in the contrary direction, is given to the second frame s', and consequently the splints held between the rubbers r s are rotated first in one direction and then in the other.

During the rotation of the splints, their ends are acted upon by pointing-rollers v, provided with cutting surfaces. The axes of these rollers are mounted in frames v', and on axes to which motion is given by a strap V″, passing partly around a wheel fixed on the shaft n. These pointing-rollers v are removed from contact with the splints by means of cams, acting upon adjusting-screws, carried by the frames V′; and the pointing-rollers are taken into position by the weight p', acting through a lever, carrying a tension-roller upon the band V″. A blade w is mounted in the frame r, in order to cut the double splints nearly into two. To facilitate the discharge of the pointed splints from the machine, a wiper x, consisting of a strip of indiarubber mounted between the two halves of a shaft, is employed to act upon the splints.

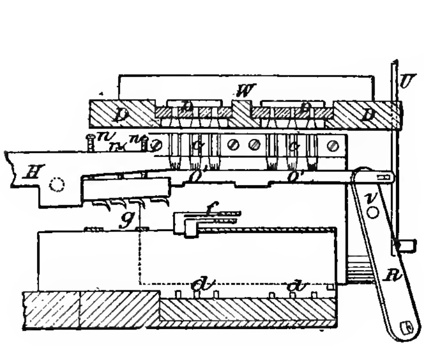
Machinery is much more employed in this manufacture in the United States than in Europe, and, with the exception of splint-cutters and common filling-machines, most of that here described is due to American ingenuity. Figs. 983, 984, 985, show McC. Young's cutting- and filling-machines.

983.

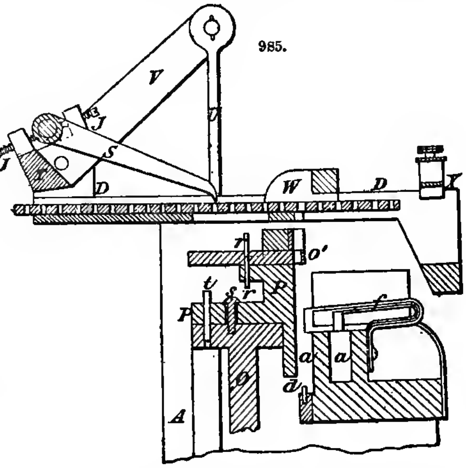


The main frame A is made very strongly of cast-iron. In bearings B is hung the shaft C, and on it are arranged a series of cams and cranks. On the top of the main frame A is secured the secondary frame D, set obliquely. To the main frame, is joined a feeding-trough E, in which are

984.



985.



two guideways *a a*, for containing the blocks of wood from which the match-splints are to be cut. Behind, is a feeder *b*, to which is attached a cord, passing over a pulley, and having upon its end a falling weight *e*, by which the blocks are fed up to the splint-cutters. A spring *f* is arranged to press upon the foremost of the series of blocks, to prevent them from slipping back when the feeder g is out of the wood, and recedes to take a new hold. The weights e move the blocks up to the real feeder g, and the latter forces the blocks along to the cutters. The two toothed feeders g are arranged side by side, so that each one feeds up its own line of blocks. A lever F is pivoted to the main frame at h, and, upon its lower end, is a friction-roller that runs in an undercut cam-groove G on the cam-shaft C, so that F has a positive motion in both directions. To this lever F, are attached, by a cross-arm, arms to which is pivoted the rear of the frame H that carries the feeding-points g; by this arrangement, the forward and backward feed-motions are attained. Another lever I, pivoted to the main frame at i, has upon its lower end a friction-roller, running in an undercut cam-groove K on the cam-shaft C, by which it also receives a positive vibratory motion. On the lever I, is a crank-arm, to pivot pins j, in which the lower ends of connecting-straps L are attached, the upper ends of these straps being pivoted at k to the frame H, which carries the feeding-points g; by this mechanism, the feeding-points receive their upward and downward motions. An adjusting-screw at l regulates the backward movement of the frame H, and consequently the length of the feed. The spring m holds the frame H to its bearings.

On the end of the shaft C is a crank-wheel M, to a wrist in which is joined the pitman N, whose upper end is attached to the vertically reciprocating frame O, carrying the series of knives o o and o' o'. The cutters and the knife-frame are set obliquely to the line in which the blocks are fed, both sets cutting and moving at the same time. Above o o', are guides c, partially open, to allow small slivers of wood to pass out, and thus prevent clogging; above these guides c, is a guide-plate with countersunk openings, by which the splints are guided into the holes of the moving plates p, and carried out of the machine. The points d hold the wood to form the splints, and allow the cutters to go clear through, and entirely sever the splints from the blocks, these points entering slightly into the cutters for that purpose.

The cutters o o' are made upon the ends of small steel bars; each of these has a seat in the knife-stock, into which they are slipped from the rear of the machine. They are held in exact position in relation to each other, and to the blocks of wood they are to act upon, by pins r passing through them into the stock; they can therefore be drawn out or replaced with great accuracy. The stock P is made adjustable on the gate O by a slot and set-screw as at s; to hold it in position, steel pins t pass through the stock and into the gate. At times it may be necessary to redrill and enlarge the holes and the pins t, when the stock, by wear, has to be moved up any material distance; for this purpose, these parts are so made as to be readily reached.

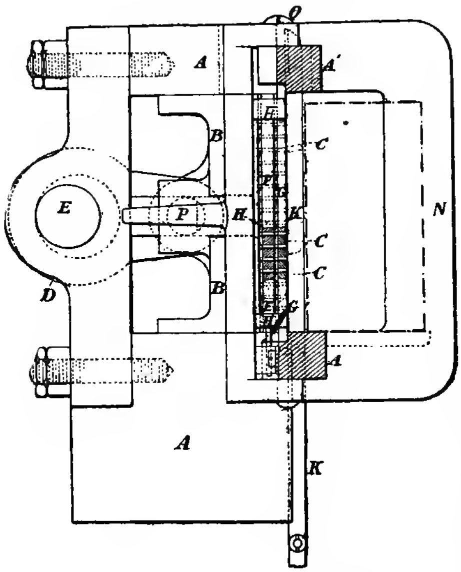
In a plate Q attached to the main frame, is a cam-slot u, in which runs a roller on the end of the lever R; this lever is pivoted to the gate at v, and is vibrated by the slot. To the upper end of R, is pivoted the sliding keeper-plate w, which, when the splints are in the cutters, guides, or carriers, and are being carried up to be stuck in the plates P, moves underneath and forms a support for them, forcing them into the plates P. In ways x in the carriage-frame D, the two plates p are moved by feeding-fingers S, which take into the holes in these plates, and so push them along in exact time to receive the match-splints as they are brought up to it. These fingers S are loosely arranged upon a shaft with washers y between them; this shaft is hung in a rocking-box T, by screw-points J, diametrically opposite to each other, and at each end of the shaft, so that the shaft and the fingers may be adjusted with precision, as the holes in the plates p must be exactly over the splints, and at the exact time to receive them, the machine being run at a very high speed. The box T is rocked from the gate O by means of the connecting-rod U and arm V. The plates p are connected together, fed along in an endless series, and separated after they come out filled with match-splints for convenient handling. On the frame D, is placed a rigid presser-bar W, bearing upon the plates p near the points where they are receiving the splints; and near the end of the frame D, is a yielding presser-bar X, for holding the plates to the ways, and against accidental movement.

The set-screws n are for defining the extent to which the feeding-points g shall enter the wood, and to compensate for their wearing away. At Y, is a wind-trunk, through which an exhaust-current of air is drawn by a fan, to clear the machine of all small slivers of wood and other material that would tend to clog it.

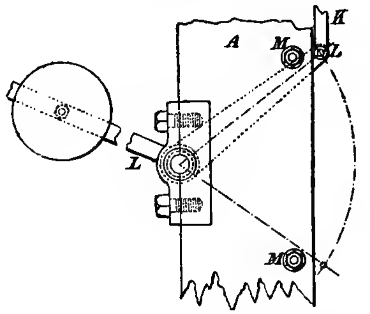
For the purpose of expelling the splints from the perforated plates after dipping, McC. Young employs the machine shown in Figs. 986 (end view), 988 (plan), and 987 (detail of framing): A is the framing; B in a sliding block carrying punches C, passing through a perforated guide-plate F; D eccentrics on a shaft E for moving the block B to and fro. The shaft has a partial turn given to it by a long lever-arm whenever B is to be moved. G is one of the plates holding the finished matches; it is slid into grooves in top and bottom cross-bars A′, forming part of the frame, and is so brought into position in front of the set of punches. As the plate is slid forwards along the grooves, Fig. 986, it moves freely past a stop H, until its forward end comes against a stop I. The stop H is then, by a spring, caused to turn in behind the rear end of the plate, and prevent it from moving back. When thus held, the holes in G are opposite to the punches.

It requires considerable pressure to simultaneously expel all the matches from a plate, and to support it against the action of the punches. Thin metallic bars K are used, raised or lowered by turning the weighted lever L, Fig. 987, and held in either position by the weight. M are stops. Whilst the plate is being placed in front of the punches, the bars K are in their lowest position. The bars are then raised, one edge of each coming against the plate, and the other against parts of the frame. The block carrying the punches is advanced, and the matches are expelled, and

986.



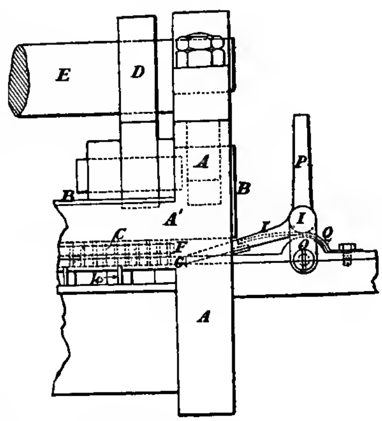
987.



received into a box. To allow the plate to be moved forward, the stop I must be turned aside; the stops I H therefore turn on pins O, and have lever-handles P, by which they can be moved by hand; they are also acted on by a spring Q, to bring the stop into position.

An ingenious machine for filling splints, devised by E. B. Beecher, of Connecticut, is shown in Figs. 989 (plan), 990 (longitudinal section), 991 (side elevation), and 992–994 (details). The frame *a* rests upon a bed-plate, to which the legs of the frame are fastened. On the main driving-shaft *b*, are fast and loose driving-pulleys, and a toothed-wheel which gears it to a counter-shaft *c*, surrounded between its bearings by a sleeve *d'*, attached to the vibratable frame *d*, which swings thereon as its axis, irrespective of the rotation of the shaft. The splint-frame mandrel *x* rotates in a long pipe-bearing *x'*, attached to the end of the frame *d* that hangs over the mechanism for setting the splints. Upon this mandrel, is placed the drum *f*, upon which the splints are framed, this being slipped upon the mandrel at the end and held so as to rotate with it, and be readily removed.

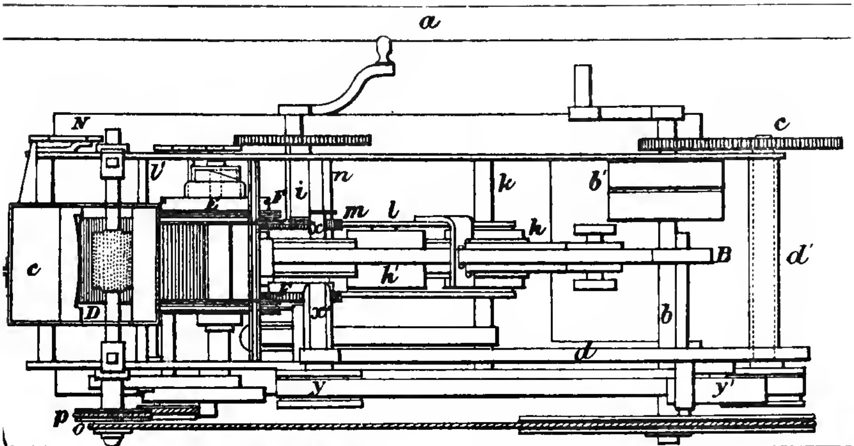
988.

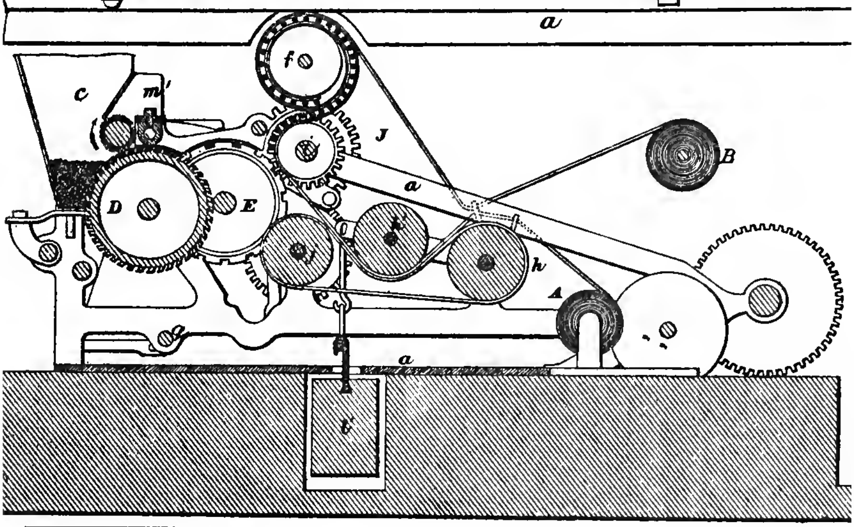


To compensate for the increasing size of the frame, and to maintain a constant tension on the binding-tape, the frame-drum mandrel is driven by a rapidly-revolving friction surface on the mandrel-pulley *y*, its tension being regulated by the adjustable tightening-pulley *y'*. The frame-drum should be about 3 in. in diam., and for two-length splints about 3 in. wide.

The binding-tape A is of cotton-webbing, about the thickness of the splints, some 2½ in. wide, and attached at one end to the frame-drum by winding a coil around the same. The other end of the tape is placed in a coil upon a journal, from which as it uncoils it passes through the guide *s* to a holding mechanism, consisting of an endless band *h*, which is mounted on drums and a weighted pressure-roller *h'*. The coil of secondary tape B is located in a plane above the lower belt, and carried through a guide to the winding-drum. The main tape passes from A upwards, partially around a guide-roller, and thence to the frame-drum *f*. The guide-roller turns loosely on the shaft *i* between two setting-wheels F, constructed with notches the thickness of a splint apart, to take the splints one by one from the count-wheels, at a point above the binding-tape, as it passes over the guide-roller, to carry in the splints regularly between the binding-tape going in to the frame and the preceding coil, the splints being lifted out of the notches of the setting-wheel by the binding-tape; the auxiliary tape is at the same time drawn in over the latter. By this arrange-

989.





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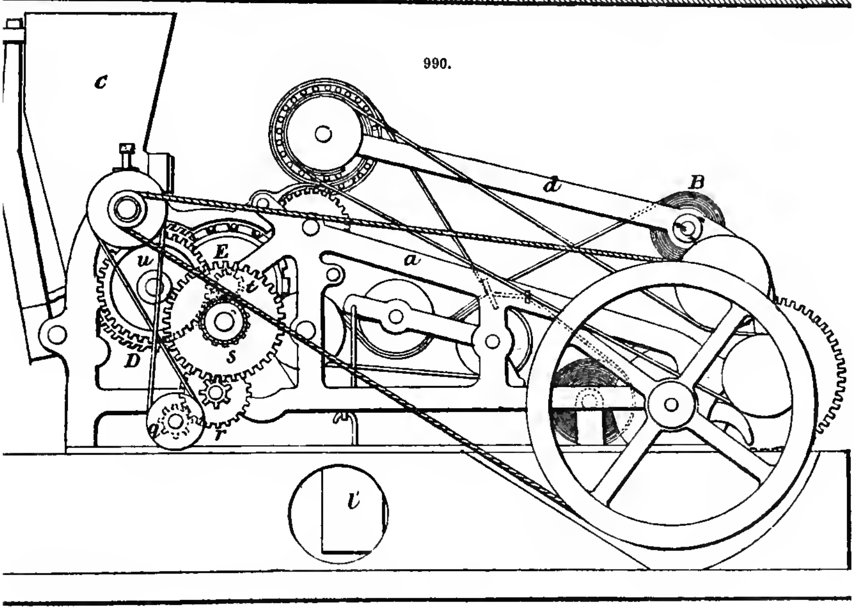
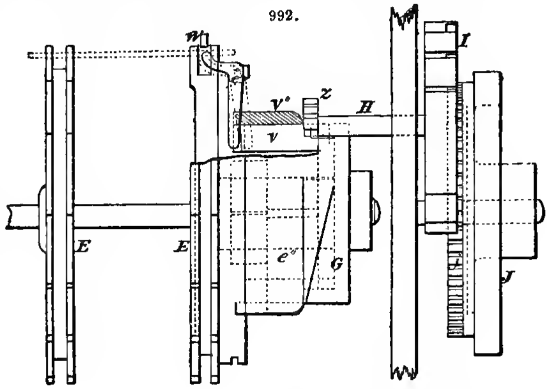


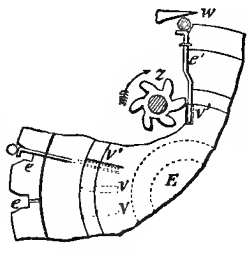
991.

ment, the splints lie between two thicknesses of taping, the order being: (1) the main belt, (2) the splints, (3) the auxiliary belt, (4) the main belt, and so on.

The frame, having been completed, may be removed from the machine, and treated in the ordinary manner. When it is desired to unroll the frame, the upper tape should first be unwound, one turn, for the purpose of changing the relative position of the belts, so that in unwinding them the matches will lie between them. The splint-setting wheels are rotated by a toothed-wheel J on the end of the shaft *i*, which gears into and is driven by a toothed-wheel on the shaft *j*, actuating the holding and feeding mechanism of the binder-tape, so that the setting-wheels and feed-mechanism move simultaneously.

992.





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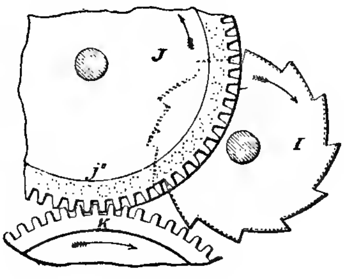


994.

The driving-drum which moves the endless belt *h* is fast to the shaft *j*, and the loose drum runs on a bearing in the middle of the tie-rod *k*, which is fast at both ends to the sides of the machine frame. The pressure-roller *h'* runs loose on a fixed axis *l*, fast to a frame which swings on bearings on the tie-rod at each side of the loose drum, and is connected with a heavy weight *l'* by links.

A rotating wire-brush cylinder, covered with card-teeth inclined backwards, is placed over the receiving-cylinder D, as close to it as possible, and is rapidly rotated in the direction of the arrow, Fig. 990, for the purpose of sweeping from the surface of the cylinder those splints which are not taken into the grooves. There are also curved guides placed over the receiving-cylinder and count-wheels E, and running up in front of the setting-wheels F, for the purpose of keeping the splints in the grooves and notches of these devices. The hopper *c*, which is of suitable width for the splints, is wider than the receiving-wheel, the excess width being equally apportioned at both ends of the receiving-cylinder, so that the splints, when taken into the grooves of the receiving-cylinder, project equally from both ends of the same, in order that the count-wheels may lift them by their projecting ends, and transfer them to the setting-wheels.

A pair of stationary cams *m*, fast at one end to the tie-rod *n*, come up close to the sides of the setting-wheels, and extend forward with a curve into the groove of the count-wheels. These cams assist in the transfer of the splints from the count-wheels to the setting-wheels, by lifting them from the former at the point of transfer.

Motion is communicated to the machine from the fly-wheel on the main shaft by a band *o*, running on a grooved rest-pulley fast to the wire-brush shaft, and which, by a groove of larger diameter, drives a cross-band *p*; the latter turns a grooved pulley fast to the shaft *q*, which rotates in bearings on the under side of the frame of the machine. On this shaft, is a pinion gearing with a carrier-toothed-wheel *r*, running on a stud-pin at the side of the frame, and carrying with it a pinion which drives a second toothed-wheel, with a pinion *s*, which gears with the wheel *t* fast to the receiving-wheel shaft, and also with *u* on the count-wheel shaft.

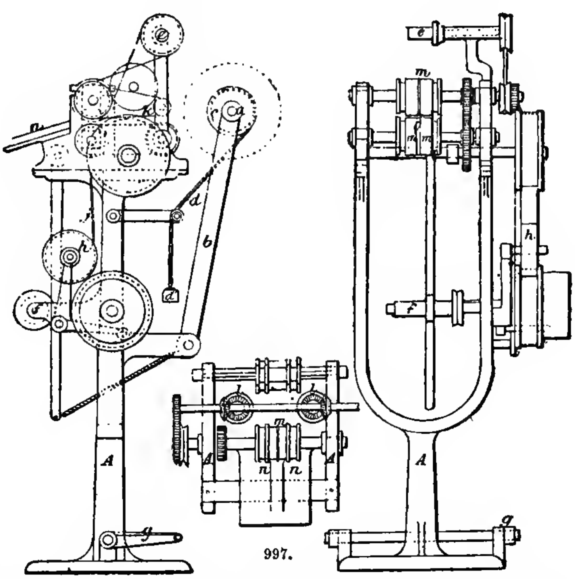
The wheels on the receiving-cylinder and count-wheel shafts, being both driven by the same pinion *s*, must bear the same proportion to each other, as the number of opposite pairs of teeth in the count-wheels do to the number of splint-grooves in the receiving-cylinder. Figs. 992–994 show on a larger scale the connecting and disconnecting mechanism; *e*, Fig. 993, are recesses in the count-wheel E, which receive the splints from the cylinder, and convey them to the setting-wheels; *e'* is one of a series of bent levers pivoted at its angle to studs projecting from the face of one of the count-wheels; a bent end of this lever extends into the recess of the count-wheels, and furnishes a bearing for the match-splint; the long arm of the lever extends inwards toward the axis of the wheel. At e'', is seen a block secured to the count-wheel in such a manner as to revolve with it, and which is provided with radial recesses, Fig. 992; v' is a shuttle lying in this, and able to move in a longitudinal direction to a limited extent; v'' is a ring by means of which the shuttles v' are securely fastened in their proper position; *w* represents a cam arranged over the count-wheel.

By the fixed cam-piece G, the shuttle-pieces are moved in one direction. The shaft H is supported in bearings, and provided at one end with a pinion *z*, whose teeth engage successively with the projecting ends of the shuttles when the latter are thrust out of the casting. On the other end of this shaft, is the check-wheel.

The count-wheels receive in the recesses *e* the splints from the cylinder D. As these pass beneath the cam *w*, the short arm of the lever e' is depressed, and the long arm is moved, causing the shuttle to slide outward. The latter thus projects into the plane of movement of the pinion *z*, and serves as a cog to give it movement for a determined distance, by which the setting-wheels are moved through the intermediate connecting mechanism to a corresponding extent. If, however, a splint is wanting, the lever e' is not actuated, and no tooth is presented to engage with the spur-wheel. As the latter remains stationary, the setting-wheels of the winding-band will not be moved, and consequently no vacant spaces are left in the frame.

The shuttles, after being thrown out to engage with the spur-wheel, are returned to their former position by the action of the cam G, against which they are carried by the continued revolution of the wheel. The check-wheel I, Fig. 992, the end of shaft H of the spur-wheel *z*, is a disc, having its periphery provided with a series of inclined planes overhanging upon one side. The check-wheel I engages with a wheel K, which actuates the mechanism for holding and feeding the main tape. J is provided with a series of pins j'', which lie in the plane of the movement of the check-wheel I, the construction being such that this wheel J can only revolve as its pins are successively driven or released by the revolution of the wheel I. With these parts so constructed, all the movements of the spur-wheel will be positively communicated by the check-wheel to the setting and framing mechanism; but the force applied to turn the frame-drum cannot be exerted through the connecting-mechanism to turn the check-wheel, when the latter is stationary. The shaft of the check-wheel should be set at such an angle, that its inclined planes will engage with the pins of the gear-wheel at one point only. The hopper c is pivoted in front to a seat upon the tie-rod l', to which it is confined, so as to vibrate freely by the screw-pin m'; it is also supported behind near the top by being jointed to a long elastic rod n', fast at the lower end of the tie-rod. A shaking motion is given to the hopper by the bell-crank T, connected by a link N with the lever, and playing between the pins projecting from the bottom of the hopper.

995. 996.



997.

After being dipped, the splints have to be unwound, and cut at the middle. This is effected in the machine shown in Figs. 995–997: A is the frame of the machine; *a*, a shaft on which the coil of matches is placed to be unwound; *b*, an arm carrying *a*; *c*, a tension-pulley operated by the strap *d* and weight d'; *e f*, shafts on which the webs of the coil are wound; *g*, a treadle; *h*, a pulley connected with it, and serving for tightening the driving-belt; *k*, endless bands; *l*, guiding-discs covered with indiarubber; *m*, a revolving cutter, fitted between two blocks, and working above similar blocks m', which are provided at *o* with some soft material for the knife to work on; *n* wires for keeping the matches in place. The circular bundle, consisting of matches held between webs, is placed on the shaft *a*, and the operator, taking the ends of the bands of the coil, places one of them round the shaft *e*, and another round *f*. The machine being set in motion by depressing the lever *g*, and so causing the pulley *h* to press against the driving-strap *j*, and tighten it, the web is unwound from the coil, and wound upon the shafts, leaving the matches between the endless bands *k*, which carry them between two revolving discs, and forward under the cutter *m*, which divides them in the centre. The discs present the splints to the cutter in such a manner as to ensure their being divided into equal lengths, and during this operation, they are kept from flying out of place, by two wires *n*, and are finally delivered into a trough, ready to be put into boxes.

Vestas.—In making wax vestas, the first process is the coating of the cotton. A number, say 20, of strands or wicks, composed of 15–20 threads each, are led from a bale placed upon the ground through guides arranged overhead, down into an oval steam-jacketed pan, filled with wax composition, underneath a presser arranged in the centre of a pan, and through a draw-plate pierced with holes of the required gauge of the match-body; thence it is led some 15–16 ft. over a drum 5–6 ft. in diameter, and then to a similar drum on the opposite side of the bath, from which it is repeatedly passed through the paraffin, wooden guides being arranged to support the wick whereever necessary. The distance traversed after the cotton has passed through the bath is made as long as possible, since the composition neither dries so readily, nor adheres so uniformly to the strand, as in the after-dipping. It is passed and repassed about six times through the bath, until the wax coating is of sufficient thickness, and just passes the holes in the gauge-plates. Considerable care is necessary to ensure evenness in the first coating, and to watch against broken threads.

The drum has a metallic plate on one part of its circumference, and here the wax taper is cut into lengths of the circumference of the drum, is tied in bundles, and is carried to the table having partitions to hold each bundle of lengths. The lengths are pressed against a gauge, and cut up by means of a knife working on a pivot. The match-bodies so cut off are carefully transferred to shallow zinc frames, constructed of the required depth, and made with a lid which is slid down when the frame is filled; they are then carried to a filling-machine similar to that shown in Fig. 967, but of a smaller size, and usually worked by hand. Here they are filled into dipping, frames in the same way as ordinary matches, the machine having its hopper arranged to suit the size of the bodies. Wax matches can be dipped in the same way as those of wood; but some years since, S. A. Bell devised a machine in which frames are attached to two chains running on either side of guides. Between each, a flannel roller revolves in a pan of liquid composition. The frames with the splints arranged downwards run over this roller, and the composition is thereby added to the bodies with considerable regularity and dispatch. The machine will dip 3500–4000 frames a day, and since each frame holds about 4500 splints, it will dip about 18,000,000 splints in that time. The drying is effected, when practicable, in the open air, the frames standing together in twos or fours. At other times, the splints are dried by hot air, distributed by means of revolving fans, in rooms set apart for the purpose. After drying, they are sorted and packed in boxes of various size, pattern, and capacity.

Vesuvians.—The "vesuvians" principally used as lights by smokers, have rounded splints, made from alder, or some similarly hard wood, the object being to prevent the ignition of the wood, and consequent dropping of the burning composition. The more expensive kinds are made on glass bodies, consisting of glass piping of small section (see Glass, p. 1072), which is chiefly procured from Italy, and should yield some 1200 splints to the lb. J. W. Hunt and Co., of London, have an ingenious method of retaining the composition by means of a piece of wire, about $\frac{1}{3}$ in. long, inserted by hand into the end of each splint; it answers the purpose effectually. The vesuvian-splints are placed by hand into the dipping-frames, dipped twice or three times into the burning-composition, until the head is of sufficient size, and then finally dipped into the igniting-composition, in the same way as an ordinary match, an interval being allowed between the operations for drying.

Compositions.—Igniting-compositions are generally manufactured of some form of phosphorus mixed with oxidizing agents, with which it will readily inflame by friction. Such are saltpetre, chlorate of potash, and red-lead; these are mixed up with glue, which causes them to adhere to each other and to the wooden splints. Most makers have a particular mixture of their own; the following practical recipes may be taken as fairly representative, the first being the best:—(1) $\frac{1}{2}$ part by weight phosphorus, 4 chlorate of potash, 2 glue, 1 whiting, 4 finely-powdered glass, 11 water; (2) 2 parts by weight phosphorus, 5 chlorate of potash, 3 glue, $1\frac{1}{2}$ red-lead, 12 water.

The Germans replace the chlorate either by nitrate of potash or nitrate of lead, together with red-lead, hence their matches strike silently, without the short detonation peculiar to English goods.

The match composition is coloured either with a coal-tar colour, ultramarine blue, Prussian blue, or vermilion. In preparing the composition, the glue and the nitre or chlorate of potash are dissolved in hot water, the phosphorus is then added, and carefully stirred in until intimately mixed, the whole being kept at a temperature of about 38° (100° F.). The fine sand and colouring matter are then added, and the mixture is complete.

Dipping-composition for safety-matches consists of 1 part by weight chlorate of potash, 2 glue, 1 sulphide of antimony, 12 water. For the rubber on the box, 2 parts of amorphous phosphorus and 1 of powdered glass are mixed with the solution of glue, and painted on the box.

Vestas are tipped with similar ingredients, but the taper being less rigid than wood, a larger proportion of phosphorus is added.

The heads of vesuvians are made up principally with powdered charcoal and saltpetre in some such proportions as those in the following:—18 parts saltpetre, 19 charcoal, 7 powdered glass, 5 or 6 gum arabic or gedder; to these, are added a little scent, in the form of satin-wood, lignum vitæ dust, cascarilla-bark, or gum benzoin, which render them fragrant when burning. The igniting-composition is identical with that for ordinary matches.

The production of matches is so enormous that it cannot be estimated, some idea of its magnitude may be gained from the fact that many large firms, such as Bell & Black, Hunt & Co., and Anthony Briaker & Co., of London, turn out daily upwards of 80,000,000, the first-named firm frequently producing this quantity of wax vestas alone per diem.

(See Explosives; Paraffin; Timber.) E. S.

MORDANTS (Fr., *Mordants*; Ger., *Beizen*).

In dyeing and tissue-printing, a very important part is played by "mordants." If we examine the action of colouring matters upon organic fibres and tissues, we find that they may be divided into two great classes. One group—the so-called substantive colours—are capable of attaching themselves at once to the article to be dyed, on simple immersion or steeping. Thus, if a piece of clean white silk or wool, or the human skin, be moistened with a solution of magenta, or, in fact, with the majority of the aniline colours, it is permanently dyed, and cannot be rendered white again by mere rinsing in water. The other group of tinctorial matters, which, till lately, at least, were by far the more numerous, have received the name of adjective colours. If yarn or cloth be steeped in solutions of these bodies, it may when taken out seem dyed; but on squeezing or wringing, and still more on washing in pure water, the colour is entirely removed, leaving the cloth merely somewhat soiled. It is true the distinction between these two classes is not absolute; many dyes which are substantive upon animal fibre prove merely adjective when applied to cotton or linen. Still, the classification, though not scientifically correct, is practically useful, and, as such, may be retained.

In order to cause the adjective colours to attach themselves to the fibre, so as to yield a full, thoroughly-dyed shade of a reasonable degree of permanence, recourse is had to the intervention of some third body, which is called a "mordant," and which enables the colour and the tissues to combine. Even in the case of substantive colours, mordants are very frequently called into requisition, because they brighten and modify the shade which would be obtained if the colour alone were employed.

One and the same colouring matter, if employed with different mordants, may give totally different shades—a fact which comes into great prominence in the so-called "madder-style" in calico-printing. If, for instance, there be printed upon different portions of a piece of calico: (1) strong acetate of alumina, (2) weak acetate of alumina, (3) strong acetate of iron, (4) weak acetate of iron, and (5) a mixture of the acetates of alumina and iron, and the cloth be then dyed in the madder beck, or, as is now the ease, in a solution of artificial alizarine, there are produced: (1) full red, (2) pink, (3) black, (4) purple [violet], (5) chocolate. Other dyes can also be made to produce varied effects, according to the mordant selected, though not to such an extent.

The properties which a good mordant should possess are various. If for general use, it should not alter the colour of the fibre. This is the great advantage possessed by the compounds of alumina and tin; they leave the fibre white as they found it, and hence may be successfully used for all pure and bright shades, such as the prismatic colours. Other mordants, e. g. the preparations of iron, and certain chromium compounds, alter the colour of the fibre, or darken—technically called "saddening"—the colour of the dye. Thus cotton yarn, steeped in a solution of iron and exposed to the air, takes a rusty or buff shade; hence the preparations of iron cannot be employed for dyeing any colour with which such a ground would be incompatible. Iron, further, is a powerful saddening agent; in contact with tannin in its various forms, the dye-woods, cochineal, and the madder colours, it produces blacks, deep-olives, dark-browns, &c. Hence its use is necessarily very much restricted.

Mordants must, as a matter of course, be soluble, so that they may be presented to the fibre in a liquid state. Doubtless, many substances, when in a very fine state of suspension, are capable of combining with the fibre; but in this case, there is greater difficulty in producing perfectly even shades. It is, however, necessary that the mordants, or at least their essential constituents, should be easily rendered insoluble, as soon as they have combined with the fibre. Were this not the case, they could be washed away, and would prove useless.

Insolubility may be produced by various methods. Sometimes it depends on the escape of a volatile acid. Thus, if cotton yarn be mordanted with "red liquor" (acetate of alumina), and then hung up to dry, the acetic acid flies off, and the alumina is left behind upon the fibre, in an insoluble state, but still capable of combining with and retaining certain classes of colouring matters.

In other cases, the mordant, when brought into contact with the yarn or cloth, especially in presence of a large quantity of water, is decomposed. An oxide—perhaps under some circumstances an oxychloride, or a basic salt (sub-salt)—is deposited upon the fibre, whilst the bulk of the acid with which it was combined remains in the water. This takes place when yarns or cloths are worked in a solution of tin crystals, or in nitrate of iron.

Sometimes a new compound is formed; the colouring matter and the mordant, each soluble when taken singly, combine to form an insoluble compound, which is deposited in the pores of the material. This case occurs very frequently in wool dyeing, when the mordant and the colour are applied jointly to the fibre.

Lastly, insolubility may be produced by some special treatment. Thus, if a fibre is worked in stannate or aluminate of soda, and is then passed through a weak solution of sal ammoniac, the first-mentioned salts are decomposed, and the stannic acid (peroxide of tin) or alumina is left in an insoluble state in the fibre.

Hence, it may be concluded that, as far as the mineral mordants are concerned, they must be of an unstable constitution, held together by very feeble affinity, which may be easily overcome. In fact, many of the best mordants undergo spontaneous decomposition on keeping for a long time, on dilution with water, or on exposure to light. As a rule, the larger the proportion of acid to the base, the feebler is the mordant. If to a well-made tin spirit be added a proportion of free muriatic acid, the stability of the mixture is increased. The acid refuses to part with the oxide of tin, so the fibre is unable to counteract its opposition. As another instance, alum is not very efficacious as a mordant, because the sulphuric acid retains the alumina with a force which the fibre cannot readily overcome. But if a certain proportion of alkali be added, so as to combine with a part of the acid, the alum is converted into basic alum, which parts with its alumina more readily, and is a more efficacious mordant. Hence the so-called "balance" or proportion between the acid and the base is a point of the highest importance. If the base be in relative excess, and the mordant consequently too dead, the oxide will be precipitated rapidly and irregularly upon the fibre, and the shade produced will be cloudy, streaky, and dull. If the acid be in excess, the result is worse; the yarn or cloth is generally corroded ("tendered"), and the mordant is not deposited upon it in sufficient quantity. Hence the colour produced has a hungry, impoverished appearance. There is a very decided difference—which is not easily described—between a light colour fully dyed, and that which ought to have been a full shade, but has turned out meagre. Further, a mordant to be useful must have a decided affinity at once for the material and the dye, so as to enter into permanent union with both. On the other hand, this affinity may be too strong. If the mordant lays hold of the fibre too greedily, the shades produced will not be even. This is often the case in dyeing cochineal scarlets, unless the goods on being first entered into the dye-pan are turned very rapidly, so that the mordant may have less opportunity of attaching itself to one end of the piece of yarn in preference to the other. If, on the other hand, the affinity of the mordant for the dye be excessive, the colour produced, instead of being deposited on the fibre, is to a very considerable extent precipitated to the bottom of the dye-pan as a lake or pigment, whilst the goods are neither thoroughly nor permanently dyed. Such, for instance, is very generally the result if a solution of bismuth is used as a mordant along with any of the red woods. A fine, bright lake is produced, but the fibre is very imperfectly dyed. A combination between tissue, colour, and mordant should be effected regularly and slowly. If this point be not satisfactorily regulated, the shade produced will be flat, irregular, and loose, and will often smear off.

It must be remembered that mordants are not universal in their action; those adapted for wool are not suitable for vegetable fibres. As a general rule, the preparations employed for woollen and worsted goods are more acid than those which serve for dyeing cotton and linen; the latter require mordants of a very faintly acid, a neutral, or even an alkaline character, such as the aluminates and stannates. On the other hand, alkaline mordants can very rarely be used with safety upon wool. Preparations of lead, iron, and manganese play a very important part in cotton and linen dyeing, but they are of very little value for wool, where lead, indeed, is totally inadmissible. The nature of the colouring-matter to be employed is also an essential consideration. Tin has always had the preference for use in conjunction with cochineal, lac, and bright colours produced with the red woods, e. g. bar-wood reds, sapan pinks, &c., but it has given little satisfaction for madder reds, where the compounds of alumina have been found preferable. It has been proved that the acid employed in the composition of a mordant decidedly influences the colouring-matter, and must likewise be regulated in accordance with the fibre. It is known that a chloride of iron, or a nitrate of iron into the composition of which hydrochloric acid has entered, cannot be safely used for dyeing cotton warps of mixed goods, such as coburgs, delaines, merinos, &c. It delivers the iron, not only upon the cotton, but also upon the worsted. On the other hand, a pure nitrate or nitro-sulphate of iron will mordant the cotton fully, leaving the worsted or woollen warps untouched. Tin mordants which contain oxalic or tartaric acids are used for the brightest cochineal reds upon woollens and worsteds. If sulphuric acid is used instead of the oxalic or tartaric, as was done by Bancroft, the red is of a brown cast. Sulphate of tin produces a redder claret shade, if used upon woollens along with logwood, than does the muriate of tin under similar circumstances. These facts are of importance as regards the theory of the mineral mordants. It is generally supposed that hydrated alumina, hydrated oxide of tin, iron, &c., as the case may be, is deposited in the minute pores of the fibres in conjunction with the colouring matter, thus forming a lake. But in view of the facts just mentioned, showing the influence of the acids present, it must be presumed either that the substances precipitated upon the fibre retain a certain proportion of the acid in the state of a sub-salt (basic salt), or that the acids effect a permanent change in the properties of the colouring matter. It must be remembered that acids have a decided affinity for animal matter. If the finger-tips be plunged into sulphuric acid, and immediately afterwards washed in flowing water, the acid taste and the reaction with litmus paper will not be readily removed.

It is obvious that the theory of the action of mineral mordants, briefly given above, cannot be extended to the organic mordants. The action of albumen and its kindred substances in fixing many aniline colours upon vegetable fibres is totally different, and is best characterized by the common phrase, "animalizing cotton." Magenta, orchil, &c., are substantive colours upon wool, and, by coating cotton with albumen, it is furnished with a surface which is chemically identical with wool. The magenta is not combined with the cotton, but merely with a substance mechanically adhering to the cotton.

The most recent experiments decidedly refute the theory that dyes are fixed by the acid of a capillary tube in the centre of the fibre, into which the mordants and colours were supposed to penetrate. No such capillary tube exists, for example, in silk.

A brief description of the principal mordants and their application will now be given.

ALUMINA MORDANTS.—Alum, known also as rock-alum, roach-alum, is probably the most ancient and the most widely-used mordant. It is a double sulphate of potassium and aluminium (potash-alum), or of ammonium and aluminium (ammonia-alum). For most purposes, these two kinds differ little in value and utility, ammonia-alum containing a larger proportion of alumina, and dissolving more readily in water. These alums are not only used to a great extent as such, especially in wool dyeing, both alone and along with argol, chrome, &c., but also in the preparation of other aluminous compounds.

The most dangerous impurity which alum may contain is iron, a substance very injurious even in the minutest traces. To detect its presence, a portion of the sample dissolved in water is mixed with a few drops of solution of potassium ferrocyanide and ferricyanide (yellow and red prussiate of potash): an immediate blue precipitate shows the presence of iron. Or a little solution of tartaric acid is added to the solution, then an excess of pure caustic soda, and a drop of ammonium sulphide: a black coloration shows the presence of iron.

To distinguish ammonia-alum from potash-alum, add to the solution a little caustic soda, and apply heat. Ammonia-alum is at once known by giving off ammoniacal fumes, which may be recognized by the smell, by turning red litmus-paper blue, and by forming a white cloud with a rod moistened in hydrochloric acid; ammonia-alum, which, 20 years ago, was by far the more commonly met with, is now rare in the market. The Roman alum, which is now again coming into use, has a reddish cast, derived from the presence of a small quantity of oxide of iron, which, being in a condition insoluble in water and dilute acids, is perfectly harmless. It often contains a proportion of basic sulphate of alumina, and hence deposits its base, hydrate of alumina (aluminium hydroxide), more freely on the fibre. Basic alum is formed by adding ammonia or potash-lye, as the case may be, till the precipitate formed begins to appear permanent on shaking.

Cubic alum is obtained in a very similar manner, by dissolving alum in boiling water, and adding slaked lime in the proportion of $\frac{1}{13}$ the weight of the alum. It forms cubic crystals. Potash, soda, or their carbonates, if cautiously added to solutions of alum, withdraw a part of the acid, and form a salt which has a greater affinity for the fibre.

Sulphate of alumina, known also as cake alum, patent alum, or concentrated alum (aluminium persulphate), differs from alum in not containing an alkaline sulphate. It contains much more actual alumina—the really active principle—than either potash or ammonia-alum, and is much more readily soluble in water. Hence it goes farther, and is more convenient in use. Its disadvantages are—not being a crystalline compound, its composition is not absolutely invariable, traces of free acid being not unfrequently present; sometimes also it contains iron to a serious extent. It must be remembered that great improvements have been effected in the preparation of this salt, and it will doubtless be ultimately obtained free from iron and from uncombined acid. When this end is accomplished, alum will have no further claim on the dyer. Sulphate of alumina may be rendered basic in the same manner as potash- and ammonia-alum.

Next in importance to alum, comes red liquor, acetate of alumina, or aluminium acetate, a compound very largely used in cotton-dyeing and -printing; more rarely with animal fibres. It is prepared in two general methods. A solution of alum, or of sulphate of alumina, is mixed with a suitable proportion of lead acetate (sugar of lead) or of acetate of lime. Sulphate of lead (or of lime) is precipitated, and the clear liquid is the acetate of alumina required. Various prescriptions for this mordant will be found in the article on Calico-printing. It may be noted that small variations in the quantities of the ingredients often make an important difference in the results. Carbonate of soda crystals are generally employed to give a more basic product, and many practical men hold that a red liquid prepared from alum is often preferable to one produced from sulphate of alumina, the acetate of potash or of ammonia present in the former case playing a certain part in the production of the colour.

Red liquor may also be obtained by dissolving precipitated hydrate of alumina in the strongest acetic acid, until the latter is completely saturated.

In whatever manner acetate of alumina is prepared, the absence of iron is essential. Red liquor cannot be indefinitely preserved, especially if freely exposed to the air, as the acid gradually escapes, and the composition of the mordant is consequently altered.

Nitrate of alumina (aluminium nitrate) is not extensively used. It is prepared when needed by mixing together, in equivalent proportions, solutions of alum or sulphate of alumina, and nitrate of lead. Sulphate of lead is deposited, and the clear liquid is nitrate of alumina.

Muriate of alumina (aqueous aluminium chloride) is also rarely used. It is prepared by dissolving hydrated alumina in hydrochloric acid, by decomposing a solution of the sulphate of alumina with one of chloride of calcium, or more economically under Fournier's patent, by mixing solutions of sulphate of alumina and common salt, and exposing the mixture to a temperature of $-2°$ to $0°$ ($28\frac{1}{2}°$–$32°$ F.). Sulphate of soda is deposited in fine crystals, whilst hydrochlorate of alumina remains in solution.

Hyposulphite of alumina (aluminium thiosulphite) has been proposed by Kopp as a substitute for red liqnor. It is readily obtained on decomposing sulphate of alumina by hyposulphite of lime. By the action of sulphurous acid gas upon a mixture of the tank-waste from the soda manufacture, with 10 per cent. of its weight of sulphur and water, previously boiled together, hyposulphite of lime is obtained in fine crystals. Kopp considers that it possesses distinct advantages over red liquor; but in England, the opinion of practical men is not in its favour.

Oxalate of alumina has been made by dissolving precipitated alumina in oxalic acid, but is rarely used.

The aluminate of soda (alkaline pink mordant) forms an exception to the rest of the aluminous mordants, as it consists of alumina dissolved not in an acid, but in an alkali. It was originally prepared by precipitating alumina from alum or from sulphate of alumina by means of caustic soda, and adding the latter in excess, with the aid of heat, till the precipitate was redissolved. It is now to be met with in the solid state, and nearly pure.

In dyeing, it produces every effect yielded by alum, and, in addition, certain results which cannot be otherwise obtained. Notwithstanding its alkaline nature, it may be used to fix colours upon wool. In calico-printing, it serves as a pink mordant, the pieces being afterwards taken through a bath of sal ammoniac, or chloride of zinc.

Antimony Mordants.—Compounds of antimony play but a limited part as mordants. An American authority recommends the "oxymuriate" of antimony—which may perhaps mean antimony terchloride, or antimonic acid dissolved in hydrochloric acid—as a mordant for dyeing a scarlet shade on cotton with Sehlbach's "extra-scarlet," a coal-tar colour.

Muriate of antimony (antimony terchloride), has been used along with oxalic acid for dyeing grain and lac scarlet on woollens. The result is harsh and chalky. Antimonial compounds have been used as a "prepare" for steam colours in printing, but without advantage.

Antimony tartrate and tartar emetic (antimony potassium tartrate) are now used to some extent along with tannin in fixing certain aniline colours upon cotton.

Arsenic Mordants.—Arseniate of soda along with red liquor is used to a large extent in fastening aniline and other coal-tar colours upon cotton tissues. The discovery of an available substitute for so dangerous an article is very desirable, especially in the present excited state of public feeling with regard to poisonous colours.

Bismuth Mordants.—Bismuth is too expensive, and though capable of yielding rich lakes, its affinity for textile fibres is feeble, and the colours dyed and printed with its solutions, e.g. the aceto-nitrate, are loose and uneven.

Chromium Mordants.—Several compounds of chromium are largely used in dyeing and printing. The sesquioxide of chrome dissolved in acids, such as sulphuric, nitric, or acetic, has a considerable affinity for textile fibres, and also for certain colouring matters; but as it gives a pale greenish colour, it is at once excluded in the case of most light and bright colours, to which an admixture of green would be fatal. The aceto-nitrate of chrome is prepared by G. Witz as follows:—Into a large stoneware pan, holding 20 gal., are poured 6 gal. boiling water, $47\frac{1}{4}$ lb. nitric acid at 62° Tw., and 6 lb. 9 oz. bichromate potash in very coarse powder. The following mixture is then poured in, by about 17 fl. oz. at a time, stirring with a large glass rod, and allowing the frothing each time to subside before adding a fresh lot:—$3\frac{3}{4}$ lb. white glycerine at 44° Tw., and $90\frac{1}{4}$ lb. acetic acid at $25\frac{1}{4}°$ Tw. Whilst adding the first half of this mixture, it is needful to proceed slowly, but afterwards it is added more briskly, to keep up the reaction. This process is performed in the open air. When all is dissolved, the liquid is passed into a copper pan fitted with a steam-jacket, heated quickly to a boil, and kept at that point for two minutes, or until a shallow layer of the liquid takes a fine green. It is then poured back into the stone vessel, and allowed to cool over-night. The liquid is next poured off, and the crystals of saltpetre are washed with 4 lb. cold water; the liquid is decanted off, and mixed with the former, so as to form 2 gal. mordant at about 57½ Tw. This mordant may be used for alizarine pieces, for cœruleine shades along with bisulphite of potash, for logwood blacks, and for "Havraneck green," along with prussiate of potash, &c.

Chrome-alum is a double sulphate of chrome and potash. It contains no alumina and no chromic acid, and cannot be prepared, as some dyers erroneously imagine, by mixing bichromate of potash and ordinary alum. It is chiefly obtained as a residual product, e. g. in the conversion of anthracene into anthraquinone, in the manufacture of artificial alizarine, and is recommended by Dr. Reimann for dyeing logwood blacks, especially in conjunction with iron-alum. (See Iron Mordants.)

The chromium-compounds most widely used in dyeing are the combinations of chromic acid with an alkaline base, generally potash. The yellow or neutral salt (potassium chromate, not to be confounded with chrome yellow, a lead chromate) would be very useful, if it could be obtained in an unvarying state. It is generally found contaminated with various proportions of carbonate of potash, and containing more or less moisture. Those who wish to witness its interesting behaviour with many organic colouring matters may avoid this difficulty by using 151 parts of the bichromate and 143 parts of clear soda crystals not effloresced. The yellow chromate is much more widely used on the Continent than in England.

The bichromate of potash (potassium dichromate), and often known as red chromate, bichrome, red chrome, or simply chrome, is used to a very large extent in dyeing blacks upon wool, in conjunction with logwood. Along with fustic, red woods, orchil, &c., with or without logwood, it yields browns, yellows, bottle-greens, dark-greens, olives, purples, and intermediate shades. All these colours are cheap, requiring little time or labour, and are very fairly fast.

Copper Mordants.—Compounds of copper, though used in dyeing and printing to some extent, serve rather as oxidizing agents or alterants, than for fixing colours upon the fibre. The principal are:—

Ammoniuret of copper is formed by adding liquid ammonia in excess to a solution of sulphate of copper, till the precipitate is redissolved, and a beautiful violet-blue liquid is produced. When diluted, it is sometimes used for giving a pale-green upon vegetable tissues by padding, dyeing, and rinsing.

Chloride (muriate) of copper is most used on the Continent in printing. In England, nitrate or sulphate of copper is used in its place, along with sal ammoniac. It may be easily prepared, if desired, by mixing solutions of sulphate of copper and chloride of calcium, drawing off the clear liquid for use.

Nitrate of copper is generally obtained as a residual product in cleaning articles of copper and its alloys. The nitrate is sold as a deep-blue liquid at about 90° Tw., and is often very impure, containing zinc, iron, &c., not intentionally, but from carelessness. It is chiefly used as an oxidizing agent in printing, e. g. in catechu browns.

Sulphate of copper, known also as blue vitriol, blue-stone, and Roman vitriol, is generally prepared directly from copper ore. It is used by printers as a resist, and by dyers as a mordant, generally in conjunction with copperas, alum, argol, &c. Sulphate of copper sometimes contains more than 60 per cent. of sulphate of iron. Such mixtures are frequently known by the names of Salzburg vitriol, Cyprus vitriol, admont vitriol, and eagle vitriol. They are to be condemned. If the dyer requires the joint action of blue-stone and copperas, he had better have both these substances in a pure state, and mix them himself in known proportions.

Verdigris (acetate of copper) is now comparatively little used. It is employed in catechu colours, in resists for indigo-styles, and as an oxidizer in some steam colours. In dyeing blacks on silks, and logwood blues on wools, it is also used. An old Act of Parliament (George III., 20) imposes a penalty of 20*l*. for every piece of woollen cloth dyed a logwood blue in this manner. This curious statute is said to be still unrepealed.

Iron Mordants.—These are both numerous and important.

Copperas (green vitriol), scientifically known as ferrous sulphate, may be made by dissolving scrap iron in dilute sulphuric acid. Practically it is obtained by exposing the soft whitish iron pyrites of the Coal-measures, often known as "brass-lumps" or "coal-brasses," to the action of air and moisture. The water being decomposed, the hydrogen escapes, and the sulphur and iron are both oxidized. The solution thus obtained is concentrated, when it deposits copperas in pale greenish-blue semi-transparent crystals, containing 45 per cent. of water, which, on exposure to a gentle heat, escapes, leaving a white powder. Copperas should be hard, clear, and dry. If soft, and of a whitish or greyish-green colour, sulphate of alumina is probably present—the most objectionable impurity—which is often met with if the pyrites have not been duly selected, or if the crystallization has been carried on at too high a point of concentration. To detect the presence of alumina, a little of the sample is dissolved in water, heated with some pure nitric acid to peroxidize the iron, and the solution, after being heated till all the free nitric acid has been expelled, is mixed with a considerable excess of pure caustic soda. The mixture is heated in a clean iron vessel, diluted with water, filtered, and a solution of sal ammoniac is added to the clear liquid. If the copperas contains alumina, a white precipitate will be formed.

Old copperas, especially if it has been exposed to moist air, turns brown—a feature preferred by some consumers, though only valuable as a sign that the crystals do not contain any sulphuric acid. This brown appearance is therefore imitated by scattering lime-dust over the heaps, or watering them with stale urine.

"Calcined copperas" is an article for which some dyers have a peculiar liking. It is prepared by heating ordinary raw copperas. If merely the water of crystallization is given off, the copperas remains soluble, and is, weight for weight, stronger than in its original state. If actually calcined, it becomes to a greater or less extent insoluble, and is therefore, *pro tanto*, wasted.

Copperas is now very extensively used in the manufacture of so-called nitrate of iron, and sometimes of acetate of iron. As a mordant, it is less employed than formerly.

Persulphate of iron, otherwise known as red sulphate (ferric sulphate), is not produced in the form of crystals. It may be made by dissolving copperas in water, applying heat, and gradually adding nitric acid in small proportions, till a little of the liquid no longer gives a blue precipitate with potassium ferricyanide (red prussiate of potash). Or native hydrated ferric oxide is boiled in oil of vitriol. Persulphate of iron is little used under its own name, but much of the nitrate of iron, commonly so called, is little else than persulphate.

Iron-alum is much used abroad, and is recommended by Dr. Reimann in conjunction with chrome-alum when dyeing logwood blacks. It may be obtained as follows:—78 parts of the red oxide of iron are dissolved in 147 parts of oil of vitriol with the aid of heat. The solution is then diluted with water, and mixed with 87 parts sulphate of potash. The solution is next allowed to crystallize. These crystals, being absolutely unvarying in composition, are free from many of the objections made to the nitrates and the persulphate.

Muriate of iron (solution of ferrous chloride) is prepared by dissolving waste iron in hydrochloric acid of the common commercial strength (32°–34° Tw.) till the solution reaches 80°–85° Tw. It requires to be kept from contact with the air. It is sometimes used in producing catechu drabs and slates.

Permuriate of iron (solution of ferric chloride) is made by dissolving scrap iron in a mixture of nitric and hydrochloric acids. It is used still less than the muriate.

Nitrate of iron is a name given to a whole group of mordants, differing widely in their nature, manufacture, and applications. Some of these compounds contain no acid except nitric, others are made with a mixture of nitric and sulphuric, and in others, again, acetic acid is present in addition. In general, the iron is entirely in the ferric or most highly oxidized state; whilst in others, there is more or less of the proto or ferrous salt. Some nitrates of iron are made from copperas, others from scrap-iron, and others of a mixture of both. In sp. gr., they range from 40° to 120° Tw. However they may differ in other respects, it is important that they contain no hydrochloric acid, nor any chloride. If such is present, the iron will be less readily deposited upon the fibre, and—a greater evil—in dyeing mixed goods, it will work upon the woollen or worsted in preference to the cotton. Another very important point is that the acid and the base should be accurately proportioned, or, as it is technically termed, "balanced." If there is an excess of acid, the fibre will not be able to take up a sufficient quantity of the base, whence the shades produced will be meagre. The tissue itself, and in case of printing, the rollers and doctors, will be corroded. If, on the other hand, the proportion of iron is relatively too great, much of the colour will be deposited not on the fibres, but at the bottom of the dye-beck, and the shades obtained will be dull, irregular, and deficient in fastness. This balance between the acid and the base varies, however, according to the purpose for which the nitrate of iron is prepared.

A "black-iron," i. e. for dyeing and printing black upon cotton yarns, pieces, or the cotton warps of mixed goods, should be very thoroughly neutralized, or, as it is termed, "killed." Still, even here, if the oxide of iron is deposited too rapidly and irregularly to combine with the organic colouring matter, the goods will not only appear cloudy or streaky, but may even display buff patches. For this purpose, a nitrate of iron—or rather a nitro-sulphate—made from copperas is preferable to one from the metal. It is not necessary that the whole of the iron should be peroxidized. A mordant containing a mixture of proto- and per-salt (ferrous and ferric nitro-persulphate) yields fuller and richer blacks; the former of these compounds, if used alone, giving a bluish, and the latter a brownish cast. The following process will yield a good black-iron. Take a large, strong cask, holding about 140 gal.; remove one end, and put into it 5 cwt. of dry, clean copperas, free from alumina and from both fine powder and very large lumps. Upon it, pour 120 lb. of nitric acid at

64° Tw. (the so-called double aquafortis of commerce); and stir the whole up together with a long pole, so that every part of the copperas may come into contact with the acid. In the stirring, there is a certain art. A violent revolving movement must be avoided; the copperas should be turned over from the very bottom, working as if trying to find some lost article with the end of the pole. As the fumes given off are absolutely suffocating, the cask should be placed in a shed with open sides, so that the workmen may stand on the windward side. In case of inhaling these fumes, relief is obtained by drinking very strong vinegar, or acetic acid diluted with water. On no account should whisky or rum be used. In the evening, the cask is stirred up again. This process is repeated on the second day at morning and evening, and again on the morning of the third day. At night the reaction will be over, and if the operation has been well conducted, the copperas will have been entirely dissolved, or a very small quantity may be left in the cask. Water is then poured in, until the whole, after being thoroughly stirred up, marks about 75°–80° Tw. The liquid is allowed to settle, and is run off into carboys, which should stand in a dark place, exposed neither to heat nor cold.

Some manufacturers modify their "black-irons" by adding a solution of brown sugar of lead, in proportions below 95 lb. to 138 lb. of the copperas originally employed. In consequence, the lead precipitates its equivalent of the sulphuric acid present, its place being taken by the acetic acid previously present in the sugar of lead. If any free nitric acid exist, it will combine with some of the iron, formerly held by the sulphuric acid; whilst a corresponding proportion of acetic acid will be set free. A black-iron thus corrected will neither injure tissues, colours, nor printing machinery. Hence it may safely be used for burl or burr dyeing.

When woollen pieces have been dyed, they are often found more or less spotted over with small grey specks, upon which the dye, as mixed for woollens, has not taken effect. These are due to small portions of vegetable matter, which have become entangled in the wool. To render the piece of a uniform black, it must therefore undergo a second process, which is, in fact, cotton-dyeing. For this purpose, the "burling" iron is required, and the nitrate of iron must be very accurately prepared. If too acid, it may discharge or modify the colour of the wool; and if too dead, it may occasion rust-smears.

"Common iron" is used for "saddening," as it is called, such colours as olives, dark-browns, drabs, &c. It is sharper than black-iron, and is a perfect per-salt (ferric salt).

It may be obtained by the process just recommended for black-iron, using 130–135 lb. of nitric acid to 5 cwt. of copperas. If any copperas remains in the cask unattacked, the liquid is drawn off before diluting with water.

A saddening-iron for drabs is often made as follows:—Ordinary nitric acid is let down to 34° Tw., and of this, 100 lb. are placed in a large stoneware pan. In it, are dissolved, firstly, 4 lb. of clean scrap-iron, and afterwards, as much copperas is gradually added as the acid will take up, which is generally about ¾ cwt. It is finally set at 60° Tw. with water.

So-called "blue-irons" were formerly very much used for dyeing Prussian blues upon cotton yarns, and upon the cotton warps of mixed piece-goods where the weft had been dyed with an aniline blue, and in producing a blue base for greens. These uses are now of very much less importance, since the discovery of coal-tar colours, which work well upon vegetable fibre.

Blue-irons are sharper than black and common irons, as their acidity is to a great extent neutralized by the prussiate of potash. A blue-iron for cotton yarn and unmixed cotton piece-goods may be made by the first process for a common iron, viz. 5 cwt. copperas to 130 lb. nitric acid.

For light-blues on the warps of coburgs, delaines, &c., double aquafortis (nitric acid) is let down to 32° Tw., and clean scrap iron is dissolved in it as long as there is a good action, and reddish fumes are thrown off. It should mark 42°–43° Tw.

For darker blues, verging towards a violet, put 24 lb. nitrate of soda, freed from common salt, into 15 gal. water, and stir till dissolved. Then add by degrees 20 lb. of oil of vitrol, feeding with scrap iron as required. The heat must not be allowed to get very high. In cold weather, both the oil of vitriol and the iron are added more rapidly than in summer. This nitrate of iron contains sulphate of soda, and, if kept for any length of time, deposits a sediment.

Analytical processes are of little avail in finding the practical value of an "iron," since the quality of any sample depends not merely upon the proportions of the ingredients, but upon the manner in which they are combined.

Pyrolignite of iron, likewise called acetate of iron, black-liquor, and iron-liquor, is less used in dyeing than in calico-printing, where it plays a great part, especially in the madder-style. It is generally prepared on a large scale at wood-vinegar works. Scrap-iron is submitted to the action of raw acetic (pyroligneous) acid in a series of vats, till thorough saturation is obtained. It has been perfectly well ascertained that the purified acid, free from tarry matters, gives a much less satisfactory product. These impurities retard the conversion of the iron into a salt of the peroxide (ferric salt), in which state its efficiency is much lessened. Black-liquor is also sometimes prepared by the consumer by a process of double decomposition.

A solution of copperas is mixed with one of brown sugar of lead, or crude acetate of lime, and after settling, the clear liquid is drawn off for use. (For particulars concerning both these processes, see p. 31.)

The specific gravity of black-liquor, as met with in commerce, ranges from 30° down to about 10° Tw. Its properties are very considerably modified by the degree of strength at which it is used. At 6° Tw., it gives with madder a full and fast black. If diluted down to 4° Tw., or lower, it yields with madder and artificial madder colours various shades of purple and lilac. These colours are called by Continental writers violets. The words *purpur* (German) and *poupre* (French) are applied to shades between crimsons and reddish-violets. Artists in England use the word "purple" in the same sense, and not as synonymous with "violet." Used in combination with red-liquor in different proportions, it gives shades of chocolate.

Along with black-liquor, may be mentioned a proposed substitute, which possibly deserves more attention than it has yet received—hyposulphite of iron. It may be prepared by mixing a solution of copperas with crystals of hyposulphite of soda, or by decomposing copperas with hyposulphite of lime. According to Kopp, the fixation of the base of this mordant upon the fibre is very slow and very intimate, and the tissues are not in the least injured. Other authorities, among them C. O'Neill, maintain that the action of the hyposulphite is irregular, and that the colours produced are consequently uneven.

It has been proposed by Persoz to dissolve pyrophosphate of iron in ammonia. The solution, if printed on cotton, and dried very slowly, gives, when dyed with the madder-colours, exceedingly pure purples and lilacs. It is said that cloth thus mordanted can be successfully dyed in becks which no longer give any colour on cotton prepared with black-liquor.

Lead Mordants.—Four compounds of lead, the acetate, nitrate, and sulphate, and the plumbate of soda, are used in dyeing and printing. The affinity of oxide of lead for the fibre is feeble, and though it combines very readily with organic colouring matters, the resulting compounds—lakes—are wanting in depth of colour and beauty. Hence salts of lead are but rarely used as true mordants, i. e. for fixing animal, vegetable, or artificial colours upon tissues. Another defect of lead is that it is very readily blackened by sulphuretted hydrogen, &c., or if brought into contact with organic matter containing sulphur, such as wool. The nitrate of lead was used in fixing murexide purple, a colour now, we believe, no longer in the market. The acetate—sugar of lead—and the basic acetate, otherwise known as subacetate of lead, Goulard's extract, or lead vinegar, have been used with some success in dyeing and printing aniline colours upon cotton. The cloth is alternately padded in the lead solution, and in weak ammonia, or is soaped, and then mordanted with lead.

The chief use of all the lead compounds is the production of yellow and orange colours upon cotton in conjunction with bichromate of potash, a style of work much in vogue in printing.

Manganese Mordants.—Manganese has a very powerful affinity for organic matter. Cotton steeped in the permanganate of potash soon takes a deep-brown colour. The same effect is produced if the cotton is worked in a solution, as nearly neutral as possible, of sulphate, chloride, or acetate of manganese, and is then taken through a weak bath of chloride of lime. The colour thus obtained upon the fibre is too dark to admit of this process being used for fixing any organic dye. But the hydrated protoxide of manganese is white, or of a very faint pink tint, and hence, to use manganese successfully as a mordant, it is merely needful to pass the tissue, after being worked in permanganate of potash, into a solution of some powerful reducing agent, preferably a solution of tin-crystals. By this means, a deposit of white protoxide is left upon the fibre, and may serve as a mordant.

Silica as a Mordant.—Silica in the amorphous, and still more in the hydrated, state, has a decided affinity for organic colours—a circumstance which approximates it to alumina. This property may be practically utilized in the following manner. The tissue is worked in a solution of silicate of soda—so-called soluble glass—and is then taken through a dilute acid, such as sulphuric, or hydrochloric at about 1°–1½° Tw., or through a solution of sal ammoniac.

The silicate of soda is thus decomposed, and hydrated silica is deposited upon the fibre. If the goods are then worked in a solution of a colouring matter, they become thoroughly and permanently dyed. This process has chiefly been used for the fixation of certain aniline dyes upon cotton. It is less applicable upon silk and wool, to which, moreover, the same colours adhere in general without the intervention of a mordant.

Sulphur as a Mordant.—Hyposulphite of soda was proposed some time ago for fixing certain aniline greens, and was used with success. The suggestion was due to a photographer, who, having been accustomed to employ hyposulphite of soda as a fixing agent in his own department, concluded that it would "fix anything." This case is interesting as an example of practical success reached by a false theory. There are many such.

It has since been found that the value of hyposulphite of soda depends on the fact that tissues saturated therewith, and afterwards taken through an acid, or even exposed to the air, become coated with finely divided sulphur, which, in this state, absorbs colours by surface attraction, very similarly to amorphous silica. Sulphur in this condition is a useful mordant for many coal-tar colours, but is of little value for the fixation of eosine.

Tin Mordants.—Till within the last twenty years, tin mordants might, perhaps, claim the supremacy over all others, since the brightest and most beautiful colours, whether upon cotton, silk, or wool, were fixed by their means. Their importance is now diminished, inasmuch as many of the finest shades formerly obtained from natural colouring matters with their intervention are obtained in even greater purity and brightness from the aniline colours. Still the applications of tin in dyeing and tissue-printing remain extensive and manifold. To enumerate and describe all the tin compounds which have been, and still are, in use, would require a volume of fair size. They comprise both stannous and stannic salts, or, as they are still technically named, protomuriate, protosulphate, &c., and on the other hand, permuriate, nitromuriate, or oxymuriate. Lastly, in the stannate of soda, the tin appears not as a base, but as an acid. The affinities of tin, both for the fibre and for the colours, are strong, and the "lakes" which it forms with the latter are rich and bright. Though not exempt from the action of sulphur, it blackens much less rapidly than lead.

The so-called protochloride of tin, protomuriate, or simply muriate (stannous chloride), is made by allowing hydrochloric acid at about 32° Tw. to act upon granulated or feathered tin, with the aid of heat. The process is generally conducted in large stoneware vessels heated by hot water or steam. In some establishments, hydrochloric acid gas, just as evolved by the action of sulphuric acid upon common salt, is allowed to pass over granulated tin in stoneware cylinders, down which water is constantly allowed to trickle. Muriate of tin is sold in three states, differing merely in concentration.

Single muriate is a solution ranging in strength from 40° to 60° Tw., and containing from 1 to 2 oz. metallic tin in the lb. It is used by woollen dyers. Double muriate of tin varies in strength from 70° to 120° Tw., and contains proportions of tin from 2½ to 5 oz. a lb. The weaker and more acid kinds are used in woollen-dyeing; and the more neutral and thoroughly saturated kinds, from 110° to 120° Tw., for cottons. The mere specific gravity, however, gives no certain clue to the composition of a sample, as, even in the absence of all impurities, a variety in proportion may occur. Some makers dissolve the tin in undiluted acid at 32° Tw., whilst others add water before dissolving. The higher the original specific gravity of the acid taken, the smaller will be the proportion of tin needed to bring it up to any given degree of the hydrometer. The chief impurities which may be met with are sulphuric acid and sulphates of zinc and magnesia.

Tin crystals, sometimes called salts of tin, are merely muriate of tin evaporated to crystallization. They should contain about 52 per cent. of metallic tin. A good sample dissolves in about ten times its weight of water, with little or no turbidity. If a few drops of pure hydrochloric acid are added to this solution, no precipitate should be formed on dropping in a solution of barium chloride. Should a white precipitate appear, sulphuric acid in some combination is present.

The ordinary hydrochloric acid used for dissolving tin generally contains a little sulphuric acid, but the quantity is too small to produce more than a faint white turbidity in the solution of the tin crystals.

To determine the actual proportion of tin present in a sample of tin crystals, or of the liquid muriates, the following volumetric process may be used. A standard solution of tin is first made up by dissolving 500 gr. of pure tin (grain-bar) in pure hydrochloric acid, an operation which may be facilitated by putting it into contact with a platinum crucible. The liquid is then made up with distilled water to exactly 10,000 grain-measures. Every 20 grain-measures of the solution will contain consequently 1 gr. of tin.

A standard solution of iodine is then prepared by weighing out 127 gr. of pure iodine and 180 gr. of pure potassium iodide. They are then dissolved in 10,000 grain-measures of water, without applying heat, and the solution is preserved in 6-oz. stoppered bottles.

To find the value of this iodine solution, 100 grain-measures of the standard tin-liquor, containing of course 5 gr. of tin, are measured off into a beaker, and mixed with bicarbonate of soda in excess, and with sufficient double tartrate of potash and soda to keep the liquid from precipitating. A little weak starch paste is then added, and the iodine-solution is dropped in from a burette, till a faint but permanent blue tinge is seen in the glass. The number of degrees on the burette consumed show how many grain-measures of the iodine solution represent 1 gr. of metallic tin.

For the actual test of the crystals, a known quantity is weighed out, put into a beaker, and dissolved in distilled water, with the aid of a drop or two of hydrochloric acid, so as to give a perfectly clear solution. Bicarbonate of soda and double tartrate of potash and soda are added as before. The starch-paste is then added, and the iodine solution is dropped in as before, till the blue colour appears. From the number of grain-measures consumed, as shown on the burette, the percentage of tin in the crystals is readily calculated.

Next come what may be called mixtures of muriate of tin with other acids, their properties being thus modified. The following are specimens in extensive use :—

Amaranth Spirit.—Mix 95 lb. hydrochloric acid at 32° Tw. with 5 lb. oil of vitriol, and dissolve in it 4 lb. 11 oz. of tin. Used for dyeing reddish-violet with the woods on woollens and worsteds.

Yellow and Orange Spirit.—Take 5 lb. 11 oz. of double muriate at 80° Tw., mix separately 2 lb. oil of vitriol and 2 lb. water, and when cold, stir it into the double muriate. The more tin there is in the double muriate, the more the cloth will show a greenish reflection, if held up to the light and looked at along the surface. For woollens or worsteds.

Scarlet Finishing Spirit.—Take 3 pints muriate of tin at 54° Tw., and 2 oz. oxalic acid. Dissolve, before mixing, in hot water enough to set the whole at 40° Tw. Used for finishing grain scarlets which have been grounded with nitrate of tin. Some dyers prefer to substitute tartaric acid for a part, or even for the whole, of the oxalic acid. In soft woollen goods, the strength of the muriate of tin may be raised to advantage at 70°–80° Tw. A spirit thus prepared acts well for cochineal orange, maize, &c.

On the Continent, nitro-muriate of tin (see below), is generally used for dyeing cochineal and lac scarlets, &c., on woollens.

Plum Spirit.—Take 2 gal. muriate of tin at 70° Tw. In another vessel, mix sulphuric acid and water till the mixture stands at 28° Tw. when cold. Add of this 1 gal., and stir well. This mordant is used for dyeing plums, reddish-violets, and brownish-purples on wool.

Oxalate of Tin.—In the strict sense of the words, this is not a commercial article, but the name, generally shortened into "Ox. Tin," is given to mixtures of muriate of tin with sulphuric and oxalic acids in different proportions. The following, which is largely in use, may serve as an example:—

Muriate of tin at 80° Tw., 6 gal.; sulphuric acid at 42° Tw., 3 gal.; oxalic acid, 2 oz. a gal. These spirits are used for finishing royal blues, topping blacks, where "bloomy" reflection is required, and as a scarlet or orange spirit with cochineal, lac, flavine, young fustic, &c.

Some compounds of tin are used in dyeing which probably contain an oxide intermediate between stannous and stannic. These solutions are of a rich deep-amber colour, and in warm weather keep very badly. Of these mordants, the most important is nitrate of tin, scarlet spirit (or bowl spirit), much used in Yorkshire and in Scotland for grounding cochineal colours on woollens and worsteds.

To prepare this spirit, a quantity of so-called "single," or "dyers'" aquafortis, i. e. nitric acid at about 32° Tw., containing a quantity of hydrochloric acid, or of an alkaline chloride, and totally free from sulphuric acid, and from the lower oxides of nitrogen, is placed in a large clean stoneware bowl. The finest quality of grain-bar tin, not feathered, is then dissolved in it, in the proportion of 1 lb. to every 8 lb. of the acid. Certain niceties in working are essential to success. If the acid is average in quality, and the weather is temperate, some 4–5 rods are laid in the bowl, and allowed to dissolve quietly, without stirring, or the application of heat. After a time, the liquid "turns," i. e. assumes a deep-amber or light-orange colour. When this has occurred, all difficulty is over, and nothing is needed but to add the rest of the tin by degrees, taking care that the reaction neither dies down nor grows violent. There must be no effervescence, nor production of orange-coloured bubbles or fumes. If the process fails, the change of colour does not occur, and the liquid, after remaining colourless for some hours, suddenly turns thick and turbid. If too much tin has been introduced at first, orange fumes rise up, and the tin is deposited in an insoluble state, and is useless. In winter, 8–10 rods may be put in at the beginning, without danger. In hot weather, two or even one is sufficient, and, if convenient, the bowl may be cooled by placing it in a stream of cold water. If the temperature is very high, the spirit may be started by putting into the bowl half a handful of dry, clean, granulated tin. Nitrate of tin, if well made, marks 58°–60° Tw., and contains $2\frac{1}{4}$ oz. tin per lb.

Purple Spirit, for producing wood purples and violets upon wools and worsteds, is made as follows: —Fresh, well-made nitrate of tin is gently warmed by setting the bowl in a larger vessel of hot water, and is allowed to dissolve as much grain-bar tin, in the rod, as it can take up. It marks about 80° Tw., and should be used immediately.

Aniline Spirit, so-called, is used for fixing aniline colours upon the cotton warps of delaines, &c., and for producing some very rich shades with dye-woods. It is prepared from 5 lb. single aquafortis at 32° Tw., $2\frac{1}{2}$ gal. hydrochloric acid at the same strength, and 12 lb. grain-bar tin in the rod. The acids are mixed in a bowl with upright sides. About 12 rods are put in at first, arranged at equal distances round the side of the bowl. More tin is added as these dissolve, but the temperature must not become excessive. The finished spirit is of a reddish-amber colour, and contains about 20 oz. of tin per lb.

Many recipes, in which tin is directed to be dissolved in different proportions of nitric acid, with the addition of sal ammoniac, will yield a mordant similar in properties to the above.

The stannic salts or per-salts of tin are prepared by two very different processes: (1) A pure aqueous stannic chloride, otherwise called perchloride of tin, bichloride of tin, stannic hydrochlorate, dyers' composition, and sometimes scarlet spirits, may be obtained by saturating double muriate of tin at the highest strength, with chlorine gas till a small portion, taken out and dissolved in water, no longer gives a black precipitate with a solution of mercuric chloride (corrosive sublimate). The solution, with or without the addition of tartaric or oxalic acids, may be used for dyeing cochineal and lac scarlets upon wool. Or (2) tin crystals are dissolved in hydrochloric acid, heat is applied, and nitric acid is added in small proportions at a time, avoiding excess, till the above-mentioned black precipitate is no longer obtained. Or the metal is dissolved in mixtures of nitric and hydrochloric acids. Whenever nitric acid is used, it is never entirely driven off, and the resulting product differs in its action upon colours from that obtained by other processes. Hence it is improbable that pure tin composition would give all the results obtained with these mixtures. The following prescriptions may serve as specimens :—

Red cotton spirit, known also as crimson spirit, is made by mixing 6 gal. hydrochloric acid at 32°–34° Tw., 1 gal. nitric acid at 64° Tw., and 1 gal. water. After standing for a short time, enter by degrees 6 lb. of tin in the rod, beginning with 6 rods more or less, according to the weather, and adding the rest by degrees. The mixture must never get very hot, so as to give off orange vapours, nor must it ever be stirred. In 8–9 hours the whole of the tin will be dissolved, and the liquid will be of a clear pale straw-colour. Another red cotton spirit is made with 8½ gal. hydrochloric acid at 35° Tw., 1½ gal. nitric acid at 64° Tw., 1 oz. bichromate of potash, and sufficient tin to bring up the sp. gr. of the solution to 54° Tw.

Barwood spirit is made with 5 gal. hydrochloric acid at 32° Tw., 1 gal. nitric acid at 64° Tw., and tin at the rate of 1 oz. per lb. of mixed acids.

Tin solution is used for very similar purposes to red cotton spirits, from which it is not distinguished by any well-marked outline. Such a solution is made with 6 gal. hydrochloric acid at 32° Tw., 1½ gal. nitric acid at 64° Tw., 1 gal. water, and 7 lb. tin in rods. In working, the action should be brisk, and the surface of the liquid be covered with a small fine froth; but there must be no orange vapours.

A purple cotton spirit is made by mixing 5 lb. hydrochloric acid and 1 lb. nitric acid, both of the usual strength, and dissolving 2 oz. tin per lb. of mixed acid. Afterwards, ¼ lb. bichromate of potash, dissolved in water, is added to every 18 gal.

Printers' Oxymuriates.—(1) Hydrochloric and nitric acid, 20 lb. each; sal ammoniac, 5 lb., previously dissolved in the nitric acid; and dissolve in the mixture 10 lb. tin. (2) Melt 16 lb. tin crystals in a bowl set in hot water, and add by degrees 20 lb. nitric acid. (3) Melt in the same way 60 lb. tin crystals, adding 1 qt. water, and add gradually 92 lb. nitric acid at 60° Tw. (4) Hydrochloric acid at 34° Tw., 11 lb.; nitric acid at 62° Tw., 5 lb.; and dissolve gradually 2 lb. feathered tin. No. (2) is used for "cutting" madder pinks, and No. (4) for spirit styles.

Pink salt is a double chloride of tin and ammonium. It is precipitated as a white powder, if a strong solution of the stannic chloride (bichloride or perchloride of tin, free from nitric acid) is mixed with a saturated solution of sal ammoniac. Its uses have not been fully studied.

Stannate of soda, otherwise known as preparing-salt, is very extensively used in the steam-style of printing, and may also be used in fixing certain dyes, including aniline colours, upon cotton. It is generally made according to Young's process: good tin-ore, i. e. oxide of tin free from certain impurities, is heated to about 316° (600° F.), either with caustic soda or with a mixture of nitrate of soda and common salt, while a current of steam is passed over the mass. The whole, when cold, is dissolved in water, let settle, filtered, and boiled down.

To determine the proportion of tin in a sample, weigh out a known quantity, dissolve it in water, add a few drops of hydrochloric acid, and place in the solution some pieces of clean sheet zinc. By the action set up, the tin is thrown down as a metallic sponge. It is collected, washed in distilled water, dissolved in pure hydrochloric acid, and its quantity is ascertained by the method given above for tin crystals.

It is a great mistake to suppose that the comparative value of two samples of stannate of soda, or indeed of any other compound, can be ascertained by dissolving equal weights in equal measures of water, and taking the sp. gr. by Twaddle's or Beaumé's hydrometer. Common salt, which is sometimes found in stannate to the extent of 28 per cent., raises the hydrometer, though it adds nothing to the value of the sample. Many compound stannates have been proposed in which arsenic, phosphorus, alumina, silica, and tungsten are used in place of a portion of the tin. Concerning these mixtures, the general opinion of the trade is not favourable.

Zinc Mordants.—The soluble salts of zinc, such as the nitrate, chloride, and acetate, are occasionally used in printing, but very rarely as true mordants. The addition of chloride of zinc to the crystals, which has been recommended with the view of forcing the tin upon the fibre, has not established a success in practice.

Organic Mordants.—Next come a number of bodies having little in common, save the property of fixing colours upon tissues; but which do not, like the bulk of the substances above mentioned (silica and sulphur being the only exceptions), form "lakes," if brought into contact with solutions of colouring matters. Among these bodies, the first to deserve mention is argol, otherwise known as tartar, or cream of tartar (potassium bitartrate). This substance, which consists of tartaric acid in combination with potash, is deposited from the juice of the grape in wine-tuns, and is sold in various grades of purity as red argol, white argol, grey tartar, and crystal tartar. It is very extensively used in woollen-dyeing, along with alum, salts of tin, chrome, &c., and would be employed more extensively were it less expensive. The question whether tartar is a true mordant, or an alterant—serving to modify rather than to fix colours—has been debated with some warmth, and is scarcely decided.

A variety of substitutes for tartar and argol under such names as pro-tartar, pro-argol, tartar-spirits, &c., some of them containing a proportion of tartaric acid, and others being mainly mixtures of bisulphate of soda, common salt, &c., have been used more or less; but their success is by no means unequivocal.

A very important part as mordants is played by the astringents. (See Tannin.)

The animal mordants are chiefly albumen, caseine, and gelatine. If applied to linen, cotton, or other vegetable fibre, they give it the property of taking up colours in the same manner as is done by the animal fibres, silk, wool, &c. The cotton, &c., is then said to be animalized, and can be dyed with magenta, picric acid, &c., without the aid of any ordinary mordant. In other cases, as in the so-called pigment style of calico-printing, the animal mordant in a liquid state is ground up with the colour to be applied, printed upon the fibre, and then rendered insoluble by some appropriate means.

Among these animal mordants, the principal place is due to albumen, the finest quality of which is white of egg, an article necessarily limited in quantity, and very costly. Albumen from blood, if well prepared, can be used for all but the very lightest and brightest colours. It is said that blood-albumen, perfectly colourless, and equal to the finest egg-albumen, has recently been produced in Germany. The albumen from the roe of fishes, and from certain molluscous animals, cannot be readily made available, on account of the difficulty of removing accompanying substances. Albumen in its natural state is soluble in water, but is rendered insoluble if heated to 71° (160° F.), a property which thus supplies an easy method of fastening it permanently upon the fibre. It is also coagulated and fixed by tannin, and by sugar of lead.

Caseine agrees very closely with albumen in its chemical composition, but differs from it in several of its properties. In dilute solutions, it is not rendered insoluble by the action of heat. For use, caseine is dissolved in an alkali, generally ammonia, in which case it may be permanently fixed upon the fibre by means of evaporation. It is to be regretted that, in an English patent for the use of caseine as a mordant, it received the utterly needless and unscientific name of "lactarine," to which the trade still cling.

Gelatine or glue in its various forms is also used as a mordant, though it is not well adapted for the pigment style of printing. It is generally, when required, fixed upon the fibre by a subsequent treatment with some astringent, such as decoction of nut-galls.

Another class of organic mordants consists of oily or fatty bodies. Oil has for centuries been found necessary in fixing the colouring-matter of madder (natural alizarine) upon vegetable fibre in the brightest and most permanent condition.

For such purposes, not all oils are suitable, but merely those kinds which are emulsive, i. e. which, if shaken up with a solution of pearl-ash or soda-ash, form a white, milky fluid, from which the oil does not separate for some time.

This property can be communicated to oils, otherwise suitable, by the addition of a proportion of oleic acid, or by treatment with sulphuric acid, which is afterwards neutralized or otherwise removed. Oil mordants are applied to the yarn or cloth in the cold by means of padding, the goods being then spread out to the air. This alternate process is repeated several times.

The following method has been recently adopted for preparing an oil mordant for dyeing with alizarine. Take 3000 parts of castor-oil and pour into it, in a thin stream, and with continual stirring, 650 parts oil of vitriol, in such a manner that the process of mixture may last for 3 hours, and that no rise of temperature may take place. The mixture is then left to stand for 12 hours, and is next diluted with 3500 parts of water. Then about 650 parts soda-ash, more or less according to its strength, is added by small portions at a time, till the liquid no longer reddens blue litmus-paper. In this state, it forms a white emulsion, if shaken up with water. If it is desired to avoid this property, ammonia is added by degrees, till a portion of the mixture drawn out dissolves in distilled water, without causing any turbidity. It is then allowed to settle, and after standing for 12 hours, the oil may be drawn off for use. A deposit of crystals of sulphate of soda remains at the bottom of the vat. The product obtained is a sulphoricinoleate of ammonia.

A more complicated process has been patented by Dr. A. Müller-Jacobs, who proceeds as follows:—He heats castor-oil with $\frac{1}{5}$ its weight of oil of vitriol, poured in as a slender stream. This part of the process is conducted in lead-lined iron tanks, traversed by coils of lead piping, in which, if needful, ice-cold water can be made to circulate, to prevent heating. After standing for 2–3 hours, the mass is diluted with water, and neutralized with a lukewarm solution of soda (28 lb. soda crystals to every 10 lb. acid which has been used). This alkaline solution is added very slowly, and with constant stirring. The liquid is then allowed to stand over-night, and the next morning it is found separated from the saline mother-liquid, and is drawn off for use.

Meantime pyroterebate of soda is prepared by boiling in an enamelled iron vessel 100 parts rosin with 250 parts nitric acid, the rosin being added gradually, and in powder. After 1½ hour, the mass is gradually evaporated, and the residue is heated for ½ hour to 200°–311° (392°–522° F.) in a closed iron vessel. When cold, it is heated with 20–30 per cent. of its weight of oil of vitriol; then, after the lapse of 2–3 hours, neutralized with soda, and the sulphopyroterebate of soda is reserved for use.

To make the oil mordant, equal measures of the sulphoricinoleate and of the sulphopyroterebate are mixed, and are at once fit for use.

The applications of oil mordants, both in dyeing and printing, will be found capable of further development. Various attempts have been made to use oils as a medium for the fixation of pigments in printing. The difficulty to be overcome is the tendency of the oil to spread in the fibre. This is to be prevented, without interfering with its transparency, or darkening its colour. O'Neill has obtained very satisfactory results on a small scale, but by processes which he considers too delicate and costly for actual practice.

Soaps are not unfrequently employed for fixing artificial colours upon the fibre, but almost invariably in conjunction with ordinary mordants, such as alum, red liquor, or compounds of tin and lead. In such cases, the result is that a compound of alumina, lead, or tin, with the fatty acids of the soap—in other words, an insoluble metallic soap—is deposited upon the fibre.

Mordants at the best must be regarded as necessary evils. One of the greatest triumphs of tinctorial chemistry would be the production of a complete scale of substantive colours, available on every kind of fibre. Many steps have already been taken in this direction. W. C.

(See Acid [Acetic]—Iron, Acetates of; Albumen; Alum; Alumina; Dyeing and Calico-printing.)

NARCOTICS (Fr., *Narcotiques*; Ger., *Schlafmittel*).

The term "narcotic" is applied to a class of drugs, which, in medicinal doses, allay morbid susceptibility, relieve pain, and produce sleep; but which, in poisonous doses, create stupor, coma, convulsions, and even death. The physiological effects of the various narcotics are always essentially different, each possessing its own marked peculiarities. Though the use of narcotics is regarded as an indulgence rather than as supplying any real want, it is remarkable that almost every country or race has its own, either indigenous or imported, pointing to the universal existence of the craving.

The chief narcotic, because most widely used, is tobacco; next in order come opium, hemp, and coca. These are the most important. Of minor significance, are ava or long pepper, betel-pepper, bull-hoof, emetic holly, ledum, pituri, rhododendrons, Siberian fungus, Syrian rue, thorn-apples, and tumbeki. All these will be described in alphabetical order in the present article. Another class of products possessing narcotic principles, noticed in other portions of this work, are belladonna, cocculus indicus, henbane, and lactucarium (see Drugs, pp. 794, 808, 812, and 815); and hops (see Hops, p. 1130). A fourth series, whose members are too insignificant to warrant any description, comprises clary, yarrow, ryle, sweet gale, Armenian azalea, *Kalmia spp.*, *Andromeda spp.*, &c.

Ava, Kava-kava, or Intoxicating Long Pepper.—The leaves of *Piper methysticum* are chewed along with the betel-nut, instead of those of the betel-pepper, in many parts of Further Asia. The thick, woody, rugged, aromatic root-stalk, reduced to a pulp, and steeped in water, forms an intoxicating yet most refreshing beverage in the South Sea Islands. For its medicinal uses, see Drugs—Kava-kava, p. 815.

Betel-pepper, Betel-leaf, or Pawn.—The leaves of *Piper* [*Chavica*] *Betle* and *P.* [*C.*] *Siriboa* are used in conjunction with betel-nut as a narcotic masticatory througbout a large portion of the East. It is very generally cultivated. The plantations are laid out like bean-fields, the plants standing 18 in. apart, and requiring much water. They are trained up poles for the first eighteen months, and are then directed around fast-growing young trees, planted meanwhile. The leaves are gathered in the 3rd–4th year, and the plants bear for 6–7 years, after which they die. In N. India and towards the Himálayas, where the climate is moist enough, the plants are raised under sheds, 20–50 yd. long, 8–12 yd. broad, and scarcely 4 ft. high, made of bamboo, wattled all around and on the top. Slender rods are provided for them to climb up. This mode of cultivation is profitable, and extensively prevails, though twenty-four hours' exposure to the open air would kill the plants. There seems to be much probability that the narcotic effect of betel-chewing is due much more to these leaves than to the betel-nut (see Nuts—Areca).

Bhang, Charas, Ganja, Hashish.—The sap of the hemp-plant (*Cannabis sativa*), well known in Europe as producing a valuable fibre (see Fibrous Substances, p. 934), contains a powerful narcotic principle. This principle is doubtless present to some degree in the plant wherever grown; but in northern climates, its proportion is so small as to have escaped general observation, and that which does exist is very mild in character. In the warmer countries of the East, it is developed in a marked degree in the flowers, leaves, and young stems of the plant, and is the object for which the plant is grown. Its cultivation is largely and systematically conducted in the districts of Bogra and Rájsháhi, north of Calcutta; even more widely in Turkestan, and most of the trans-Himálayan countries; also in Persia and Turkey, and throughout Mohammedan territory generally; and the use of the narcotic has extended to the Hottentots in S. Africa, the negroes of W. Africa, the Indians of Brazil, and the Malays. It is consumed in one form or another by 200–300 millions of people, chiefly Mohammedan and Hindu.

The chief constituents of the commercial narcotic are a resin and a volatile oil. The resin is obtained as a brown amorphous solid, and seems to be the seat of energetic action. Its effect is so potent that $\frac{2}{3}$ gr. taken internally suffices to produce narcotism, and 1 gr. causes complete intoxication. Dr. Preobaschensky states that he has separated the narcotic principle as an alkaloid, and makes it identical with nicotine, but his observations do not seem to have been verified. The oil is obtained only after repeated treatment of successive quantities of the plant in the same water. Freshly gathered plants just after flowering have afforded 0·3 per cent. of this oil, which possesses some active properties. The narcotic receives its various names according to the portion of the plant which yields it, and the method of preparation. These will now be described.

Bhang, Siddhi, or Sabzi, consists of the larger leaves, seed-capsules, and small stalks, in a dried state, coarsely broken, of dark-green colour, with a few fruits intermixed, of peculiar but not unpleasant odour, and almost tasteless. The leaves are gathered before any other portion of the plant is harvested; the stalks, &c., are accidentally present. Locally, it is smoked with or without the admixture of tobacco, or is made into a sort of confection, or a cold-water infusion is taken as an aromatic beverage. Very large quantities of the narcotic in this form are received into India from Turkestan; it also occurs as a commercial article in the London drug sales.

Charas, Churrus, Kirs, or Momeea, are the various names applied to a resin which exudes in minute drops from the foliage of the plant. The degree in which this resin is produced varies greatly: in India, it is copiously afforded by the plants grown at an altitude of 6000–8000 ft., but cannot be obtained from those cultivated in the plains. The plants exhibiting greatest richness in this resin in the Laos country of the Malayan Peninsula do not exceed 3 ft. in height, and have densely curled leaves. The manner in which the resin is collected is subject to variation. In Nepal, it is gathered by rubbing the tops of the plants between the hands when the seeds are ripe, and scraping off the adherent substance. This variety is very pure, and is called *momeea* or "waxen" *charas*; it remains soft, even after continued drying. In Central India, men wearing leather aprons pass rapidly among the plants, brushing violently against them, by which the resin is detached, and caught upon the apron, whence it is periodically removed. The ordinary kind from Cabul is obtained in the same way. In some districts, the coolies dispense with the leather apron, and collect the resin upon their naked bodies. In Persia, the plants are pressed upon coarse cloths; the resin is subsequently scraped from these, and melted in a little warm water. Such is the *kirs* of Herat, one of the best and most powerful varieties of the drug. Much resin is dislodged when heaps of dried *bhang* are stirred about; this is carefully collected, due precaution being observed against the effects of the dust upon the human constitution. The best Yarkand *charas* is a brown, earthy-looking substance, in irregular masses, made up of minute, transparent grains of brown resin; other specimens appear like a dark, compact resin. Crystalline structure is revealed by the microscope. However obtained, it is considered a crude form of the narcotic, and is not admitted into European pharmacy. In India, it is chiefly consumed by smoking with tobacco. For this purpose, very large quantities are exported from Yarkand and Kashgar, through Leh, into Kashmir and the Punjab. Yarkand, in 1867, thus despatched 1830 *maunds* (146,400 lb.). In 1876, Afghanistan sent 86,000*l.* worth through the Khyber Pass into British India. Kandahar and Samarkand contribute smaller quantities; and some seems to be exported from Mandchuria to China.

Ganja, Gunjah, or Guaza, the last being the corrupted name used by the London drug-brokers, is applied to the shoots of the female plant, gathered while in flower or fruit, and dried without removal of the resin. In the Calcutta markets, these are sold in bundles, about 3 in. in diameter, containing 24 plants. The shoots vary in succulence and in length; they have a compressed and glutinous appearance, are very brittle, and brownish-green in colour. Boiled in alcohol, *ganja* yields $\frac{1}{5}$ of its weight of resinous extract. Its convenience in this respect makes it best adapted to the needs of European medicine, and it is therefore the form in which we most generally import the drug. In India, it is smoked like tobacco, and often in admixture with it. In Morocco, the dried flowers are smoked, under the name of *kief*. In Africa, it is known as *djamba*, and is found in the markets packed in strips of palm leaf, or husks of maize, generally about 2 ft. long, tied at top and bottom, and at intervals of about 1–$1\frac{1}{2}$ in. throughout the whole length of the case. When required for use, one division is cut through, and suffices for one pipe. The packages are sometimes smaller, and the charges not larger than a marble.

HASHISH, DAWAMESE, MADJOUN, and EL MOGEN, are various forms in which the narcotic is prepared. Hashish, which is by far the most common, is made by boiling the leaves and flowers of the hemp-plant in water containing a little fresh butter, evaporating down to a syrupy consistence, and straining through cloth. The butter extracts the narcotic principle, and assumes a greenish colour. The preparation retains its properties for many years, and becomes but slightly rancid. For use, it is compounded with confections and aromatics, and forms the basis of the *el mogen* of the Moors, and the *dawamese* of the Arabs. The *madjoun* of Constantinople and Algeria is composed of the pistils of the flowers, ground to powder, and mixed with honey and spices. In Central Asia, the article occurs in the bazars in the form of cakes of various shapes, mostly 5–15 in. long, 5–10 in. broad, and 1–3 in. thick, dark-brown externally, greenish internally, firm, very tough, but easily cut into shavings. These cakes are prepared from the resinous juice of the fresh, unripe flower-tops, collected during spring, mixed with sand and water to a doughy consistence, spread upon a clay surface, and dried till cohesive.

Bull-hoof, or Dutchman's Laudanum.—The flowers of *Murucuja ocellata* [*Passiflora Murucuja*] are used in Jamaica, either infused, or mixed in a powder with wine or spirits, as a safe and effectual narcotic.

Coca, Cuca, or Khoka.—The name "coca" is a corruption of the Aymara Indian word *khoka*, which latter might well be resuscitated, in order to avoid the confusion now often made between this narcotic substance and the cocoa (cacao), and coco- (coker-) nut respectively. It is a product of one species of the genus *Erythroxylon*, the majority of whose species are natives of S. America and the W. Indies, and is called *E. Coca*, the specific name being derived from the product which distinguishes the plant from others of the same genus. It is a shrub or small tree, attaining a height of 4–8 ft. (usually about 5–6 ft.), and bearing a general resemblance to the blackthorn. It is a native of the tropical valleys occurring on the eastern slopes of the Andes, in Peru and Bolivia, and is also found in a lesser degree in Brazil, Ecuador, Venezuela, New Granada (Colombia), and Guiana, and is doubtfully mentioned as existing in the W. Indies. At Templado, in the Sierra Nevada of Santa Marta, Colombia, large quantities of coca (locally called *hallo*) are grown, and sent to the Goajira.

In many parts of the Andes, the shrub flourishes in a wild state, but in the inhabited districts, it forms an important agricultural crop, and the steep sides of the valleys, as high up as 8000 ft. above sea-level, where the mean temperature is 18°–20° (64°–68° F.), are often covered with *cocales*, or coca-plantations, forming the principal wealth of the settlers. The cultivation is commenced by sowing seeds in garden beds (*almacigas*) at the end of the rainy season (about 1st March in Peru). Maize is sown between the rows, to screen the young shoots from the sun, and maintain the soil in a moist condition, often the additional care is bestowed of placing arbours of palm-leaves over them; and watering must be attended to if the weather remains dry for a week or so. When 1½–2 ft. high, and 18 months old, the shoots are transplanted to holes on hill-side terraces, or to furrows on level ground. The usual distance apart is 18 in. each way. The ground must be carefully weeded. The plants thrive most luxuriantly in hot, damp situations, such as forest clearings; but the alkaloid principle for which the leaves are valued is more copiously developed when drier hill-side localities are chosen. The first crop of leaves may generally be taken 12 months after the transplantation, or in September, when the plants will be 2½ years old. This will be only a small picking; but 6 months later, the shrubs will be in full bearing, and will yield 3–4 crops of leaves yearly, according to the suitability of the locality, and the care taken in watering, &c. Usually there are 3 pickings—the first and most abundant in March, after the rains, the second in June, and the third in September–November. With due attention, the shrubs will continue productive for 40 years. Ants appear to be great enemies to them.

The leaves are narrow, and 2–3 in. long, tapering at the extremities, and of a lively green tint when fresh. When ripe, which is known by their cracking or breaking off when bent, they are carefully stripped from the branches by women, and sun-dried. The latter operation needs especial care. The green leaves (*matu*) are spread in thin layers on coarse woollen cloths, stretched upon prepared earthen or cement floors, after the manner of the "barbecues" used in coffee-drying, and exposed to the heat of the sun; when perfectly dry, they are pressed into serons, or skin bags. Every precaution must be taken to prevent their imbibing any moisture during exposure, and to ensure their not sweating either then or subsequently. Well-cured leaves are uncurled, of a deep-green colour on the upper surface, and grey-green beneath, with a strong tea-like odour and pleasant pungent taste, and produce a sense of warmth when chewed; inferior ones are dark-coloured, with a less agreeable camphoraceous smell, and are almost devoid of the pungent flavour and physiological effect.

About 100 plants are reckoned to yield 1 *arroba* (say 26 lb.) of leaves at a crop. The total yearly produce averages about 800 lb. of dried leaves from an acre; occasionally it amounts to 50 per cent. more, but often also it is much less. Altogether probably 30 million lb. of the dried leaves are produced annually, for the consumption of some 8–10 million people; this implies an area of nearly

40,000 acres occupied by the culture. The best districts appear to be the eastern slopes of the hills in northern Bolivia. The great centre of production is the province of Yungas, in the Department of La Paz, embracing the low tropical region below 5000 ft. A very large trade in the leaves is carried on at most of the towns in Bolivia and Peru, but Totora appears to be the principal depot.

In Bolivia and Peru, the Indians masticate the leaves in combination with an alkaline substance. Most commonly, the alkali takes the form of pulverized quick-lime; but in Cerro di Pasco, and places still further south, this is replaced by the pungent ashes of the quinoa (*Chenopodium Quinoa*), and sometimes a little tapioca is added. In Brazil, the leaves are dried, and reduced to powder in a wooden mortar along with the ash from the burnt leaves of *Cecropia peltata*. Occasionally the leaves are infused, and the tea-like beverage is drunk; but far more generally the compound of leaves and alkali is chewed like a quid of tobacco. The physiological effect is stimulating rather than purely narcotic, increasing the nervous energy, preventing fatigue, assuaging hunger and thirst, and rendering respiration easy at altitudes and under conditions otherwise most trying. It is therefore recommended for athletes, and should be invaluable to troops on the march or before action. Its use in excess is accompanied by the usual ill effects of too great indulgence in all narcotics. The substance is now known in European medicine and commerce. The dried leaves suffer much deterioration by the sea-voyage, and give unreliable results; but the fluid extract prepared from the fresh leaves, and imported in bottles by Christy & Co., Fenchurch St., seems to retain its full virtues. The properties of the plant are due to an alkaloid, called "cocaine," which has been shown to bear strong analogy to the alkaloids of the dietetic beverages—tea, coffee, cocoa, guarana, &c.

Emetic Holly.—An infusion or decoction of the leaves of *Ilex vomitoria* is the narcotic beverage of the indigenes of Florida. Little or nothing is known of its active principle.

Ledum.—The leaves of the marsh ledum or wild rosemary (*Ledum palustre*), a heath-plant common in N. Europe, were formerly used in Scandinavia and N. Germany, for giving bitterness and headiness to malt-liquors. The broad-leaved ledum (*L. latifolium*) possesses identical properties. In N. America, both are known as "Labrador tea," and are largely used as a beverage. The former is probably the better for this purpose. They deserve further investigation.

Opium.—This well-known narcotic is the concreted juice obtained from the fruits or "heads" of the so-called "opium-poppy" (*Papaver somniferum*), an annual plant of several varieties. The principal are:—(1) var. α. *setigerum* (*P. setigerum*), a truly wild form, occurring in the Peloponnesus, Hières, Cyprus, and Corsica; (2) var. β. *glabrum*, cultivated chiefly in Asia Minor and Egypt; (3) var. γ. *album* (*P. officinale*), cultivated in Persia, India, China, &c. The petals of these varieties range in colour from white to red or violet, with generally a dark-purple spot at the base. In England, the white-flowered are preferred. The seeds vary from white to slate-coloured.

The climatic conditions necessary to the successful culture of the poppy for its yield of opium are to be found throughout a very wide area, and the collection of the narcotic is possible in all temperate and sub-tropical countries which are not subject to excessive rainfall. Numerous experiments made in England, France, Germany, Switzerland, Italy, Greece, and even Sweden, have proved that a rich opium, equal to that of the East, can be produced in most parts of Europe. Grown in moist rich ground, in England, the heads attain double the size (3 in.) of those from Asia Minor and India. French opium has yielded the highest percentage (22·8) of morphine yet observed; and at Clermont-Ferrand, a pure inspissated juice, called "affium," containing 10 per cent. of morphine, has been produced for many years. Experimental culture in the neighbourhood of Amiens showed that 14,725 capsules incised within 6 days gave 431 grm. of milky juice, affording 205 grm. (47·6 per cent.) of dry opium, containing 16 per cent. of morphine.

Opium has been produced in Algeria. The cultivation of the poppy is being established in E. Africa; 50,000 acres of land in the Mozambique or Zambezi territory have been sown with the best Malwa seed, and a 12 years' monopoly has been granted to the cultivators. The plants thrive well, and their fruits are much larger than in India. In several of the United States, notably Georgia, Virginia, Tennessee, and Philadelphia, the culture of the opium-poppy has been initiated. The alluvial soils are best. The seed is sown in drills 3 ft. apart, and 12–18 in. between the plants, in July–August, the winter having no injurious effect (in Virginia). The ultimate success of the industry seems to be regarded as certain by American agriculturists, an excellent product having been obtained. The Australian climate seems very well adapted to the growth of the poppy, and opium of superior quality has been produced in Victoria; in 1878–9, 3 acres were occupied by this crop, yielding 60,000 heads.

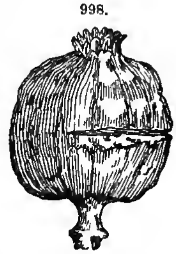
Production and Commerce.—Yet in spite of the wide adaptability of the plant, and the still wider employment of its valuable products, the cultivation has become of importance only in those countries which afford land and labour in abundance and cheapness, and where the narcotic is in popular use as such. Thus it happens that the commercial production of opium is limited to Asia Minor, Persia, India, China, and Egypt. As the varieties of poppy grown, the modes of cultivation of the plant, and the preparation and quality of the narcotic product, vary in these several countries, it will be convenient to consider each separately in the order just mentioned.

In Asia Minor.—The poppy cultivated in Asiatic Turkey is var. β. *glabrum*; its flowers are commonly purplish, but occasionally white, and its seeds are coloured white to dark-violet. The crop is raised both on the elevated and on the lower lands. None is more uncertain, spring frosts, droughts, and locusts causing it frequent injury, and sometimes complete destruction. The soil chosen must be naturally rich and moist; large quantities of manure are required, and the land is frequently ploughed till it has attained a thoroughly pulverulent condition. Moisture is indispensable, but is injurious when in excess. Consequently, after a wet winter, the best crops are got on the hilly grounds; in a dry season, on the plains. The seed, mixed with dry sand to avoid casting it too thickly, is sown broadcast. The sowings take place at three distinct periods, the objects being to obviate the chance of a total failure of the crop, and to ensure different portions of the crop maturing in succession. Without the latter precaution, the labour-supply would be quite insufficient; and even in spite of it, quantities of the drug are wasted when the crop is a full one.

The first and principal sowing, to which somewhat more than a half of the total available land is devoted, usually begins after the first winter rains, varying from October till November, and is sometimes postponed even later on in the high lands. This sowing is termed *giuzmaly*, or "winter sowing," and affords the hardiest plants, from their having greater time to establish themselves. In fact, no subsequent sowings compensate for the loss of this crop. A second sowing takes place in December–January, should the weather be sufficiently mild to encourage it. In favourable years, the returns from this sowing (*kishmaly*) nearly equal those from the winter sowing; but they are so uncertain that but little reliance can be placed on them. A third and important sowing is performed in the spring, February–March. Land is always reserved for this, the *yazmaly*, as a means of partially redeeming any loss entailed by the failure of the *giuzmaly*; but exceptionally favourable weather is required to make it a success. When delayed by the weather till March–April, it is an almost certain failure. The quantity of seed required is estimated at $\frac{1}{4}$–$\frac{1}{3}$ *oke* (say $\frac{3}{4}$–1 lb.) for every *toloom* (1600 sq. yd.). After sowing, the land is harrowed by means of the rough native implement, consisting of a few planks fastened together, and weighted by the driver standing upon it. In the early spring, when the plants of the *giuzmaly* have acquired some strength, hoeing and weeding commence, and are continued till the flowering season. These operations devolve upon the women and children of the proprietor, almost the whole cultivation of opium in Asia Minor being in the hands of a landed peasantry.

By about the end of May, the plants in the low lands arrive at maturity, and the flowers expand; on the uplands, this does not happen till July, owing to a reduced temperature. Gentle showers at this critical period greatly increase the yield of opium. The operation of extracting the latter from the capsules or "heads" of the plant commences when these are matured. This condition is reached a few days after the petals of the flowers have fallen off, and is further marked by the capsules changing to a lighter green hue. While the capsules are still quite green, and at that time about 1½ in. in diameter, they are subjected to incision for the purpose of liberating the juice. The operation is performed by drawing a knife around the head, generally at about the centre, and extending horizontally over about $\frac{2}{3}$ of the circumference, or carried spirally till it overlaps itself by about $\frac{1}{2}$. This horizontal (or nearly so) incision (Fig. 998) is adopted as affording less trouble in scraping off the subsequent exudation, and some assert that it cuts the greatest number of the vessels whence the exudation takes place, though experiment seems to indicate that no essential difference in the quantity of the product can be detected from the various systems of cutting. In all cases, great nicety is required to prevent the knife penetrating the interior coating of the capsule, and causing some of the juice to flow inside and be lost. The incisions are made after the heat of the day; on the following morning, the capsules are found covered with the exuded juice. If there has been heavy dew during the night, the yield is greater, but the product is weaker and of dark colour; if dew has been wanting, the yield is less, but the colour is lighter. A shower of rain, always possible at this season, is nearly sure to wash away the whole crop that had been prepared. Windy weather is prejudicial, causing much dust to adhere to the exudation. This latter is removed from the head by scraping with a knife, and is transferred to a poppy-leaf held in the left hand. After every alternate scraping, the knife-blade is drawn through the mouth, that the saliva may prevent the adhesion of the juice. A proposal to substitute a vessel of water for this objectionable practice has not been adopted. Usually each head is cut but once; as each plant, however, produces a number of heads, which mature at intervals, the same field needs to be visited a second and third time. As soon as sufficient of the juice has been gathered on a leaf, a second leaf is wrapped around it, and the cake or lump thus enveloped is put for a short time to dry in the shade. No definite size or weight

998.



is observed for these cakes, which vary from a few oz. to over 2 lb.; but in some villages, the average is higher than in others.

The gathered opium in the crude cakes passes from the grower to the local merchant. Money is advanced by the latter to the former on the security of the standing crop; and when this crop is gathered, the debt has to be liquidated, either (optional with the growers) in money or produce at the opening prices. When the crops are all in, the growers and buyers meet before the *mudir* or governor of each district, to "cut" or arrange a mutually satisfactory price. Should the price named not meet with the approval of the growers, they must either liquidate their debts in money, or bring forward other buyers who are ready to redeem their bonds, and take the produce, otherwise the grower must accept the prices offered by their creditors. In the event of competition, the parties who made the advances are entitled to the preference at the prices named at the meeting.

The purchasers receive the opium in its soft, crude, natural state. Occasionally they pack it without subjecting it to any sophistication, for conveyance to a sea-port. More generally, however, the soft drug is manipulated with a wooden pestle, and powdered poppy-heads, half-dried apricots, turpentine, figs, inferior gum tragacanth (often used by the Jews of Smyrna), a compound formed of evaporated grape-juice thickened with flour, stones, clay, scraps of lead, &c., are mixed up with it. The manipulated article is made into larger masses, which are enveloped in poppy-leaves, and packed in cotton bags, sealed at the mouth. These bags are packed into oblong or circular wicker baskets, to the weight of 80–100 *chequis* (130–162 lb.) in each, quantities of the little chaffy fruits of a native dock (*Rumex ?* sp.) being placed between the cakes to prevent cohesion. The baskets are transported in pairs on mule-back to the port. On arrival, they are placed in cool warehouses to avoid loss of weight, and remain unopened till sold.

On reaching the buyer's warehouse, the seals are broken, and the contents are examined piecemeal by a public examiner in the presence of buyer and seller. All of suspicious appearance is cut out and thrown aside. The examination is not based upon any scientific method; the character is judged only by the colour, odour, appearance, weight, &c., of the sample, but so expert are these officials that their estimation is generally very correct. The classification appears usually to be three-fold:—(1) "Prime" or *yerly*, not so much a selected quality as the produce of certain (empirically) esteemed localities; (2) "current," the mercantile quality, and constituting the bulk of the crop; (3) *chiquinti* (*chicantee*), the inferior article rejected during the examination. A 4th quality might include the very bad and wholly spurious sorts. The strength and quality are reckoned in carats, 24 carats constituting pure opium; according to custom, the examiner must pass all which reaches 20 carats, consequently a wide difference in quality may actually exist in two baskets valued alike. After examination, the tare (including the chaffy fruits used in the packing) is taken. The fruits are afterwards returned to the buyer for packing his cases. These are made large enough to hold each the contents of one basket.

The average yield of a *toloom* of land may be stated at 1½ *chequís* (2·43 lb.) of opium, and 4 bush. (of 50 lb.) of seed, valuable for the oil (see Oils—Poppy-seed). A good full crop may give 3–5 *chequis*, and even 7½ is not unknown. The amount produced varies exceedingly on the same plot. Thus the actual crops from 1 *toloom* in 4 different years were 7½, ⅓, 2¼, and 4½ *chequís* respectively. An estimate of the average expense and result of cultivating 100 *tolooms* of land with opium, supposing labour to be procurable at ordinary wages, would give the subjoined figures:—

PRODUCE.

	Piasters.
100 *tolooms* of land—average yield of opium at 1½ *chequí* a *toloom* = 150 *chequis*, at 80 *p.*	12,000
Average yield of seed, 4 bush. a *toloom* = 400 bush. at 20 *p.*	8000
	20,000

EXPENSES.

	Piasters.	
Tithes, 10 per cent. on value of produce	2000	
Ploughing, 118 days, at 8 *p.*	944	
Manure, 5000 donkey-loads, at 1 *p.* a load	5000	
Seed, 36 *okes*, or 2 bush., at 20 *p.*	40	
Hoeing, weeding, &c., 400 days, at 8 *p.*	3200	
Making incisions, 200 days, at 8 *p.*	1600	
Gathering, 100 days, at 8 *p.*	800	
Collecting seed, 100 days, at 8 *p.*	800	
Cleaning, 100 days, at 8 *p.*	800	
Cattle food, &c.	240	
		15,424
Average gain to a grower		4,576

This statement must be regarded as approximative only. Presuming the grower should send his opium to Smyrna for sale, the cost would be as follows:—150 *chequís*, at 80 *p.*, 12,000 *p.*; packing charges, 20; inland duty at $5\frac{1}{10}$ *p.* a *chequí*, 825; carriage, 300; loss on money by bills 2 per cent., 240; factor's commission in Smyrna, 2 per cent., 200: brokerage, 1 per cent. on 100 *p.*, 100; total, 13,685 *piasters*. This shows a cost of 91·23 *p.* a *chequí*, to which add 9 *p.* for shipping charges to Europe, making a total of 100·23 *p.*; or, at the exchange of 110 *p.* per £ sterling, and the usual equivalent per *chequí* of 1·62 lb., it would cost 11*s.* 1*d.* a lb. free on board; add charges in England, insurance, freight, &c., 5*d.* = 11*s.* 6*d.*

The purest opium is said to be collected at Ushak. Bogaditch, and Simav; but the pieces are small and stick together, which makes them unsightly. The Karahissar produce is reckoned not so good, and the pieces are larger. The fancied superiority of the article from certain districts is proved to be only partially correct by the fact that the quantity sold under these particular names is often 3–4 times as great as the localities could produce. Formerly the only opium-growing districts in the interior were Karahissar, Konieh, Yerli, Bogaditch, and Balikesri, and the crop was usually about 2500–4000 baskets. The crop of the Karahissar district was estimated to fluctuate between the following figures, representing a "good fair" and a "full" crop respectively:—Karahissar, 400–500 baskets; Afion Cassaba, 50–100; Sandukli, 200–250; Sitchanli, 60–80; Karamuk, 25–30; Tzai, 30–40; Bolavadin, 50–60; Ushak, 250–400; Ishikli, 100–200; Ekmé, Takmak, Coullah, 100–200; Tzal, Baklan, 80–100; Simav, Ghediz, Eneòvassi, Taouchanli, 200–250; Kutayah, 40–50; Boladitch, Eskihissar, 30–50; Ak Shair, 250–300; Yalavatch, 250–300; Karagatch, Sparta, Bourdroun, 150–200; total, 2265–3110. The largest quantities are now produced in the north-western districts of Karahissar Sahib, Balahissar, Kutaya, and Kiwa (Geiveh), the last on the river Sakariyeh, running into the Black Sea. These centres send a superior quality by way of Ismid to Constantinople, the best it would seem from Bogaditch and Balikesri, near the Susurlu river. The chief northern centres are Angora and Amasia. In the centre of the peninsula, Ushak and Afion Karahissar are important localities, as well as Isbarta, Buldur and Hamid farther south; the product of these places is concentrated at Smyrna. The export of opium from Smyrna was 5650 cases, value 784,500*l.*, in 1871. Samsoon, in 1878, exported 19,865 kilo., value 31,784*l.*, to Turkey (Constantinople), and 1667 kilo., value 3000*l.*, to Great Britain. The crop of 1879 was an average one, amounting to about 5200 chests in Asia Minor. The cultivation has extended into several new districts in Anatolia; also in Thessaly, where very superior qualities are produced.

The names and qualities of opium as classified at Smyrna are as follows:—Bogaditch, Yerli, Karahissar, common, *talequale*, and *chiquinti*. It is bought and quoted at so many *piasters* ("good money," i. e. in silver *medjidiés* at 20 *p.*) the *chequí*. The approximate relative values may be given as:—"Karahissar," last year's crop, 250 *p.* a *chequí*; *yoghourma*, good quality, 225; *yoghourma* seconds, 210; *talequale* and *chiquinti*, mixed, 220. Since 1868, when the crop was very short, the demand has rapidly increased; in 1877–8, the consumption in America and on the Continent reached 6900 baskets, and in 1878–9, 6300. This fact has induced a widely augmented cultivation. The production in baskets, and price (min. and max.) in *piasters* a *chequí*, during the last 10 years, have been as follows:—1870, 4500, 250–285; 1871, 8500, 130–200; 1872, 4400, 160–220; 1873, 3200, 165–260; 1874, 2500, 130–274; 1875, 6300, 122–145; 1876, 3250, 137½–190; 1877, 9500, 122½–138; 1878, 6100, 120–145; 1879, 4200, 135–250.

The first baskets of opium reach Smyrna at about the end of May or beginning of June, but it is not safe to effect any shipments before the month of August, for the following reasons:—(1) too fresh opium is liable to get heated, (2) the *chiquinti* is not so easily detected, and (3) it suffers a loss of weight. Apart from agricultural causes, the crop of opium depends in a great measure upon the prices ruling at the close of a season, which influences the area of land sown; after a large crop, with low prices, a small crop, with high prices, is almost sure to follow, and *vice versâ*. The best time for purchasing is, as a rule, at the commencement of a season; with a small crop, however, the chances are often most in favour of the buyer at the end of a season, prices being affected towards the close by the coming crop.

"Turkey," "Smyrna," or "Constantinople" opium, the produce of Asia Minor, occurs in commerce in the form of indefinite masses, which, according to their softness, become more or less flattened, many-sided, or irregular, by mutual pressure in the packing-cases. The most usual weight is ½–2 lb. but it is governed by no rule, and varies from 1 oz. to more than 6 lb. The exterior is coated with fragments of poppy-leaves, and strewn with the dock chaff before mentioned, and is thus rendered sufficiently dry to bear handling. The consistence is such that the substance can be readily cut by a knife and moulded by the fingers. The interior is moist and coarsely granular, varying in colour from light-chestnut to blackish-brown. Fine shreds of the epidermis of the head are easily visible. The odour is peculiar, but not disagreeable; the flavour is bitter.

In Persia.—The variety of *Papaver somniferum* grown in Persia is γ. *album* (*P. officinale*), having ovate-roundish heads, containing white seeds. It is cultivated principally in Yezd and Ispahan, and partly in the districts of Khorasan, Kerman, Fars, and Shuster. The opium produced in Yezd is considered better than that obtained in Ispahan and elsewhere, owing to the climate and soil of the former place being better adapted for the growth of the drug. But the district of Yezd, notwithstanding the existence of a large cultivable area, is not capable of any considerable extension of the cultivation of opium, owing to the insufficiency of the means, both natural and artificial, of irrigation. Ispahan, however, differs from Yezd in this latter respect, as it abounds in streams and rivers, and is capable of greater extension of the cultivation of the drug. But the cultivation of cotton and cereals takes up a large part of these resources, and tends in no small degree to reduce the culture of opium. A few years ago, the profits of opium having attracted the attention of the Persians, almost all available or suitable ground in Yezd, Ispahan, and elsewhere, was utilized for its cultivation, to the exclusion of other produce. It was then supposed that opium cultivation would be indefinitely extended in Persia, but circumstances eventually showed that such could not be the case. These attempts, combined with drought and other circumstances, resulted in the famine of 1871–2. The costly experience then gained has made the Persians more careful in appropriating space for the cultivation of opium, yet it is being yearly extended to fresh districts, and about Shiraz and in Behbehan is now occupying much of the land.

From a consular statement of the fluctuations of the annual estimated produce of opium in Persia from the year 1868–9 to 1874–5, it appears that the largest product of any one year did not exceed 2600 cases, an inappreciably small quantity, and in 1874–5, it had fallen to some 2000 cases. In the following year, there was a further decline, the exports amounting to about 1890 cases. Since 1876–7, however, a reaction seems to have taken place; in that year, 2570 cases were exported from Bushire and Bunder Abbas alone. In the early part of 1877–8, the probable yield of the crop was estimated at 3500, but the actual number exported from Bushire and Bunder Abbas amounted to 4730 cases. In the year 1878–9, the amount produced was stated to have been 6700 cases, while 5900 were shipped from these ports. The probable yield of the crops of the year 1879–80 was estimated to be as follows:—Khonoar, about 950 cases; Kerman, 300; Yezd, 1000; Ispahan, 2400; Nereez, 400; Shiraz, 1300; Kazran, 100; Shuster, 100; making a total of 6550 cases. In addition, about 300 *shah mans*, or say 550 cases, were expected to come to Yezd from Herat, making the whole stock about 7100 cases.

The values (in rupees) of the opium exports from Persia during the year 1879 were:—From Bushire: 1,50,000 to England, 2200 to Zanzibar, 50,00,000 to China, total 51,52,200; from Lingah: 50 to the Arab coast of Persian Gulf, and Bahrein; from Bahrein: 50 to Koweit, Busrah, and Bagdad.

The system of cultivation does not call for any special remark; but it may be noted that the incisions in the heads are made in a vertical direction with diagonal branches. The crop comes to hand in May–June, and the greater part of the opium finds its way to the shipping-ports between September and January following. Since the attention of Persian merchants was attracted to the trade, about 25 years ago, there has been, with two or three exceptions, a gradual annual increase in the production of the drug, though not to such an extent as to be prominently noticeable. Now, the cultivation of the poppy and exportation of opium through Bushire and Bunder Abbas increases rapidly; the returns from Bushire for 1878 show an increase in value over the previous year of 1,754,000 rupees, the quality being also very superior to that of previous years. Great care is now taken to prevent adulteration, the chests containing the opium being occasionally examined by experts. When the Persian opium trade was in its infancy, the drug was sent in sailing vessels to Java, and thence re-shipped in steamers for Singapore and Hong Kong. The Dutch Government, however, having imposed restrictions at Java, Aden was subsequently selected as a port of transshipment, and later Suez, at which port no duty is levied for trans-shipment. The Persian Steam Navigation Co. now send occasional steamers from the Gulf to Galle for conveyance of opium, when a sufficient quantity is collected.

The strongest opium, called *teriak-e-arabistani*, is obtained in the neighbourhood of Dizful and Shuster, east of the Lower Tigris. Good opium is produced also about Sari and Balfarush, in the province of Mazanderan, as well as in the southern province of Kerman. The lowest quality, which is mixed with starch, &c., and sold in light-brown sticks, is made at Shahabdulazim, Kashan, and Kum. Quantities of opium are collected in Khokan and Turkestan. About 100 cases of opium in cakes are brought annually from Herat to the Yezd market. From Yezd also, a quantity of opium, prepared in the shape of small sticks and cylinders, is sent to Herat for consumption there. The whole produce of Ispahan and Fars is carried to Bushire. The produce of Khorasan and Kerman is taken to the Yezd market, and this, together with that of Yezd itself, is sent partly to Bushire and partly to Bunder Abbas. The Shuster opium is sent through Mohammerah direct, and sometimes viâ Bushire to Mussah for transmission to Zanzibar, but a part of it is supposed to be smuggled into the Indian frontier provinces viâ Mekran and Beloochistan. Small quantities of opium are said to be grown in Teheran, Tabreez, and Kermanshah, but these mostly find their way to Europe viâ Turkey, Smyrna being the port where it is mainly taken to, and where it is mixed with the local drug, and forwarded to the Continental markets. Some Persian opium is carried overland to China, through Bokhara, Khokan, and Kashgar; but the bulk now goes by sea. A considerable portion leaves the country by way of Trebizonde and Samsoon, principally for Constantinople, where it is worked up in imitation of the Asia Minor article, and adulterated; the remainder comes directly to Great Britain.

About five-sixths of the total produce of Persian opium is intended for China. The drug suitable for that market being required to be fine, prepared with oil, and not rich in morphine, permits of its being swelled up with foreign substances, and thus adulterated as far as practicable, while precluding discovery by the mode of testing or "touching" used in China. It is said that pure and superior opium, though not so finely manipulated, has been rejected in China, while the fine opium, containing admixtures, has found favour and fair market. The preparations made for the China marts being, say, of a quality of 80 touch (containing 80 per cent. pure juice and 20 per cent. foreign substance) yield 9–10 per cent. morphine. Persian opium for the Chinese markets, where it is now assuming great importance, is made up in cakes, varying in weight from ¾ lb. to 1½ lb., and in number from 96 to 192 or more, and these are packed in fig or vine leaves, and sometimes in poppy seeds or stalks, into cases containing each 10½–11 *shah mans*—a *shah man* (or more properly, *batman-i-shah*) being equivalent to about 13½ lb. The object in so packing in cases, as regards the weight, is that the contents, after the loss caused by drying up in course of transit, calculated at 5–10 per cent., may realize at its destination (China) 1 *picul* (133⅓ lb.). Another reason is that the weight is arranged for convenience of carriage by pack animals.

The drug despatched to London occurs in various forms, the most typical being a short rounded cone, weighing 6–10 oz. Sometimes it is met with in flat circular cakes, 1¼ lb. in weight. It is usually of firm consistence and good odour, and of a comparatively light-brown tint internally, the surface being strewn with fragments of stalks and leaves. Some is collected with the aid of oil, as in Malwa (India), as attested by the greasiness of the cone, and the globules of oil displayed on cutting it. The best samples give 8–10¾ per cent. of morphine, reckoned on the opium in its moist state. Very inferior, or almost altogether spurious, samples also come into this market occasionally; thus some of a soft, black, extractiform character has given only ½–3 per cent. of morphine, reckoned in the moist; and some very pale, in small sticks, wrapped in papers, afforded but 0·2 per cent.

In India.—The kind of poppy generally cultivated in India is the same as in Persia, *P. somniferum* var. *γ. album* (*P. officinale*), with white flowers and white seeds; but a red flowered and black-seeded kind is met with in the Himálayas. The principal opium-producing region of British India lies in the central tract of the Ganges, embracing an area about 600 miles long and 200 wide, and bounded by Dinajpur (Dingepore) in the east, Hazaribagh in the south, Gorakhpur (Goruckpore) in the north, and Agra in the west, thus including the flat, populous districts of Behar and Benares. In 1874, 330,925 acres in the former, and 229,430 acres in the latter, were under poppy-cultivation. The next important region embraces the broad table-lands of Malwa, and the slopes of the Vindhya Hills, in the dominions of the Holkar. According to one authority, the kind of poppy grown here is var. *β. glabrum*, as in Asia Minor and Egypt. The regions just indicated collectively afford the chief supplies of the drug obtained in India, and their products are commercially known as "Patna," "Benares," and "Malwa," respectively.

Outside these extensive regions, the amount of land under poppies is relatively very small, though on the increase. The plant is grown for its narcotic throughout the plains of the Punjab, but less commonly in the N.-W. provinces. In the valley of the Bias, east of Lahore, it is cultivated up to an altitude of nearly 7500 ft. Most of the outer districts grow the poppy to a certain extent, and produce a small quantity of indifferent opium for home consumption. But the drug prepared in the Hill States and in Kulu, is of excellent quality, and forms a staple article of trade for the region. Opium is also produced in Nepal, Bassahir and Rampur, and at Doda Kashtwar, in the Jammu territory, at the base of the Himálayas, south and south-east of Kashmir. From these districts, it is exported to Yarkand, Khutan, Aksu, and several Chinese provinces,—to the extent of 210 *maunds* (16,800 lb.), in 1862.

The opium industry in Bengal is completely under the control and monopoly of the Government. The districts producing the narcotic are divided between two agencies—one, the more important, for Behar, and having its head-quarters at Patna; the other, for Benares, at Ghazipur. Within these districts, anyone who chooses may engage in opium-culture, but is under an obligation to sell the produce exclusively to the government agent, at a price fixed beforehand by the latter. This price is approximately 3*s.* 6*d.* a lb., the article being sold by the government at about 11*s.* a lb. The profit realised by the government is thus enormous; but the peasant is well and fully remunerated by the price he receives, and engages in the culture solely of his own free will. The system has been called oppressive, but is really paternal; with greater freedom to the cultivators, probably over-production and less would soon result.

In Malwa, the opium is free-grown, and is of immense importance to the people, giving a value to the land which no other crop can equal. Thus, while wheat and other cereals in the best soil pay 12 *a.*—3 *r.* a *beegah*, land under poppies gives 10–20 *r.* and even 40 *r.*, and in unusually advantageous positions, up to 60 *r.* a *beegah*. The produce is subjected to a heavy duty on entering

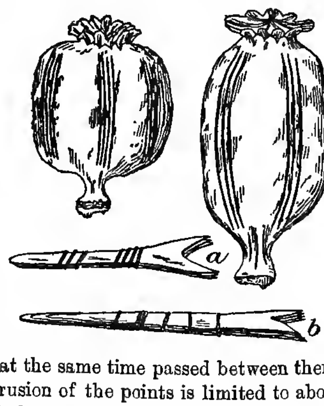
British territory. Formerly, Indore was the only place at which scales were established for levying this duty; but since the opportunity has been afforded of paying duty at Ujjani, Jaora, and Udepur, and the facilities of railway transit from Indore and Ujjani, the export has increased at the rate of 500 chests a month. The product goes to Bombay for shipment. Opium grown in the Bombay Presidency is subject to the same dues as that from Malwa.

The poppy is a delicate plant, and liable to many injuries from wind, hail, and unseasonable rain. Of late years, the Indian plantations have suffered from blight. Moist and fertile soil is indispensable; it was said in 1873 that the ground devoted to poppy-culture in Bengal was becoming impoverished, and that the plants no longer attained their usual proportions. Successful trials have been made of the effect of interchanges of seed between the agencies of Behar and Benares; but the experiments with Persian and Malwa seed resulted in failure.

The cultivation and preparation as conducted in Bengal are as follows:—The lands selected for poppy-culture are usually in the vicinity of villages, where the facilities for manuring and irrigation are greatest. On a rich soil, the cultivators often take a crop of maize or vegetables during the rainy season, and after its removal in September, prepare the ground for the poppies. Elsewhere, the poppy-crop is the only one taken throughout the year, and from the commencement of the rains in June–July, till October, ploughing, weeding and manuring are successively carried on. The final preparation, in October–November, consists in loosening the soil with a plough, and subsequently breaking down the surface to a fine condition by draggiug a heavy log over it. The seed is then sown broad-cast about the 1st–15th November. After 3–4 days, the plough is passed over to bury the seed, and the surface is again levelled by means of a heavy log. It is then divided into square beds, measuriog about 10 ft. each way, and with little channels between for purposes of irrigation. The amount of irrigation necessary depends upon the season: if some heavy showers fall in December–February, two irrigations may suffice; but in a cold season with little or no rain, it may need repetition 5–6 times. The seeds germinate in 10–12 days. After the plants have reached a height of 2–3 in., they are carefully weeded and thinned. In favourable situations, they vegetate luxuriantly, commonly attainiug a stature of 4 ft. About $3\frac{1}{2}$ months are required by the plant in arriving at maturity, the cultivation being restricted to the cold season, November–March. During growth, the plant has to contend with several enemies. It may be nipped by unusually severe frosts, or may be stunted through the failure of the first sowings, or through great heat and deficient moisture. The roots of many plants are attacked by a vegetable parasite, a species of broom-rape called *tokra* (*Orobanche indica*). Another fatal disease, termed *murka*, is attributed to an infusorial worm, which corrodes the tender roots. *Khurka* is a kind of blight arising from sudden excessive damp.

Towards the middle of February, when the plant is in full flower, and just before the time for the fall of the petals, these are carefully collected. They are then formed into circular cakes, 10–14 in. in diameter and $\frac{1}{16}$ in. in thickness, in the following manner:—A circular shallow earthen or iron vessel is heated by inversion over a slow fire. A few petals are then spread upon its heated convex surface, and as soon as their glutinous juice exudes, others are added to the moist surface, and pressed down by means of a cloth. This process is repeated with more layers, until the cake has reached the desired dimensions. These cakes of petals, technically known as "leaves," on reaching the opium factory, are sorted into three classes, according to size and colour. The small and dark-coloured "leaves" are used in forming the inner portions of the shells of the opium cakes, while the largest and least discoloured are reserved for the outside coverings.

999.



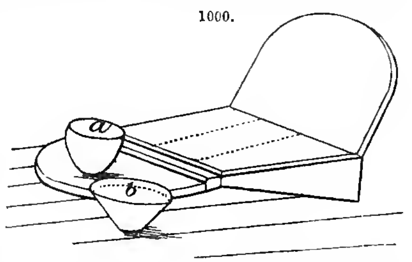
A few days after removing the petals, the poppy-heads or capsules are fully developed, and the collecting of the opium commences, lasting in Behar from 20th February to 25th March, in Malwa, March–April. The scarification of the capsules takes place at 3–4 p.m., and is performed by means of *nushturs*, bunches of (3–5) forked blades, about 6 iu. long, and increasing from $\frac{1}{4}$ in. wide at the handle-end, to 1 iu. at the blade (Fig. 999). The sides of the fork are sharpened and slightly curved. The blades are bound together with cotton thread, which is at the same time passed between them, so as to separate the cutting-ends by about $\frac{1}{16}$ in. The protrusion of the points is limited to about $\frac{1}{12}$ in., which thus determines the depth of the incision. Only one set of points is used at a time, and the incisions are made vertically, from base to summit, usually along the eminences on the outside of the capsule, which mark the attachment of the internal dissepiments. This is supposed to be the most effective way of scarifying; but in some parts of Bengal, horizontal incisions are adopted, as in Asia Minor. The number of incisions (2–6) varies with the size of the capsule, and

2–3 days are allowed to alternate. A little milky-white juice exudes almost immediately, and quickly becomes coated with a slight pellicle, from the solar heat. The exudation, evaporation, and inspissation of the juice continue throughout the night, and are affected by the same causes as elsewhere, already noted. The collection of the juice takes place early on the morning following the scarification. In Bengal, it is performed by a small sheet-iron scoop (*seetoah*), which is twice drawn briskly upwards over each incision, and is occasionally emptied into an earthen vessel carried for the purpose. In Malwa, a flat scraper is used; attached to the upper part of the blade, is a small piece of cotton soaked in linseed-oil, with which the thumb and the edge of the scraper are occasionally smeared, to prevent adhesion of the juice. This lowers its quality. A still worse practice is the use of water for the same purpose.

The stems and leaves of the poppies are left standing after the removal of the seeds and capsules, till perfectly dried by the hot winds of April-May, when they are gathered, and crushed into a coarse powder, termed "poppy-trash," used in packing the opium cakes. The collected juice, as brought home, consists of a wet, granular, pinkish mass, beneath which collects a dark coffee-like fluid, termed *pasewa* or *pussewah*. The whole is placed in a shallow earthen dish, tilted so that all the *pasewa* may drain off, for the latter injures the physical qualities of the opium, causing it to look black and liquid, while it gives the drug an artificially high assay when tested by evaporation. It is set aside in a covered vessel until taken to the factory. Meantime the more consistent portion, forming the opium proper, is exposed to the air in the shade, and regularly turned over, in order to ensure its thorough desiccation. This is continued for 3–4 weeks, or until it has reached within a few degrees of the standard consistence, which, in Benares, is a residue of 70 per cent. after evaporation at 93½° (200° F.). The price paid to the cultivator for his opium is regulated by this standard. On reaching the factory, it is turned out of the pots, and weighed in wide tin vessels (*tagars*) in quantities not exceeding 20 lb. It is then examined by a native expert (*purkhea*) as to impurities, colour, texture, fracture, aroma, and consistence; and a weighed sample is evaporated to dryness in a plate on a metallic surface heated by steam, for final determination of the value. The grosser adulterations are mud, sand, powdered charcoal, soot, cow-dung, powdered poppy-petals, and various powdered seeds. All these are physically discoverable by breaking up the drug in cold water. Flour, potato-flour, *ghee*, and *goor* (crude date-sugar), are often used; their presence is revealed by the odour and consistence they impart. Many vegetable juices, extracts, pulps, and colouring matters are occasionally added, e. g. the inspissated juice of the prickly pear, extracts from tobacco, stramonium, and hemp, gummy exudations, pulp of the tamarind and bael-fruit, and catechu, turmeric, and mowha flowers. The examination of the drug in a physical manner for the detection of these impurities is the only kind necessary, as the commercial criterions of its excellence are colour, aroma, and texture; the intrinsic value, i. e. the proportion of narcotic alkaloids present, is less regarded by the buyer.

When weighed into store, the opium is kept in large wooden boxes, holding about 10 cwt.; if below the standard, it is occasionally stirred up, to favour its thickening; and if very low, is placed in shallow wooden drawers, and constantly turned over. Whilst keeping, it becomes coated with a thin blackish crust, and deepens in colour according to the degree of exposure to air and light. From this general store (*malkhana*), it is taken daily, in quantities of about 250 *maunds* (of 82$\frac{2}{7}$ lb.), for manufacture into "cakes." Various portions are selected (by test assay) so as to ensure the mass being of the standard consistence, and these, weighing exactly 10 *seers* (21 lb.) each, are thrown promiscuously into shallow drawers, and rapidly and thoroughly kneaded up together. The mass is filled into boxes, all of one size, from each of which a specimen is drawn and assayed. The mean is taken as the average. Before evening, these boxes are emptied into wooden vats, 20 ft. long, 3½ ft. wide, and 1¼ ft. deep, and the opium is further kneaded and mixed by men wading knee-deep through it from end to end, till the consistence appears uniform.

1000.



Next morning the manufacture of the cakes commences. Each cake-maker sits on a wooden stand, and is provided with a brass cup and a graduated tin vessel (Fig. 1000). The "leaves" for forming the shells of the cakes are weighed out over-night, tied in bundles, and damped to make them supple; and boxes are provided containing *lewa*, for agglutinating the "leaves" to form the shells of the cakes. This *lewa* consists of an admixture of inferior opium, *pasewa*, and the washings of vessels that have contained good opium, forming a semi-fluid paste of such a consistence that 100 gr. evaporated to dryness at 93½° (200° F.) leave 53 gr. residue. The *lewa*, "leaves," and opium are accurately weighed out for each cake. In his brass cup, the operator rapidly forms the lower segment of the shell of the cake, pasting "leaf" over "leaf," till a thickness of ½ in. is reached, and allowing a certain free portion of the most external "leaves" to hang down around and over the sides of the cup. The cake of opium brought from the scales is now inserted, and held away from the sides with the left hand, while one "leaf" after another is tucked in, well smeared with *lewa*, and imbricated one over the other, till the circle is complete. The free portions of the "leaves" left hanging over are drawn up tightly, and the opium cake is well compressed within the casing. A small aperture remains at the top; this is closed by adding more "leaves," and finally the cake is completed by applying a single large "leaf" to the entire exposed half. The finished ball or "cake" resembles a Dutch cheese in size and shape. It is rolled in a little finely powdered poppy-trash, which adheres to its surface, is at once placed in a small earthen cup of the same dimensions as the brass cup used in shaping it, and is carried out and exposed in small dishes to the sun. It is so exposed for three days, and is meantime constantly turned and examined; should it become distended, it is opened to liberate the gas, and again tightly closed. On the third evening, still in their earthen cups, the cakes are placed on the "frames,"—open battens allowing free circulation of air. The operation thus far is terminated by the end of July. The constituents of the average perfect cake are :—

Standard opium	1 *seer* 7·50 *chittaks.*	
Lewa	3·75 „	
"Leaves" (poppy petals)	5·43 „	
Poppy-trash	0·50 „	
	2 *seers* 1·18 *chittaks*	= 4 lb. 3½ oz.

The number of cakes made by one man in a single day is about 70, though some can turn out 90–100. After manufacture, the cakes require much attention, and constant turning, on account of the mildew which attacks them. This is removed by rolling and rubbing in dry poppy-trash. Weak places are also looked for, and strengthened with extra "leaves." By October, the cakes are perfectly dry to the touch, and fairly solid; they are then packed in chests, furnished with a double tier of wooden partitions, each tier with twenty square compartments for the reception of so many cakes, which latter are steadied and packed around with loose poppy-trash. The chests must be most carefully kept from damp for a length of time; but ultimately the opium in the cake ceases to yield any more moisture to the shell, and the latter acquires extreme solidity. Each case contains 120 *catties* (about 160 lb.). The foregoing remarks refer exclusively to the Government-prepared opium for the Chinese market, which includes the great bulk of the entire product.

Bengal opium intended for internal consumption, and known as *abkari* opium, is prepared in the following manner :—It is inspissated by exposure to direct sun-heat till its standard is 90 per cent., and its consistence resembles wax. It is then moulded into square bricks weighing 1 *seer* each, which are wrapped in oiled Nepal paper, and packed in boxes furnished with compartments for their reception. Put up in this way, it has not the powerful aroma of the "cake" drug, but it is more concentrated, and more easily packed. It is sometimes also made into flat square tablets.

In Malwa, the cultivation and preparation of the drug are entirely in the hands of the natives. The details of cultivation are much the same as in Bengal; not so the preparation. The crude exudation (*chick*), as collected, is thrown into an earthen vessel, and covered with linseed-oil (2 parts oil to 1 part *chick*), to prevent evaporation. In this state, it is sold to itinerant dealers. Quantities of 25–50 lb. are tied up in double bags of sheeting, which are suspended from the ceilings, out of the light and draught, while the excess of oil drips through. This operation terminates in 7–10 days, but the bags are left for 4–6 weeks, by which time the oil that has not escaped has become oxidized and thickened. The whole process lasts from April till June–July, when the rains begin. The bags are then taken down, and their contents are emptied into shallow vats, 10–15 ft. across and 6–8 in. deep. Here the drug is worked up with the hands for 5–6 hours, until its colour and consistence are uniform, and its toughness enables it to be formed into balls of 8–10 oz. These, as formed, are thrown into a basket containing chaff of the seed-pods. They are then rolled in leaves and stalks of the poppy, left there for a week or so, and turned over occasionally till hard enough to bear packing. In October–November they are weighed, sent to market, and packed in chests, about 150 balls in each, the weight of each chest being as nearly as possible 1 *picul* (133⅓ lb.). The petals and leaves of the plant are used in packing the balls in the cases, but are not formed into "leaves" for enveloping the balls as in Bengal. The quality of Malwa opium is very uncertain, and much inferior to the Government-prepared article. The production is said to be about 20,000 chests annually.

The exportations of opium from India during the last quarter of a century, divided into quinquennial periods, have been as follows :—1854–5 to 1858–9, 74,239 chests annual average, 7,884,611*l.* average aggregate value (106*l.* a chest); 1859–60 to 1863–4, 68,119 chests, 10,608,648*l.* (156*l.* a chest); 1864–5 to 1868–9, 81,976 chests, 10,898,542*l.* (133*l.* a chest); 1869–70 to 1873–4, 87,840 chests, 11,722,111*l.* (133*l.* a chest); 1874–5 to 1878–9, 92,797 chests, 12,175,696*l.* (131*l.* a chest). The lowest aggregate value reached during this period was 6,200,871*l.* in 1855–6, the quantity being 70,626 chests. The highest aggregate was 13,365,228*l.* in 1871–2, being 93,364 chests. The figures for 1878–9 were 91,200 chests, 12,993,979*l.*, being a decrease caused by deficient crops in Malwa. The export trade is pretty equally divided between Bombay and Calcutta, and is mostly in Jews' hands in both places. The bulk goes to Hong Kong, and the largest proportion of the remainder to Singapore. The exports in 1880 were 144,638 cwt.; of this, 59,633 chests went to Hong Kong, 35,202 to the treaty ports, and 10,586 to Singapore.

In China.—The kind of poppy grown in China seems to be the same as that cultivated in Persia and India—*P. somniferum* var. *γ. album* (*P. officinale*). Though the production of Chinese opium is now considerable, and is, moreover, increasing in a very rapid manner, the chief interest concerning the drug in China has hitherto been centred upon its consumption. The inhabitants of that empire consume not only the whole quantity produced within their own boundaries, but are also customers for about 90 per cent. of the total Indian crop, besides drawing considerable supplies from Asia Minor and Persia. It is computed that 30 per cent. of the native male population throughout China are addicted to the use of the narcotic, and in the opium-producing districts, the proportion is increased to 50 per cent. Few moderate smokers consume more than 1½ lb. in a year, while occasional smokers do not take more than 1 oz. or so. The most immoderate scarcely require more than 4 lb., so that the approximate average all round may be taken at about ½ lb. a head for all classes of smokers. The native production is estimated at about 5,000,000 lb. annually, and the excess demand is supplied by importations of about 12,000,000 lb. This being so, the flourishing success of the opium industry in India, &c., may be said to depend absolutely upon the maintenance of the trade with China, and this again upon the conditions governing the extent to which the Chinese may or can become their own producers. This subject will receive attention presently. It will be convenient first to consider the modes of cultivating the poppy and preparing its narcotic, as practised by the Chinese, so far as they are known.

In the northern provinces, the cultivation of the poppy requires the richest soil and the utmost care. The plant can be successfully raised only on the terraced slopes, or on the most fertile bottom-land, which allows of thorough irrigation, and which is adapted for the cultivation of wheat and garden-stuffs. In the southern and central provinces, on the other hand, the soil is so rich and fertile that the most suitable lands for poppy-culture are the terraced hill-sides, where the effects of the heavy rains are less felt than in the lowlands. The seed is sown during November. The blossoms appear in April, and mature within a month, thus leaving the ground free for a summer crop. Before the poppies have seeded, an intermediate crop of wheat, maize, cotton or tobacco is put in, the poppy-stalks being cleared off in time to avoid interference with the up-coming shoots. The yield is very uncertain and quite dependent upon the weather, 1 *man* (say ⅙ acre) will give a value of 6–11 *taels* (of 5*s.* 10*d.*), according to the season, which is a much higher return than can be got from any other crop. For the collection of the opium, the heads are incised, much the same as in India, by a three-bladed lance, in a series of 3–5 vertical wounds, and the exuded juice is scraped off, and transferred to a small pot hanging at the waist. Of the subsequent manipulation for the market, little is known, beyond the fact that it is usually sun-dried to a certain consistence, and either mixed with the imported drug, or adulterated with liquorice, inspissated sesamum-juice, &c.; sometimes it undergoes both operations.

In entering upon a consideration of the circumstances surrounding the present and future prospects of the opium trade with China, the order most readily followed by the reader will perhaps be that of the Treaty Ports where the trade is carried on, commencing with the southernmost:—

(1) Kiungchow Foo, in the island of Hainan, province of Kwangtung.—The imports in 1876 were 520 *piculs* (of 133⅓ lb.), value 65,050*l.* In 1877, they were as follows:—Malwa, 320 *piculs*, 48,667*l.*; Patna, 388 *piculs*, 51,013*l.*; Benares, 16½ *piculs*, 2091*l.* And in 1878: Malwa, 242½ *piculs*, 42,795*l.*; Patna, 731 *piculs*, 95,985*l.*; Benares, 47 *piculs*, 6125*l.* In 1879, the imports were:—Malwa, 98¼ *piculs*, 18,409*l.*; Patna, 992½, 133,300*l.*; Benares, 27, 3414*l.*; total, 1117, 155,123*l.* The chief feature is the increase of Patna at the expense of Malwa, mainly due to difference in price. The Hainanese have not acquired a taste for Benares, which is used only by emigrants returning from the Straits Settlements. The increase observable in the figures quoted does not imply a greater consumption, but a larger proportion brought by steamer. The total importation from Hong Kong is estimated at 1200 *piculs* yearly for distribution over the north of the island and the southern coast of Leichow. The southern and eastern portions of the island draw their supplies from Singapore; the quantity cannot be estimated. As yet, no Yunnan, Kweichow, nor Szechuan opium has reached Hainan.

(2) Pakhoi, province of Kwangtung.—The only kind of Indian opium imported is Benares, of which the annual receipt is 300–400 chests. Native opium grown in the neighbouring (western) province of Yunnan is for sale, but is little used; its price is about ⅔–¾ that of Indian. Kwangse province, intervening, consumes very little Indian, drawing its principal supplies from Yunnan, and growing some itself. The flavour of the native drug has such a hold, that it will hardly be deserted for the dearer foreign article.

(3) Canton, province of Kwangtung.—The opium imported here in foreign vessels is very small, the needs of the city and district being supplied through Swatow, where the taxation is much less. The foreign imports in 1876 were:—Malwa, 239 *piculs*; Patna, 211 *piculs*; and in 1877, 121¾, and 202¼ respectively. During the past few years, the consumption of Yunnan, Kweichow, and Szechuan native opium has largely increased here. In 1878, the imports of Patna increased to 671½ *piculs*, mainly owing to the levying of a tax on all opium prepared in the prefecture of Kwangchow, and which is not expected to survive long. Still, in 1879, the imports of Patna increased to 1134¾ *piculs*, while Malwa fell to 58¾; the latter will probably soon disappear altogether from the Returns.

(4) Taiwan, island of Formosa, province of Fuhkeen (Fokien).—Opium is not grown, nor is Chinese opium much used here. The few lb. of the latter occasionally brought from Wenchow scarcely find purchasers. The imports and re-exports (in *piculs* of 133⅓ lb.) of foreign opium here for the years 1869–79 are shown (omitting fractions) in the annexed table:—

Years.	Imports.						Total Re-Exports.	Nett Total Imports.
	Benares.	Patna.	Persian.	Malwa.	Turkey.	Total.		
1869	1038	161	342	..	..	1541	8	1533
1870	1259	102	372	..	..	1733	2	1731
1871	1342	232	438	2	12	2026	53	1973
1872	1203	372	417	..	..	1993	52	1941
1873	1370	341	296	9	..	2016	64	1952
1874	1414	730	502	..	..	2645	142	2503
1875	1547	354	752	6	2	2661	61	2600
1876	1403	370	803	117	1	2693	35	2658
1877	1721	177	1325	9	2	3233	65	3168
1878	1480	38	1435	20	85	3059	206	2853
1879	1884	86	1331	71	138	3510	123	3387

The main features of this table are the enormous increase in Persian, and the decline in Malwa and Patna. The Persian is in great favour with the poor and hard-working colonists, and is largely imported for land transport to the north of the island, where the taxation is much heavier. Even Benares seems in danger of being driven out by Persian. Patna and Malwa will probably soon vanish from the returns, while Turkey shows a tendency to grow.

(5) Tamsui and Kelung, island of Formosa, province of Fuhkeen (Fokien).—The poppy is now grown near Oulan, on the seaboard to the south, and at two inland places, near the Tokoham river, within about 30 miles of Tamsui; the production is quite inconsiderable, and the consumption principally local. But there is a large consumption of native opium, grown partly in Szechuan and Yunnan, and partly in the neighbourhood of Ningpo and in the provinces of Chekiang and Fuhkeen. It would seem that the largest quantities come from Ningpo and Chinchew, the inland produce arriving entirely from the former. The proportion of this article as compared with foreign is said to be as 1 is to 5, so that the total imports of native opium in 1877 may have been 400 *piculs* (of 133⅓ lb.). There is thus a large (and increasing) consumption of the native drug; but its harshness, disagreeable flavour, and deficiency in strength cause its use alone (unmixed) to be confined to the poorest and lowest classes. The native article occurs in three qualities, two of which even the poorer people will not smoke unmixed. The proportions of admixture with Indian opium vary in different localities: at Bangka, and the larger towns on the W. side of the island, the usual ratio is 1 part native to 6 parts Indian; at Suao, and on the E. coast generally, half of each is adopted by the better classes, while for the lower classes, the proportion of native is probably greater. The annexed table shows the imports of foreign opium (in *piculs* of 133⅓ lb., neglecting fractions) in the years 1873–9:—

Description.	1873.	1874.	1875.	1876.	1877.	1878.	1879.
Benares	1404	1260	1194	1440	1408	1398	1799
Malwa	3	..	..	9	1	..	..
Patna	109	286	105	115	72	25	25
Persian	191	158	271	284	455	514	314
Turkey	..	..	8	13	..	12	26
Total..	1708	1706	1579	1862	1937	1949	2164

From this, it will be seen that the consumption of foreign opium is increasing; at the same time, will be noticed the decrease in Indian, and rapid increase in Persian. This latter is largely used alone, and also in admixture with Indian, on the score of economy. It is not considered likely that Persian will ever supplant Indian entirely; but its consumption may be expected to increase in a higher ratio for some time to come.

(6) Amoy, province of Fuhkeen (Fokien).—The poppy is cultivated in the neighbourhood; but the production of native opium does not as yet seem to affect the foreign importations, as the imperfect system adopted in its preparation renders it far inferior in quality and flavour. The nearest native opium gardens are just outside the district city of Tung-ngan. The crop is sown yearly in December–January, and gathered in early April. The yield of the harvest gathered in 1879 was 221 *piculs*, which was all consumed in the vicinity, except some 10–20 *piculs* that reached Amoy without paying *li-kin*. In 1878, 1 *picul* of Szechuan opium, value 87*l.* was imported and re-exported. The imports and re-exports of foreign opiums in the same year, stated in *piculs* of 133⅓ lb. were as follows: Patna: imports, 2113¼; re-exports, 386½; Benares: imports, 3092½; re-exports, 1613; Malwa: imports, 1; Persian: imports, 965¾; re-exports, 636; Turkey: imports, 74¾; re-exports, 26; total: imports, 6247·15 *piculs*, value 957,285*l.*; re-exports, 2661·21 *piculs*, value, 276,819*l.* In 1879, the imports were:—Patna, 279,360 lb., 199,632*l.*; Benares, 608,480 lb., 422,751*l.*; Persian, 99,179 lb., 81,688*l.*; Turkey, 2993 lb., 2462*l.*; total, 990,012 lb., 706,033*l.* The re-exportation is almost entirely to Formosa, which trade is being gradually assumed by Hong Kong. The import trade is still chiefly in European hands, but is passing into Chinese.

(7) Foochow (Fuh-chow-Foo), province of Fuhkeen (Fokien).—The growth of the poppy is slowly but steadily increasing in the districts of Fuh-tsing, Fuh-ngan, and Tung-ngan. The production of opium is small as yet, and chiefly for local needs; in Fuh-tsing, it does not exceed 6 *piculs* (of 133⅓ lb.) yearly; in Fuh-ngan, about 10; and in Tung-ngan, 4. It is used in admixture with the stronger Indian drug, and its consumption is almost confined to the poorest classes. The native opium that finds its way into Foochow and the immediate neighbourhood comes from Wenchow and Tai-chow, in the adjoining province of Chekiang. The production there is said to amount to 2000 *piculs* yearly, but there is nothing to shew what proportion reaches Foochow. The wealthier classes are likely to continue the use of the Indian drug, from force of habit, and preference for the superior article; but the native drug being much cheaper, easier to get, and less potent, will increase in favour with the remaining population. Hitherto, the commerce in Indian opium has not been seriously affected by the competition of the native product. The imports of Malwa were 2506 *piculs* in 1876, 1855⅓ in 1877, and 1479⅓ in 1878; of Patna, 1587½ in 1876, 1320½ in 1877, and 1725½ in 1878; of Benares, 141½ in 1876, 187¼ in 1877, and a little more in 1878. The import of Persian in 1878 showed an increase of 628 *piculs* over the figure for 1877. The figures for 1879 are:—Malwa, 1609½ *piculs*; Patna, 1768¾; Benares, 375½; Persian, 519. The native drug consumed was estimated at about 1000 *piculs*.

(8) Kewkeang (Kiukiang), province of Keangse.—A little native opium is produced in the centre of the province, about Kianfu, and is all consumed locally. The consumption of Szechuen native opium in this province seems to be limited to about a dozen chests annually. The annexed table shows the comparative imports (in *piculs* of 133⅓ lb.) of foreign opiums in the years 1868–78.

	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.	1879.
Malwa ..	1910½	1895	2077½	2047½	1919¼	2349½	2889½	2231½	2037	1845	1475	1960
Patna ..	12	8½	6	8¼	13¼	16¾	15½	8½	4¾	4¾	8¼	6
Benares } Persian }	1	2	27	8	2	..	..	6	1	1¼ 1	.. 170	.. 204
Total	1923½	1905½	2110½	2063¾	1934½	2366¼	2905	2246	2042¾	1852	1653¼	2170

The diminution in total is due to the competition of neighbouring ports where the duties are less, rather than to reduced consumption in the province. The striking increase in Persian is ascribed to its low price.

(9) Wenchow, province of Chekeang.—Large districts are under poppy-culture in this province. The production of native opium in the Wenchow and Taichow prefectures in 1877–8 was:—Taichow prefecture, 1500 *piculs*; Wenchow prefecture: Yungchiachan, 600; Pingyang, 350; Yoching, 350; Hsichi, 400; Nanchi, 300; Massu, 700; grand total, 4200 *piculs*. In 1878–9, about 20 per cent. more land was planted, and the season was so favourable that the crop was expected to reach 8000 *piculs*. The native opium is used in and about the producing districts in an almost liquid state when exposed to the air; after keeping for a time, it dries up considerably, and loses as much as 35 per cent. by weight. It is said to possess little more than half the strength of Indian; but is more easily prepared, and much cheaper. Its liability to lose greatly in weight is likely to confine its use principally to the producing districts. Abundant crops and correspondingly low prices will

cause it to be largely consumed in admixture with Indian. The product supplies a great part of the adjoining province of Fuhkeen (Fokien), and is taken also to Formosa, Shanghai, &c. The direct importation of Indian opium here is much crippled by the competition of Ningpo and Shanghai. In 1878, it amounted to 3 *piculs* of Malwa and 11 of Patna; yet the consumption in the town alone was 50 chests Malwa, and 90 chests Patna. In 1879, the recorded imports of Patna were 57½ *piculs*.

(10) Ningpo, province of Chekeang.—The native drug from the Wenchow and Taichow prefectures is brought to this city in a fluid state, in small earthen jars containing 2–4 lb., and a market for its sale is held at stated periods at one of the city gates. The export through this city of native opium produced in those portions of the provinces of Anhui (Gan-hwuy) and Kiangsu north of the Yangtse-kiang, is on the increase. In 1879, some 300,000–400,000 lb. of native opium came on the market, but this is probably less than half the total product of the province. Indian opium will always be preferred by those who can afford it; but Persian and other cheaper kinds are expected to almost monopolize the market in the near future, unless the prices of Indian are much reduced. The nett imports of foreign opiums (in *piculs* of 133⅓ lb.) in 1877, 1878, and 1879 respectively, were as follows:—Malwa, 7642, 6518, 6768; Patna, 204, 400, 486; Benares, 183, 170, 302; Persian, 30, 163, 94.

(11) Hankow, province of Hoopih (Hupeh).—Native opium is largely used in this province. It comes chiefly from Szechuen, but the Yunnan article is considered superior. The dealers from Shansi province visiting Hankow smoke Yunnan opium, and take it home with them, as in Shansi and Kansuh provinces poppy-culture is now prohibited. The quantities (in *piculs* of 133⅓ lb.) of the native product (*a*) imported and (*b*) re-exported, on which taxes were paid, were as follows:—1875, *a* 1600¼, *b* 893½; 1876, *a* 2888, *b* 1696½; 1877, *a* 1684½, *b* 1108; 1878, *a* 2531, *b* 881. The imports of foreign opiums (*a*, Malwa; *b*, Patna and other kinds), in *piculs* of 133⅓ lb. for a series of years have been as follows:—1867, *a* 4072, *b* 169; 1868, *a* 2770, *b* 99; 1869, *a* 3415, *b* 193; 1870, *a* 3473, *b* 206; 1871, *a* 2988, *b* 156; 1872, *a* 2285, *b* 115; 1873, *a* 2811, *b* 162; 1874, *a* 2717, *b* 133; 1875, *a* 2160 *b* 158; 1876, *a* 2017, *b* 172; 1877, *a* 2274, *b* 201; 1878, *a* 1905, *b* 218½. In 1879, the imports of foreign were:—Malwa, 2678½ *piculs*, 403,534*l.*; Patna, 579¼, 66,611*l.*; Persian, 36, 3281*l.* The exports of native were 120 *piculs*, 6528*l.*

(12) Ichang, province of Hoopih (Hupeh).—The poppy is cultivated in this province, and a district called Chiao-t'u has a local reputation for its opium, to which it gives its name; but the chief consumption is of the Yunnan drug. Nevertheless, native officials admit that 2000 *piculs* are produced annually in the province, chiefly in the hilly country about Patung. Foreign opium is yet scarcely known, and does not figure at all in the official Returns, though it is occasionally smuggled.

(13) Shanghai, province of Kiangsu (Keangsoo).—In 1877, the local consumption of native Szechuen opium was estimated at above 200 *piculs* a month; in 1878, not more than 20 *piculs* monthly were imported. The yield of the Szechuen crop in 1878 was placed at 50,000 *piculs*, and of the Yunnan at 15,000. Formerly, the northern province of Shensi (Shanse) was reckoned to afford 30 per cent. of the total native product, but since the famine, poppy-cultivation has been somewhat rigidly prohibited in Shensi, Honan, and Chihli. The Shensi drug was esteemed the best, having a flavour resembling Patna, and giving 85–90 per cent. on boiling. Yunnan is classed second, and Szechuen third. It is broadly estimated that about half the Yunnan product is consumed locally, and that the other half is exported to and through the adjacent provinces of Kwangtung, Kwangse, and Kweichow. Of the Szechuen crop, about 25 per cent. is kept for local consumption, 40 per cent. goes to the northern provinces, and 35 per cent. is disposed of to the provinces watered by the Yeangtse-kiang. The imports of native opium into Shanghai in 1878 were 798 *piculs* of Szechuen, and 0·69 *piculs* of "prepared." The re-exports were 35¾ *piculs* of "husk" (to Chinese ports), 65 *piculs* of Szechuen (total), and 1½ *piculs* "prepared" (to Chinese ports).

The commerce in foreign opiums at this port in the years 1878 and 1879 is shown in the annexed tables. The imports (in *piculs* of 133⅓ lb.) were as follows:—

	From foreign countries.		From Hong Kong and Chinese ports.		Total nett after deducting re-exports.	
	1878.	1879.	1878.	1879.	1878.	1879.
Malwa	28,020	32,500	875	1,453½	1,803	1,794
Patna	10,208½	12,174½	63½	107	8,525	9,454¾
Benares	6,435½	7,633¼	62½	5	5,157½	5,572¾
Persian	1,679½	2,321¼	267	221	178⅓	218¼
Turkey	21¼	..	1	..	21	..

The re-exports and their destinations in 1878 were as follows:—

	Newchwang.	Tientsin.	Chefoo.	Hankow.	Kewkeang.	Wuhu.	Chinkiang.	Ningpo.	Wenchow.	Foochow.	Hong Kong.	Total.
Malwa	783	3381½	3456½	1833	1594	2279½	8768½	4723½	11	241½	20	27,092
Patna	54	225½	44½	224½	8½	3½	747½	400¾	8½	30	..	1,747¼
Benares ..	36	34¾	140½	1½	..	..	936	192	..	..	..	1,340¾
Persian	53	397	111	33	177	53	664	190½	..	5	76¾	1,760¼
Turkey	..	..	..	..	..	..	..	1	..	..	¼	1¼

There was a further re-exportation of 8 *piculs* of Persian to Loudon. The Persian opium in the Shanghai market is competing most successfully with Indian, not for local consumption, but for re-export chiefly to Chinkiang and Tientsin. In consistence and flavour, it much resembles Malwa. The parcels of it imported in 1877 were adulterated with sugar, &c., and of irregular shape; but in 1878, a marked improvement took place both in manipulation and purity. The imports of native opium in 1879 were 117½ *piculs* of Szechuen, and 1½ of prepared.

(14) Chinkiang, province of Kiangsu (Keangsoo).—This port ranks next to Shanghai in the importance of its opium-trade, and takes about $\frac{1}{7}$ of the whole foreign opium sent to China. The imports of native opium here were 48 *piculs* in 1877, and 76 in 1878. In the latter year, the price advanced, in consequence of poppy-culture being prohibited in Hsuchow, and other places. The importations of foreign opiums (in *piculs* of 133⅓ lb.) in 1877, 1878, and 1879 respectively, were as follows:—Malwa, 9782, 8639, 8144; Patna, 506, 737, 875; Benares, 479, 936, 1357; Persian, 32, 645, 721; totals, 10,709, 10,957, 11,097. The totals for the three previous years were 10,964, 11,758, and 10,649. Malwa is rapidly giving way to Persian, the latter being so much cheaper—25–40 per cent. The native opium imported through the foreign custom-house in 1879 amounted to 19 *piculs*.

(15) Chefoo, province of Shantung.—The poppy is cultivated in the Tsaochow department; but the yield of opium is small, and none seems to be exported. The trade in foreign opiums at this port is much influenced by the native crops in the provinces of Shensi and Shingking (Liaotung). The culture of the poppy is prohibited here, but in regard to the latter, the prohibition has always been a dead letter. In Shensi, it has been at least partially enforced since the famines, and considerably lessened production in Shantung, Shensi, and Honan provinces may be expected for some years to come. The competition of the native article caused a decrease in the importations of foreign from 565,137 lb. in 1872, to 326,037 lb. in 1877. In 1878, the native Shingking (Liaotung) crop failed, and this, combined with the partial enforcement of the prohibition in Shensi, caused a great recovery in the foreign trade, the imports for that year reaching 505,618 lb. In 1879, the prohibitions against native opium-growing were more rigidly enforced, yet the consumption of foreign suffered a decline; the total foreign nett import was 471,566 lb., contributed thus—Malwa, 2996½ *piculs*; Patna, 50½; Benares, 330½; Persian, 159. The great increase in Persian is the most notable feature.

(16) Tientsin, province of Chihli.—The trade here is similarly affected by the native production. The Peking consumption consists of about $\frac{7}{10}$ Malwa, and $\frac{3}{10}$ native, the latter chiefly from Honan, Szechuen and Yunnan provinces. Honan, in 1877, only yielded about 30 per cent. of this, while in 1876, its production was 50 per cent., and the price was about 25 per cent. less. The nett import of Malwa opium in 1877 was 3769 *piculs*, and Bengal and other varieties brought the total of foreign to 4034 *piculs*, showing an increase on the previous year of 323 *piculs* in Malwa, 14 in Benares, and 37 in Persian. This rise was due to exceptional circumstances, and the figures cannot be maintained when Honan resumes the culture. Peking alone consumed 1800 *piculs* of Indian opium in 1877, one-third of which was smuggled in. The duties on foreign brands are just about double those on native. The nett imports of foreign in 1878 and 1879 respectively (in *piculs*) were:—Malwa, 3530½, 4189½; Patna, 164¼, 373¼; Benares, 21½, 66; Persian, 291, 553. In addition, 280 of Malwa, 6 of Patna, and 61 of Persian, were re-exported. The growth in Persian is remarkable; it is almost entirely used for adulterating Malwa, being mixed with it to the extent of 30 per cent.

(17) Newchwang, province of Shingking (Liaotung).—The production of native opium in many of the districts northward and eastward of this port is rapidly increasing. In the immediate neighbourhood of Newchwang, and from Naichow all round the coast, the poppy is grown only in gardens, and for domestic use. The soil is stony and unsuited, and the greater part of the native opium there consumed is brought from inland districts. But the culture is so general in most parts of the province of Fengtien, that it is said to occupy 80 per cent. of the total agricultural area. In many parts of the provinces of Kirin (Girin) and Tsitsikhar (Tsi-Tsi-Har), in E. Mongolia, notably and

for a long time past in the district lying on the right bank of the Sungari, in the angle formed by the reaches of that river, above and below its junction with the Nonni, E. and S.-E. of Petuna (Bodune), a daily increasing production is taking place. In Russian Mandchuria, in the strip of country lying on the sea-board between the Amur and Corea, the poppy is not grown, and no opium is admitted into that territory. The large and increasing production in the districts named, whither numbers of Chinese colonists had emigrated with the sole object of poppy-growing, the industry there being altogether free and untaxed, was gradually driving all foreign competitors out of the markets of N. China; but in 1879, official prohibitions were so rigorously enforced in Kirin and Fengtien, that the crop was only $\frac{1}{5}$ of the average. The imports, in *piculs* of $133\frac{1}{3}$ lb., in the four years 1876-9 respectively, were:—Malwa, 2236, 988, 1112, 2141; Patna, 28, 36, 57, 98; Benares, 37, 43, 27, 62; Persian, 2, 31, 25, 151.

There are now two other treaty ports to be taken into account, viz. (18) Wuhu, province of Anhui, and (19) Macao, province of Kwangtung. The imports of foreign opium at the former in 1877, 1878, and 1879 respectively, stated in *piculs*, were:—Malwa, 1157, $2324\frac{1}{2}$, $3036\frac{1}{2}$; Patna, $2\frac{1}{2}$, $2\frac{1}{2}$, $9\frac{1}{2}$; Benares, nil, nil, $2\frac{1}{2}$; Persian, 2, 54, $92\frac{1}{2}$. Almost half the total is consumed in the city itself. No native drug seems to be imported, the Indian being adulterated with Persian. Macao imported 5000 chests of crude Patna in 1878; in 1879, a factory was started for preparing the drug for export to California and Australia, and the future imports will probably increase immensely.

From a review of the foregoing details, it seems that certain Chinese provinces, notably Szechuen, Kweichow, and Yunnan, are serious competitors in the production of opium, while Shensi, Shantung, and N.-E. Mandchuria are rapidly becoming formidable. On the other hand, the increase must be determined by the area of land which can be spared from food-crops for the purpose, and this, judging by the recent famines, cannot be indefinitely great. Moreover, the superiority of the foreign drug is everywhere acknowledged, price being the only bar to its very much wider use. The consumption of the various kinds is curiously marked by distinct zones. Thus along the coast, as far north as the Yangtze-kiang, excluding the neighbourhood of Ningpo, Bengal is chiefly in favour, mostly Patna, but Benares in Fokien and Formosa; to the north and west, including part of Kwangtung, Kwangse, Kiangsi, Anhui, the N.-E. provinces, and Shingking, Malwa is consumed to the almost total exclusion of Bengal; whilst northward and westward again of this line, the native article stands first. Each kind of opium has special characteristics, which commend it to the natives of certain districts. The Bengal drug—Patna and Benares—is considered mild, is well prepared and genuine, is preferred by all refined smokers, and is apparently best suited to the relaxing climate of the southern portions of the empire. Those accustomed to it will not exchange it for other kinds unless compelled to do so; but they will mix inferior sorts with it to reduce the nett cost. Malwa is esteemed strong, fiery, and irritating to the nervous system, being a much cruder drug, yet far inferior to the best native; it is being largely replaced by the local product. This last, the native article, has all the bad qualities of Malwa intensified. The harshness is appreciated by the natives of the colder districts, and in those parts where the Tartar element predominates. As the taste becomes educated, preference is manifested for the superior article; and there is no doubt that, by judicious regulation of the prices, Indian producers can always command a very large market.

In Egypt.—The variety of poppy grown in Egypt is the same as that cultivated in Asia Minor. The production of opium is said to be in the hands of the Government, and to be restricted to the actual requirements of the sanitary establishments. On the other hand, it is openly exported. The cultivation is carried on in Upper Egypt, near Esneh, Kenneh, and Siout, where about 10,000 acres were said to be occupied by it in 1863. The capsules are incised in March, by drawing a knife twice round them transversely; the concreted juice is scraped off next day by a scoop-knife, collected on a leaf, and placed in the sun to harden. With due care, the product is of sufficiently good quality, containing 10–12 per cent. of morphine; but the plants are usually grown in too moist soil, and the scarification is often prematurely performed, and these circumstances combine with wilful adulteration to reduce the morphine to 3–4 per cent. on the average. The drug occurs in European commerce in the form of hard, flattish cakes, about 4 in. in diameter, covered with fragments of poppy leaf, but free from *Rumex* chaff. The fractured surface is finely porous, and dark liver-coloured, and reveals shiny imbedded particles and reddish-yellow points, besides occasional starch granules. In 1872, the United Kingdom imported 9636 lb., value 5023*l.*, of opium from Egypt; in 1879, the values of the total Egyptian exports were—to Italy, 990*l.*; France, 630*l.*; Greece, 540*l.*; Turkey, 150*l.*; total, 2310*l.*

Preparation and Use.—As a narcotic, opium is used one of three ways:—(1) Swallowed in the form of pills, or (2) as a fluid tincture; (3) smoked in pipes. The first practice prevails mostly in Asia Minor and Persia, the second is that usually adopted by Christians who become addicted to it, the third is general among the Chinese, Malays, &c., who consume about $\frac{9}{10}$ of the whole world's production. The Chinese, before smoking the opium, subject it to a process of extraction in water. This is largely done in Hong Kong and in the opium-vessels. The Bengal opium as received is removed from the outer covering of poppy-trash, &c., moistened, and allowed to stand for about 14 hours. It is then placed in shallow pans made of some copper alloy, built into furnaces, and heated by charcoal fires; 2½ cakes of opium and 10 pints of water go into each pan, being boiled and occasionally stirred till a uniform thin paste is produced, occupying 5–6 hours. This paste is transferred to a larger pan, and the bulk is made up to 3 gal. by adding cold water; it is covered, and left for 14-15 hours. A bunch of vegetable pith used for lamp-wick is then inserted into the mass, the pan is tipped, and a rich, clear, brown fluid is drawn off and filtered through bamboo paper. The residue is put on a calico filter, and thoroughly washed with boiling water, the wash-water being reboiled and repeatedly used. The last washing is done with pure water, and all the washings are used for the next day's boiling. The residues are transferred from the calico filters to a larger one, and are well pressed; the insoluble residue, called *nai chai* ("opium dirt"), is mostly sent to Canton, where it is used in the manufacture of inferior "prepared" opium. The filtrate or opium solution is evaporated at the boiling point, with occasional stirring, till of the proper consistence, requiring 3-4 hours. It is then removed from the fire, and stirred vigorously till cold, the cooling being hastened by fanning; when cold, it has the consistence of thin treacly extract, and is known as "prepared" or "boiled" opium. It is kept for some months before acquiring prime condition, and is then sent out sealed up in small pots.

The Chinese recognise four grades of opium:—(1) The "raw" as imported; (2) "prepared," as just described; (3) "dirt," the insoluble residue after exhaustion in water; (4) "dross," the scrapings from the pipe, being the unconsumed ash, which is re-manufactured as a second-class "prepared" opium, being about 50 per cent. of the amount placed in the pipe for smoking. In China, the pipe is prepared by placing a little pill of the drug upon a needle, so that it rests exactly over the central hole in the pipe-bowl; a lamp is then applied to ignite it, and the vapours are drawn deeply into the chest, and slowly exhaled through the nose and ears. In Borneo, Java, and Sumatra, the liquid extract is mixed with finely chopped tobacco and betel-nut till absorbed, and pills of this are placed in the pipe.

Nature and Properties.—Opium contains no less than 17 distinct alkaloids, in very variable proportions, but two only are of importance in determining its value as a narcotic: these are morphine ($C_{17}H_{19}NO_3$), the more valuable; and narcotine ($C_{22}H_{23}NO_7$). Of European opiums, some French samples have given 22·88, 21·23, 20·67, 17·6, 17·5 and 14·96 per cent. of morphine respectively; German specimens afforded 20, 12–15 (Würtemberg) and 9–10 per cent. (Silesia). A pure American opium, from Vermont State, showed 15·75 per cent. of morphine, and 2 per cent. of narcotine. The Asia Minor article resembles the European: the maximum recorded is 21·46 per cent., while the mean of 8 samples was 14·78, and of 12 others, 14·66 per cent.; from several cases of Smyrna opium, 12–13 per cent. of pure morphine was got from the fresh, moist drug; and of 92 other specimens, one half yielded over 10 per cent., and the richest was 17·2 per cent. Thus it may be assumed that good Turkey opium dried at 100° (212° F.) should give 12–15 per cent. of morphine, and that less than 10 may indicate adulteration. The Persian drug is extremely unequal from adulteration, but sometimes very good; four samples have given 13·47, 11·52, 10·12, and 10·08 per cent. of morphine; and other samples undried, 8–10·75 per cent. The Indian opiums are remarkable for their low percentage of morphine, due probably to the long period during which the juice is kept in a moist state, not less than to climatic influences. Samples of Benares opium gave only 2·48, 2·38, 2·20, and 3·21 per cent. of morphine. Khandesh specimens showed 6·07 and 7 per cent. Patna garden opium, prepared exclusively for medicinal use, afforded 8·6 per cent. of morphine and 4 per cent. of narcotine, while another sample gave 7·72 per cent. of morphine. Various other samples of Indian opiums yielded the following percentages of morphine:—Medical, 4·3; Behar garden, 4·6; Abkari, 3·5; Sind, 3·8; Hyderabad, 3·2 (and 5·4 narcotine); Malwa, 6·1. Chinese native opiums are as a rule about the same, thus:—Szechuen, 2·2; Kweichow, 2·5; Yunnan, 4·1; Kansu, 5·1; another Szechuen sample, 3·3; and another from Kweichow, 6·1; whilst one Chinese specimen, undried, afforded 5·9 per cent. of morphine, and 7·5 of narcotine. A sample of Egyptian opium yielded 5·8 per cent. of morphine and 8·7 of narcotine. The proportions of narcotine in opiums differ quite as much. A German sample gave 10·9 per cent.; some Turkish and Persian specimens varied from 1·3 to 9·9 per cent. The Khandesh (Indian) opium previously mentioned gave 7·7 per cent.; and E. Indian Government opium frequently contains twice as much narcotine as morphine. In the practical estimation of the value of an opium, by the British pharmacist, the only conditions considered are the percentages of water and of morphine. (See Alkalies [Organic]—Morphine, p. 231).

The value of opium in medicine is unquestioned. With regard to its use as a narcotic, great efforts have been made by a few well-intentioned but ignorant people to procure its annihilation. But though the abuse of the drug leads to evil consequences—by no means equalling, however, those of the abuse of alcohol in this country—its moderate use is extremely beneficial, if not absolutely necessary, in the malarial climate of China, where almost the whole is consumed, and the immunity of opium-smokers from diseases of the bronchial tubes and lungs, so common among non-smokers, is remarkable. The real remedy for excessive opium-smoking in China lies in the development of the resources of the country, enabling the inhabitants to occupy healthy houses and consume wholesome food; the abuse of opium would then die out of China, as the abuse of laudanum died out of Lincolnshire after the fens were drained. An antidote for opium-smoking is the use of coca (see p. 1307).

Imports and Values.—The importations of opium into the United Kingdom were 41,000 lb. in 1839, 114,000 lb. in 1852, and 400,303 lb. in 1876. The supplies of 1876 were contributed as follows:—315,624 lb. from Turkey, 51,165 lb. from Persia, 13,390 lb. from British India, 5660 lb. from China, and 14,464 lb. from other countries. The imports in 1879 were:—499,351 lb., 396,123*l.*, from Turkey; 47,240 lb., 19,977*l.*, from Persia; and 25,820 lb., 16,610*l.* from other countries; total, 572,411 lb., 432,710*l.* Of our colonies, it may be mentioned that Victoria imported prepared opium to the value of 104,557*l.* in 1876, doubtless for the use of the Chinese labourers engaged on the gold-fields.

The approximate value of "fine" Turkey opium in the London market is 15–25*s.* a lb.; "other qualities," 12–21*s.* a lb.

Pituri.—The substance known as *pituri* among the Australian aboriginals, and popularly spelt *pitcheri*, *pitchoury*, *bedgery*, &c., by Europeans, has recently attracted considerable attention. The results of investigations indicate the source of the narcotic to be the leaves of *Duboisia Hopwoodii.* This shrub extends from the Darling River and Barcoo, throughout Queensland, S. Australia, and the desert scrubs of Central Australia to W. Australia, and seems to be more plentiful than was at first supposed. The shrub is of bushy growth, with dark, thick, glossy foliage, and reaches a height of 8–9 ft. It is most commonly found on sandy spinifex flats, in well-watered country. Sylvester Brown indicates a locality of some 400 sq. miles, just on the S. Australian border, about 23° S. lat., as an admirable spot for a reserve of the plant, which grows there abundantly. The native blacks gather the leaves annually during the month of August, when the plant is in blossom, and hang them up to dry. They are sometimes sweated beneath a layer of fine sand, dried, roughly powdered up, and then packed in netted bags, skins, &c., for purposes of transport. To prepare them for use, they are damped, mixed with potash obtained from suitable plants, and rolled up into the shape of a cigar. This is chewed, and the saliva is swallowed. In small quantities, it has a powerful stimulating effect, assuaging hunger, and enabling long journeys to be made without fatigue, and with little food. In large doses, it is maddening. The narcotic principle has been separated in the form of an alkaloid, termed "piturine," prepared in the same manner as nicotine, which it closely resembles, if it be not actually identical. The leaves are an important article of inter-tribal commerce. In native use, it takes the place of the coca (p. 1307) of S. America, the ava (p. 1305) of Fiji, and the tea of China. It is suspected that *D. myoporoides*, extending on forest land from near Sydney to near Cape York, and traced also in New Guinea, shares the properties of the first species, as an alkaloid termed "duboisine" prepared from it seems to be identical with piturine. Several species of the allied genus *Anthocercis*, found throughout the greater part of the Australian continent and in Tasmania, also deserve investigation, as *A. viscoso* is known to possess the property of contracting the pupil of the eye. (See Drugs—Duboisia, p. 810).

Rhododendron.—The rhododendrons possess considerable narcotic virtues. The flowers of *Rhododendron arboreum* are eaten as a narcotic by the hill-people of India, and a snuff is made from the bark. The leaves of *R. campanulatum* are used as snuff by the natives of India, and the brown dust which adheres to the petioles is used for a similar purpose in N. America. *R. chrysanthemum* in Siberia is one of the most active of narcotics.

Siberian or Intoxicating Fungus.—The poisonous toad-stool, *Amanita muscaria* [*Agaricus muscarius*], is the narcotic of Siberia. It closely resembles some of the edible mushrooms, and is common in fir-, beech-, and birch-woods in N. England. It grows very abundantly in parts of Kamtschatka, where it is either collected during the hot months, and hung up to dry in the air, or is left in the ground to ripen and dry, and is afterwards gathered. It is more narcotic in the latter case. The most common way of using it is to roll it up like a pill, and swallow it without chewing. If steeped in whortleberry-juice, and other vegetable juices, it imparts strong intoxicating qualities. Eaten fresh in soups, &c., it is less powerful. One or two suffice to produce pleasant intoxication for a whole day. It provokes remarkable activity, stimulates bodily exertion, and induces violent exhibitions of passion. A singular feature of it is that the active principle passes unimpaired into the urine, and remains for a long time; this fact is well known to the Siberians, and is availed of by them in a most abominable manner. It is a significant fact that the exports of this fungus from Archangel in 1878 were:—230 *poods*, value 4200 *roubles*, to Great Britain; 25 *poods*, 375 *roubles*, to Holland; and 115 *poods*, 1725 *roubles* to France; the total amounting to 7 tons, value 630*l.*

Syrian or Steppe Rue.—The seeds of *Peganum Harmala*, a plant abundant in the Crimea, are occasionally eaten by the Turks as a narcotic indulgence. The active virtues seem to reside in the husk of the seed, which contains about 4 per cent. of two alkaloids, called harmine ($C_{13}H_{12}N_2O$) and harmaline ($C_{13}H_{14}N_2O$).

Thorn-apples.—The fruit of the red thorn-apple of Peru (*Datura sanguinea*), which grows on the less steep slopes of the Andean valleys, is used by some tribes of the Indians for preparing a strong narcotic drink, called *tonga.* The whole plant is narcotic, but the seeds are most powerful. The seeds of the common thorn-apple, *D. Stramonium*, possess similar properties. They are used as poison on the Continent and in India; and in Russia, China, and Upper India, they, or the seeds of other species (*D. Melet, D. fastuosa, D. alba*), are employed to increase the intoxicating qualities of fermented liquors. The dried leaves of *D. Stramonium* and *D. tatula*, made into cigarettes, are smoked as a cure for some forms of asthma (see Drugs—Stramonium, p. 826).

Tobacco.—Tobacco, the most largely and widely consumed of all narcotics, is the product of a number of plants belonging to the genus *Nicotiana.* The species and varieties having most interest for the cultivator are the following:—

I. *N. Tabacum macrophylla* [*latifolia, lattissima, gigantea*]—Maryland tobacco. Of this, there are two sub-species—(1) Stalkless Maryland, of the following varieties: (*a*) *N. macrophylla ovata*—short-leaved Maryland, producing a good smoking tobacco, (*b*) *N. macrophylla longifolia*—long-leaved Maryland, yielding a good smoking tobacco, and excellent wrappers for cigars, (*c*) *N. macrophylla pandurata*—broad-leaved, or Amersfort, much cultivated in Germany and Holland, a heavy cropper, and especially adapted for the manufacture of good snuff; (2) Stalked Maryland, of the following varieties: (*a*) *N. macrophylla alata*, (*b*) *N. macrophylla cordata*—heart-shaped Maryland, producing a very fine leaf, from which probably the finest Turkish is obtained. Cuban and Manilla are now attributed to this group.

II. *N. Tabacum angustifolia*—Virginian tobacco. Of this, there are two sub-species—(1) Stalkless Virginian, of the following varieties: (*a*) *N. angustifolia acuminata*, grown in Germany for snuff, seldom for smoking, (*b*) *N. angustifolia lanceolata*, affords snuff, (*c*) *N. angustifolia pendulifolia*, another snuff tobacco, (*d*) *N. angustifolia latifolia*—broad-leaved Virginian, used chiefly for snuff, (*e*) *N. angustifolia undulata*—wave-like Virginian, matures quickly, (*f*) *N. angustifolia pandurata*, furnishes good leaves for smoking, produces heavily, and is much grown in Germany, and said to be grown at the Pruth as "tempyki," and highly esteemed there; (2) Stalked Virginian, of the following varieties: (*a*) *N. angustifolia alata*, (*b*) *N. angustifolia lanceolata* [*N. fructiosa*], growing to a height of 8 ft., (*c*) *N. angustifolia oblonga*, (*d*) *N. angustifolia cordata*—E. Indian, producing heavily in good soil, and well adapted for snuff, but not for smoking. Latakia and Turkish are now accredited to *N. Tabacum.*

III. *N. rustica*—Common, Hungarian, or Turkish tobacco. Of this, there are two varieties: (*a*) *N. rustica cordata*—large-leaved Hungarian, Brazilian, Turkish, Asiatic, furnishing leaves for smoking; (*b*) *N. rustica ovata*—small-leaved Hungarian, affords fine aromatic leaves for smoking, but the yield is small. Until quite recently, Latakia, Turkish, and Manilla tobaccos were referred to this species; Latakia is now proved to belong to *N. Tabacum*, and Manilla is said to be absolutely identical with Cuban, which latter is now ascribed to *N. Tabacum macrophylla.*

IV. *N. crispa*—This species is much grown in Syria, Calabria, and Central Asia, and furnishes leaves for the celebrated cigars of the Levant.

V. *N. persica.*—Hitherto supposed to be a distinct species, affording the Shiraz tobacco, but now proved to be only a form of *N. Tabacum.*

VI. *N. repanda.*—A Mexican plant, with small foliage. Long thought to be a distinct species peculiar to Cuba, but none such is now to be found in Cuba, whether wild or cultivated, and all the Cuban tobacco is now obtained from *N. Tabacum macrophyllum.*

Among the many other forms interesting only to the botanist or horticulturist, the principal are *N. paniculata*, *N. glutinosa*, *N. glauca*, attaining a height of 18 ft., and *N. clevelandii*, exceedingly strong, quite recently discovered in California, and supposed to have been used by the early natives of that country.

Cultivation and Curing.—The following observations on the methods of cultivating and curing tobacco have reference more particularly to the processes as conducted in India and the United States; this branch of agriculture has been brought to great perfection in the latter, and the supervision of the operations in India is mostly entrusted to skilled Americans.

Climate.—Of the many conditions affecting the quality of tobacco, the most important is climate. The other conditions that must be fulfilled in order to succeed in the cultivation of this crop may be modified, or even sometimes created, to suit the purpose; but cultivators can do little with reference to climate: the utmost they can do is to change the cultivating season, and this only in places where tobacco can be grown nearly throughout the year. The aromatic principles, on the presence of which the value of a tobacco chiefly depends, can only be properly developed in the plant by the agency of high temperature and moisture. The fame that Cuban and Manilla tobaccos enjoy is mostly due to the climate. The article produced in Cuba is most highly esteemed; up to this time, no other country has been able to compete successfully with it. However it cannot be doubted that there are many places whose climate justifies the assumption that a tobacco could be grown there, not inferior to that produced in the W. Indies. The more closely the climate of a place corresponds with that of Cuba, the greater chance is there that a Havanna variety will preserve its peculiar aroma. In such places, a fine and valuable tobacco may be grown with less expenditure on labour, &c., than it is necessary to bestow in raising an inferior article in less suitable climes. In countries where a low temperature rules, the plants must be raised in hot-beds, and there is also a great risk that the young plants may be destroyed by frost, or afterwards by hailstones. When damp weather prevails during the tobacco harvest, it is often injured; and to give the required flavour, &c., to make the article marketable, macerating has often to be resorted to, thus involving great risk and expenditure. But in spite of these drawbacks, tobacco cultivation is often very remuneratively carried out in countries possessing an unfavourable climate. The deficient climatic conditions are here partly compensated for by making the other conditions affecting the quality of tobacco, and which can be controlled by the cultivator, the most favourable possible.

Soil.—The soil affects to a great extent the quality of a tobacco. The plant thrives best in a soil rich in vegetable mould; this, however, is not so much required to supply the necessary plant food, as to keep the soil in a good physical condition. No other plant requires the soil in such a friable state. A light soil, sand or sandy loam, containing an average amount of organic matter, and well drained, is considered best adapted for raising smoking-tobacco; such a soil produces the finest leaves. The more organic matter a soil contains, the heavier is the outturn; but the leaves grow thicker, and the aroma becomes less. As, in tropical climates, the physical properties of the soil play a prominent part in its productive capabilities generally, and the presence of organic matter in the soil tends to improve these properties, it will rarely occur that in such places a soil will contain too much humus. The more clay in a soil, the less is it adapted to the production of fine smoking-tobacco, on account of its physical properties being less favourable to the development of the aromatic principles; the leaf becomes also generally thick and coarse, but the outturn on such soils is generally heavier than on a more sandy one. A clay soil possessing a great amount of humus may, if properly tilled, produce an ordinary smoking-tobacco, and may even, if great attention be paid to the selection of the variety, &c., produce leaves for cigar-wrappers.

Of less importance than the physical properties of the soil is its chemical composition. By proper tillage and heavy manuring, tobacco is sometimes grown on comparatively poor soils. From analysis of the plant, it is clear that it contains a large amount of ash constituents, which it extracts from the soil; the most important of these are potash and lime. A soil destitute of these constituents would require a great quantity of manure to supply the wants of tobacco.

Situation.—Land intended for tobacco-culture should have good drainage, and be sheltered from high winds. In Holland, where tobacco-cultivation is carried out to great perfection, each field is surrounded by a hedge about 7 ft. high; the fields are divided into small plots, which are again bordered by rows of plants that are able to break the force of the wind, which would injure the leaves, and render them of comparatively little value. To this circumstance, must chiefly be attributed the fact that Dutch growers succeed in getting as much as 50 per cent. of leaves of the first quality, whereas in most other countries 25 per cent. is considered to be a very good outturn.

Manure.—In its natural state, the soil will rarely possess the elements of plant food in such a form as is most conducive to the production of a fine tobacco-leaf. Any deficiency must be supplied in the shape of suitable manure. Schlösing found that a bad burning tobacco was produced on a soil containing little potash, on unmanured soil, on soil manured with flesh, humus, calcium chloride, magnesium chloride, and potassium chloride. A good burning tobacco was produced on a soil manured with potassium carbonate, saltpetre, and potassium sulphate. More recent experiments carried out by other investigators tend to corroborate these conclusions. It is generally assumed that a soil rich in nitrogenous organic matter produces a strong tobacco that burns badly.

The results of Nessler's experiments clearly show that it is not sufficient to apply the element most needed by the plant—potash—in any form, but that, to produce a good tobacco, it is necessary to apply it in a particular combination. It was found that carbonate of potash applied as manure produced the best tobacco: it burnt for the longest time, and its ash contained most carbonate of potash; whereas chloride of potash produced a much inferior tobacco. The assertion of other experimenters that chlorides produce a bad tobacco is thus confirmed. Sulphate of potash and sulphate of lime produced a good tobacco. It may be noticed here that tobacco which was manured with gypsum contained a great amount of carbonate of potash in the ash, probably due to the fact that gypsum is a solvent for the inert potash salts. From the foregoing, it may be concluded that in tobacco cultivation, the elements potassium and calcium should be restored to the soil in the form of carbonate, sulphate, or nitrate, but not as chlorides. Poudrette, or prepared night-soil, generally contains a considerable amount of chlorides, and is not well suited as manure for fine tobacco. It has been found that fields manured with chlorides produced heavily; a small proportion of chlorides may therefore be applied in this form, whenever quality is of less importance than quantity. Farmyard manure may suffice when tobacco is cultivated in proper rotation, but here also, unless the soil be very rich in potassium and calcium, the application of some special manure will greatly enhance the value of the outturn. Wood-ashes are a valuable supplement to stable dung. Gypsum is an excellent dressing for soils in a good manurial condition: it supplies the lime needed by the tobacco, and acts as a solvent on the inert potash salts. Gypsum applied on poor land, however, hastens the exhaustion of the soil. It is said that crops manured with gypsum suffer less from the effects of drought, and require less irrigation, than when manured otherwise: the leaves of plants that had been manured with gypsum exhaling less water than when manured with other substances. If this assertion be correct, gypsum would be invaluable to the Indian cultivator.

With regard to the amount of manure to be employed, it may be observed that, with farmyard manure properly rotted, there is no theoretical limit, especially when the tobacco is intended for snuff, and is grown in a hot climate, where the physical properties of the soil are of the utmost importance. It is said that some Rhenish-Bavarian soils contain as much as 15 per cent. of organic matter, yet the cultivator considers it necessary to heavily manure each tobacco crop. Dutch growers apply to the rich alluvial soil as much as 25 tons an acre of well-rotted cattle-manure. In America, it is reported that the heaviest crops are obtained on soil newly taken up, and very rich in vegetable mould. It is considered nearly everywhere that tobacco will pay best when heavily manured. The first care of even the poorest peasant in the tobacco districts of Germany, Holland, &c., as soon as he sells his tobacco, is to purchase the manure which he considers essential to his success.

The amount of any special manure which can be applied without injury to the plants depends very much on the solubility of the stuff, and the manner of applying it. Highly soluble salts, such as nitrate of soda or potash, should be applied in smaller quantities than salts which dissolve slowly. With regard to the manner of applying concentrated manures, it is evident that, when a salt is applied in close proximity to the plant, less will be required than when strewn over the whole field. When applied in solution, not more than 300 lb. of nitrate per acre should be used at one time. The amount to be applied varies also with the soil; a sandy soil, which has little absorptive power, should receive less than a clay. Salts easily disintegrating should not be applied before tobacco has been planted, especially not before heavy rains which would carry off the salt. To supply the potash required by the tobacco plant, 200 lb. of good saltpetre per acre would be sufficient in most cases. Lime, although removed from the soil in large quantities, is rarely applied to tobacco as a special manure. Where wood-ashes can be had at a moderate price, lime may be applied in this form. Some ashes are very rich in lime. It has been found that ashes obtained from beech-wood contain 52 per cent. of lime, and those from oak-wood, as much as 75.

Rotation.—A proper rotation of crops is particularly advantageous for the cultivation of tobacco, since it requires a great amount of readily accessible inorganic matter in the soil, especially potash and lime. Although the importance of cultivating tobacco in rotation is admitted, there may be circumstances that justify the growth of this crop consecutively for several years in the same field. In America, tobacco is grown successively for several years on new land, where the elements of plant food exist in such abundance that the crop may be thus cultivated without for a time showing any notable decrease in yield; it is even said that the outturn of the second year is heavier than that of the first. In Hungary and Holland, the best tobacco is grown for many years in succession on the same land. There the plan is adopted partly out of necessity and partly for convenience. The small landholder is often obliged to grow tobacco on the same field, because he has only one properly fitted for it; for convenience, he grows it every year on the same place near his homestead, to allow of the closest attention to the crop, but he manures heavily. Nessler, in Carlsruhe, cultivated tobacco during six consecutive years in the same field, without noticing any perceptible decrease in yield or quality. To admit of such a system, the soil must either be very rich in the essential elements, or be heavily manured, as is the practice in Holland. It is generally assumed that, when tobacco is grown on the same field in succession, the leaves do not become so large after the first year, but grow thicker and more gummy, and contain less water.

From the foregoing, it would appear that, although tobacco may be grown successfully on the same land uninterruptedly under special circumstances, the cultivator will find it advantageous to adopt some plan of rotation. Cereals and pulses are very well adapted for this purpose, the reason being that tobacco removes but little phosphoric acid from the soil, and thus leaves it rich in the element most necessary for the growth of cereals. It has also been found that hemp thrives particularly well after tobacco.

Selection of Sort.—The cultivator must carefully compare the requirements of the different sorts, and the means at his disposal to satisfy them, before making his selection. Though tobacco is a hardy plant, and grows under varied conditions, yet to become a remunerative crop, the plant should not be placed under circumstances very dissimilar from those to which it has been accustomed. By importing seed of a fine sort directly from its native land, the plants will not retain in the new habitat all their special qualities, unless climate, soil and treatment are nearly the same. Climate must first be considered. Fine and valuable tobacco is a product of tropical countries: in a warm and humid climate, by employing common means, tobacco may be made to yield a profit not attainable in less favoured regions. A warm, moist climate permits the selection of those sorts that command the highest prices; if to this be added a suitable soil, and proper treatment, the cultivation of tobacco yields a profit not easily obtainable from any other crop.

As the Havanna tobaccos command the highest prices, the cultivator nearly everywhere attempts to introduce and cultivate them. There is no great difficulty in raising plants of these varieties, but they speedily degenerate and form new varieties, if the climatic conditions, &c., are not favourable. Virginian tobacco was previously extensively cultivated, but has of late been frequently replaced by the Maryland kind. It is still much favoured by cultivators in temperate climates, as it does not require a high temperature. On account of its botanical characteristics, it is usually not much liked by manufacturers of cigars; some varieties, however, that have less of the marked specific characters, yield tolerably fine leaves for cigars. As the price of this tobacco is rather low, it is not so well suited for export. Hungarian tobacco is considered to be very hardy, but is less valuable than the foregoing. The leaves are generally small, and possess a peculiar aroma.

A high price is generally commanded, irrespective of the species, by those tobaccos that possess a large, smooth, thin, elastic leaf, possessing a fine golden colour and a good aroma; the ribs and veins should be thin, and the former should branch off from the mid-rib at nearly right angles, and should be far apart from each other. The lower the percentage of the weight in ribs, the thinner and broader the leaf, and the fewer the leaves torn, the more wrappers can be cut out of 1 lb. of tobacco, other conditions being equal, and consequently the higher is the price of the article. The cigar-manufacturer often does not appreciate the aroma so much as the other qualities. He can do nothing to improve the botanical characters: the finest aromatic leaf would be of little value to him if it were torn; but he is to a certain extent able artificially to improve defects in flavour. Of all kinds, Maryland is considered to possess the qualities that distinguish a good tobacco in the highest degree. Some of the Havanna tobaccos belong to this sort, as also the Ohio, Amersfort, Turkish, and Dutten tobaccos. Its cultivation assumes larger proportions every year, and the number of varieties and sub-varieties increases accordingly. Perhaps the finest wrappers for cigars are grown in Manilla.

Seed.—The best and strongest plants are selected for affording seed. These are not "topped" like the remainder of the crop, and are left standing when the crop is gathered. All suckers are carefully removed from the stems, and sometimes from the leaves also. When the crop is cut, the seed-stalks should be staked, to prevent their destruction by the wind. As soon as the seed-pods blacken, the seed is ripe; the heads are then cut off below the forks of the plant, and are hung in a dry and safe place to cure. Care must be taken to gather them before frost has impaired their vitality. During leisure time, the pods are stripped from the stalks, and the seed is rubbed out by hand, and winnowed. Its vitality is proved by its crackling when thrown upon a hot stove.

Seed-beds.—A very light friable soil is necessary for the seed-beds; to obtain this, it should be broken up to a depth of 1½ ft. some months before the sowing-season. A drain is dug around the beds, and the soil is utilized in raising the surface. In America, a very warm and sheltered situation, such as the south end of a barn, is selected for the seed-beds. It is a common plan there to burn a brush-heap over the ground, thus supplying potash and killing weeds. The time for sowing in America is usually from the middle of March to the 10th of April, or as soon as the ground admits of working in the spring; in India, it depends upon the locality: when the monsoon rains are very heavy, it should follow them; in other cases, it may precede them.

Unless the soil be very rich in humus, it should be heavily manured with well preserved farmyard manure soon after breaking up. The soil of a tobacco nursery cannot contain too much organic matter; the presence of much humus will prevent, to a great extent, the formation of a surface crust, which is so detrimental to the development of the plants during their early growth, and will also facilitate the extraction of the plants when transplanting takes place. After a few weeks have elapsed, the soil should be dug over a second time, and the whole be reduced to a fine tilth. The land may now remain untouched until the sowing time, unless weeds should spring up: these must be eradicated.

The area required for a nursery depends on the area of ground to be planted, and on the distance separating the plants in the field. About 1 sq. in. space should be allotted to each of the young plants in the nursery. Taking the number to be 7260 plants required for an acre (at 3 ft. × 2 ft.), and giving each plant 1 sq. in. of room, an area of 7000 sq. in. or 50 sq. ft. would raise plants sufficient for an acre. But as some are injured during growth, many rendered useless in lifting them for transplanting, and more needed to replace those that die after transplanting, double the number should be raised, or 100 sq. ft. of nursery bed for an acre.

The amount of seed required for an acre depends chiefly on its vitality. An ounce contains about 100,000 seeds, or sufficient for nearly 7 acres if all grew; but as even the best has not a very high percentage of vitality, ½–1 oz. is generally sown to produce the plants required for one acre.

Sowing-time having arrived, the nursery is divided into beds, most conveniently, 10 ft. long and 5 ft. wide, making 50 sq. ft. each, on which plants for ½ acre can easily be raised. As, even with a small tobacco plantation, several days are required for transplanting, all the beds should not be sown at one time, but at intervals of a few days. This will also lessen the risk of the young plants being all destroyed by a storm, insects, &c. Before sowing the seed, the soil is dug over to the depth of 6 in., and levelled with a rake. The seed must then be sown evenly on the surface, and beaten down slightly with the hand or otherwise. The seed being very small, many cultivators mix it with ashes, or pulverized gypsum, in order to distribute it regularly over the bed. The seed must be covered only slightly, best done by strewing a little fine compost manure over it. Ants, which often destroy the seeds, may be kept off by sprinkling some ashes over the bed. Finally cut straw may be scattered over the surface. In India, to protect the nursery from the sun and rain, the whole is covered with a roof made of straw, leaves, or cloth, supported by poles, at only a few feet above the ground. The soil must be kept constantly moist, but not wet; weak liquid-manure may be used for watering. Much time is saved by starting the seed in a warm room before sowing.

The plants, which will appear about a week after sowing, are very tender during the first stage of their growth, and require frequent watering through a fine rose. The straw will now prevent the water falling with any force immediately on the plants, and its tendency to wash the soil from the fine rootlets. If the plants spring up thickly, they are thinned out, when about a week or two old, leaving about 1 sq. in. for each. Those taken out may be used to fill blanks in the nursery bed, or, if more plants are taken out than are required for this purpose, they should be planted in a separate bed. It is universally acknowledged that plants transplanted when very young develop more roots, grow more vigorously, and become more hardy afterwards, than when not transplanted at this stage. When the plants are about two weeks old, they require less attention, and should be watered less frequently, to harden them before transplanting. Any weeds appearing must be removed, and injurious insects must be killed. In about 7–8 weeks after sowing, the plants will be fit for transplanting.

Preparation of the Field.—Land intended to be planted with tobacco should receive several ploughings not less than 9 in. deep. As a rule, clay requires to be more deeply ploughed than sandy or loamy soil. It greatly conduces to success, if the land is allowed to lie fallow for several months before planting the crop, to admit of the proper preparation of the soil, by ploughing, rolling, harrowing, &c., and to allow the attainment of as fine a tilth as is usual in gardens. No crop will better repay the expense of proper preparation of the soil than tobacco; the fineness of the leaf, and the aroma of the tobacco depend to a great degree upon this. The land should be ridged immediately before planting. The distance apart at which to make the ridges is governed by the quality of the soil and the sort of plant to be raised. With good soil, the ridges must be further apart than in a poor one, because of producing larger leaves. The ridges should allow a passage between the rows, for the purpose of weeding, hoeing, suckering, &c., without breaking the leaves. In the lines, the plants may be 6 in.–1 ft. closer than the ridges. In some places, a plough is run at right angles across the ridges before planting, at the distance at which the plants have to stand in the lines, thus forming small hills on which the seedlings are planted.

Planting.—Planting should take place only in the evening (or even at night in India), unless the weather be cloudy, when it may be performed during the whole day. Some hours before commencing to transplant, the nursery should be thoroughly watered, to facilitate the removal of the plants, without tearing their roots. If the plants are of even size, so that all can be removed, the best plan is to take them out with a spade, or trowel, leaving a lump of soil on each. But in most cases, it will be necessary to take up each plant separately; this should be done very carefully, holding with the thumb and forefinger as near as possible to the roots, and drawing out the plants, if possible, with a little soil adhering to their roots. The plants are taken at once in a basket to the field for planting. An attendant going between two ridges places a plant on each hill, right and left. One attendant is sufficient for two planters, who follow immediately. The planting is nearly the same as with cabbages, but requires more care, the plants being more tender, and their roots and leaves springing nearly from the same point, they are more difficult to handle. The plants should be placed in a hollow made on each hill, which will serve as a reservoir for the water to be applied, and also afford some shade.

In India, the plants are watered immediately after planting; they should also by some means be shaded during the first few days, which can easily be done when only a small area is planted, but is rather difficult to manage on a large scale. In the latter case, the shade afforded by planting in a slight cavity must suffice. If the plants have been taken from the nursery with some soil adhering to their roots, and are kept sufficiently moist during the first few days, few of them will die. When the weather is dry, water should be applied at morning and evening, and after that time, once daily until the plants have taken root, after which, occasional waterings, varying with soil, weather, and kind of plant, must be given. In dry weather, and with a soil poor in humus, one watering every second or third day may be necessary, whereas with a soil rich in organic matter, and in a moist atmosphere, watering may be entirely dispensed with. During the first few days, the water is applied with a watering-pot, held very low, otherwise the soil would be washed from the plant-roots, and expose them to the direct rays of the sun, causing death.

After-cultivation.—After the plants have once taken root, they grow rapidly. They are hoed when about 6-9 in. high, and the soil is drawn from the furrows to raise the hills, maintaining a depression round the stems. If the soil is not very rich, a special manure should be applied at this stage of growth. The best manure generally will be nitre in a liquid state, which can be applied in the depression around the plants with a watering-pot. By applying it in solution and close to the plant, less is required than when spread over the whole field. Some weeks afterwards, another hoeing and heaping of earth round the plants will be necessary. It is most difficult to say the number of hoeings which may be required by a tobacco crop. The general rule to be followed is to keep the soil loose, friable, and free from weeds. The more organic matter the soil contains, the more will it remain loose and friable; the less organic matter, the more waterings will be required, which causes the soil to crust over, and to assume a close texture, and necessitates frequent hoeings. As long as the plants have not spread much, the hoeing may be done by a cultivator, followed by some men to perform the heaping. Insects which attack the tobacco must be carefully sought for and killed at once. They can easily be discovered in the mornings; if not killed, they may destroy the whole crop in a few days. Turkeys are invaluable for their grub-eating propensities.

Topping and Suckering.—The plants will commence to flower about two months after planting, when 2-7 ft. high. When the flower-buds appear, they must be broken off, and with them the top and bottom leaves. By breaking off the flower-buds at an early date, the sap that would be used in the formation of these organs flows to the leaves, which thereby increase in size, and the outturn becomes much heavier than when the plant is allowed to flower. But it is generally admitted that the leaves lose much in aroma. To what extent the early removal of the flower-buds impairs the quality has not been properly investigated. It is very probable that the greater yield does not always compensate for the loss in quality. The bottom leaves are generally of inferior quality, small, torn, and dirty. The number of leaves to be left on the plant varies greatly, according to species, quality of soil, and method of cultivation. The minimum may be placed at 6, the maximum at 22. The only rule to be observed is to retain as many leaves as the plants are able to mature. Soon after the plants have been topped, suckers appear in the axils of the leaves; these should be broken off as soon as they come, at least they should not be allowed to grow longer than 4 in. If the suckers are not removed soon after their appearance, the size of the leaves will be seriously impaired. After the plants are half-grown, great care must be taken when going through the lines, whether for the purposes of hoeing, watering, or suckering, &c., not to tear the leaves. In India, hoeing and suckering should be performed only when the leaves have lost part of their turgescence, attained at night. Insects, however, must be killed during the morning and evening; at other times, they are not easily found. Leaves which are torn are not fit for cigar-wrappers, and must often be thrown on the refuse heap as valueless, even if well developed and of good colour.

The plants commence to ripen about three months after being planted; this is indicated by the leaves assuming a marbled appearance, and a yellowish-green colour. The leaves also generally become gummy, and the tips bend downwards. It is considered that tobacco intended for snuff should have attained more maturity than tobacco for smoking. Nessler found that the less ripe leaves contained more carbonate of potash, and burnt consequently better, than the more ripe ones, but the total amount of potash was larger in the latter than in the former; cigars made from less ripe leaves kept the fire when lighted for a shorter time than those made from more ripe leaves.

Harvesting.—The leaf being matured, it should be harvested only after the dew is off the plants, and not on a rainy day. There are two modes of harvesting—gathering the leaves singly, and cutting down the whole plant. Gathering single leaves admits of removing them from the plant as they ripen; the bottom leaves are removed first, and the top ones are left some time longer, until they have attained full maturity. The cultivator is thereby enabled to gather his crop when it possesses the greatest value. This plan necessitates, however, a great amount of labour, and, in a hot climate, the single leaves are apt to dry so rapidly as not to attain a proper colour, unless stacked early in heaps. But stacking in heaps involves great risk of the leaves heating too much, and developing a bad flavour, whereby the tobacco loses more or less in value. For Indian circumstances generally, cutting the whole plants is better than gathering the leaves singly.

For cutting down the plants, a long knife or chopper is used. A man takes the plant with his left hand about 9 in. from the ground, and with the knife in his right hand, cuts through the stem of the plant just above the ground. If the plants are sufficiently "wilted," he may lay them on the ground and proceed to cut down others; if, however, they are so brittle as to cause the leaves to be injured by laying them down, he should give them to another person, to carry them at once under shade. During bright weather, the plants should not be allowed to lie exposed to the sun on the ground, or they will become sun-burnt, and lose in value. A temporary shed should be erected; it might be simply a light roof of palm-leaves or thatched straw, supported by poles; a large tree standing near will also serve the purpose. Under this shade, parallel rows of posts are put up, and on the posts, light poles or strong bamboos are fixed horizontally. The parallel lines should be about 4½ ft. apart and the horizontal poles about 4–5 ft. from the ground, according to the height of the tobacco plants. Rods are cut in lengths of 5 ft., and laid over the parallel bars, so that they will project about 3 in. at each end. A very light and convenient shelter sometimes used for sun-drying in America, consists of rods laid crosswise, supported on four upright poles, and covered with a sloping roof of boards. The plants that have been cut are immediately brought into the shade, tied in pairs, and hung across the rods. They must not be hung so close as to press each other, and the rods should therefore be 6–12 in. apart. The framework should be so large as to allow of one day's cutting being hung. The plants are left thus for one day, during which time they will be wilted sufficiently to allow handling without tearing the leaves. In a very dry wind, mats or other cover should be laid against the plants most exposed to it, or their leaves will dry rapidly, shrivel up, and remain green. Next day the leaves are carted to the drying-shed. A cart supplied with a framework, in order that the plants may be hung as they were hung under the shade, is the best means. Perpendicular uprights at each corner of a cart or waggon are fixed together by horizontal poles. The plants may be hung so close as not to press heavily on each other, 200–400 being brought to the shed at one time.

Drying.—The drying-shed is prepared beforehand to receive the tobacco. When cultivating tobacco on a small scale, any shed will do, provided that it contains a sufficient number of doors and windows to admit of regulating the circulation of air. A roof made of straw seems to answer very well. The shed should be high enough to admit of hanging three rows of tobacco in it, one above the other. The bottom tier for the first row should be about 3–5 ft. from the ground, according to the size of the plants, which should not touch the ground; the second tier should be 3–5 ft. higher than the first; the third, 3–5 ft. higher than the second; the whole being 10–17 ft. high from the bottom of the shed to the highest tier. The tiers must be so arranged that the tobacco when hung on the upper tier should not touch that of the lower one, and that the rods on which the tobacco has been hung in the field fit exactly. The windows must face each other, and be placed between the tiers, so that the bottom part of the window is on the same level as the tier. When cultivating on a large scale, the same arrangements are made, but the building is higher, and is provided with a cellar, in which to place the tobacco for the purpose of stripping, &c.

The drying-shed being ready, the plants immediately on arrival at the shed are transferred from the conveyance, on the rods, to the lowest tier. No rule can be given as to the distance the rods should be placed from each other, as it varies according to the species of the plant, the degree of ripeness, and especially the state of the weather. The purpose of hanging the plant here on the lower tier is to cause the leaves to dry gradually, and assume a good yellow colour, and to create a slight fermentation in them, while allowing such a circulation of air between the plants as will facilitate the gradual escape of the moisture from them, and prevent the injurious development of ammonia and other combinations that give rise to bad flavour in the tobacco. How to attain this, exercises the judgment of the cultivator, who, by frequent examination of the plants, and by careful observation of the changes going on in the leaves, will soon find out the right way.

The rods should be placed closer together—(*a*) when the plants are much wilted on reaching the shed; (*b*) when the air is very dry, and the temperature is high; (*c*) when the leaves of the plant are very thin and contain little water. Plants which have the leaves closely arranged on the stems must be hung further apart. When the air is very dry, and there is a strong breeze, the windows must be closed. If this is not sufficient, water may be poured on some heaps of sand, to create a moist atmosphere in the shed. When the stems of the plant are very thick, and consequently contain much sap, it is beneficial to open the windows, especially at morning and evening, for some hours, that the wind may pass over the butt-ends. As the windows are situated above the lowest tier, the leaves will not be much affected by it.

The leaves must be examined carefully every day; one plant may progress very well, whereas another close by may decompose too rapidly, and another too slowly. Although no change of weather occur, it may yet be necessary to alter the position of the rods, in order that each plant and leaf may receive air in such a degree as is most conducive to its proper decomposition. Any change in the weather necessitates different arrangements. The plant should remain on the lower tier until the leaves have turned yellow, which will take place within 6–10 days, according to circumstances; after this, they are hung on the upper tiers. There they should be more apart, each plant hanging free. When on the upper tiers, the tobacco may be said to be in the free-hang; and when on the lowest tier, in the close-hang. The object in hanging the plants more apart on the upper tier is to dry them more rapidly there, and for this purpose, the shutters may be opened, unless there be a strong dry wind. The light-yellow colour of the leaves should change into a dark yellow-golden or light-brown colour. After hanging on the upper tier for about a week, the veins of the leaves will be nearly dry, leaving only the midribs pliant. The drying of the leaf and the changing of its colour proceed gradually, commencing from the margin and proceeding to the midrib. At this time, the plants are hung closer together, the evaporation from the leaves being little, and the space and sticks being required. The plants hanging on two or three sticks may be hung on one stick. All the windows may be kept open from this time; the tobacco may also be brought into an open shed, or even hung outside exposed to the sun. In about a week more, the midribs will be entirely dried up, and the tobacco will be fit for stripping. In some climates, it may be necessary to facilitate the drying by the aid of artificial heat. For this purpose, heated air should be conducted into the drying-shed, without the fire, or the products of combustion, being admitted.

Stripping.—Stripping may be performed at any time, provided the leaves, after being once properly dried, have again become pliable. For stripping, such a number of plants as will furnish work for several days are taken down on a morning, when the plants have absorbed some moisture, and have become elastic; they are put in a heap, and properly covered, to check evaporation. If, however, the night air should be so very dry that the leaves cannot absorb sufficient moisture to become pliable, a moist atmosphere can be created either by steam, or by pouring water on the floor, or by keeping vessels with water in the shed. If this cannot be done, the tobacco must remain hanging until there is damp weather. Under no condition should the tobacco be stripped when not pliant, that is if the leaves are so brittle that they would break when bent or rolled. The best arrangement is to keep the drying-shed and stripping-room separate, since the latter requires to be more moist than the former. A cellar under the drying-shed is best suited for stripping. It should be large enough to admit of the erection of a scaffold to receive the tobacco.

Sorting.—Tobacco intended for smoking should be carefully sorted when stripped. There should be four sorts: 1st, large, equally good coloured, untorn leaves; 2nd, leaves of good size and colour, but torn; 3rd, leaves of inferior colour, and bottom leaves; 4th, refuse, shrivelled up leaves, &c., to which may be added the suckers. No. 1 leaves, when thin, elastic, and of good sorts, are mostly valued as wrappers (outside covers) for cigars. No. 2 may also be used as wrappers, but are less valued than No. 1.; they are adapted for fillers and cut tobacco. The different sorts are kept separate. The best plan is to let the most intelligent man strip the leaves from the stem, and at once separate them according to quality. The leaves should then be made into hands, i. e. 10–20 leaves should be tied together by twisting a leaf round the end of the stalks, each sort being attended by a special man, to avoid mixing. The leaves of the first sort being large, 10–15 will be sufficient for a hand; more are required of the other sorts. When making the hands of the two first sorts, each leaf is taken separately, smoothened on a flat board, and left there while another is treated in the same way, continuing thus until a sufficient number is ready to make a hand. When the hand is ready, it is laid aside, and a weight is placed upon it to keep the leaves smooth.

Bulking.—Bulking means placing the tobacco-leaves in heaps for the purpose of heating, in order to develop colour and flavour; this is carried out in various ways, nearly all involving great labour and risk, as in most instances tobacco loses more or less in value during the process called "curing." The more care is taken in raising the crop, the less attention the tobacco requires in the shed. With a good kind of tobacco, grown on light, friable soil, treated as described, little care will be needed, after the leaves are dried and stripped. By the drying process, the leaves will have undergone a slow fermentation, which makes it unnecessary to watch or guide a regular fermentation afterwards, hence bulking and fermenting, as generally understood, are not required.

After being made into hands, the tobacco is put into heaps (bulked) before it again dries. Every evening, the tobacco that has been stripped during the day is bulked; but if the weather be very dry, it must be bulked as soon as a certain number of hands is ready. The heaps should be made 4–8 ft. square and 4–8 ft. high; all the stalks are outside, and the whole is covered by mats, &c., to check evaporation. The drier the tobacco, the larger must the heaps be made, to encourage a slight fermentation. The extent of the fermentation can be easily controlled. If the colour of the leaves is not uniform, or if it is desired to give them a browner colour, the heaps must be made large, and a somewhat moist atmosphere is required in the storing-room. This will cause fermentation to set in after a short time, and the heat to rise after some days, so much so that rebulking is required, which is done by putting the top leaves of the old heap at the bottom of the new one. Under such circumstances, the heap must be frequently examined during the few first weeks, to prevent overheating. It is advisable to rebulk the tobacco also, even when not much heated, after the first fourteen days, and again a month later, to ascertain the exact state in which it is. Sometimes the tobacco becomes mouldy; this occurs especially with tobacco which has been manured with chlorides, which cause it to become more hygroscopic than when manured otherwise. If this occurs, the mould must be brushed off, and, if necessary, the tobacco be dried. The tobacco may now remain heaped in the store-room until there is a chance for sale. It must be remembered, however, that the best time for selling varies very much. Some tobacco is fit for smoking a few weeks after drying, whereas others may burn very badly at that time, yet become a good burning article after being stored for several months.

Packing.—Tobacco in America is commonly packed in barrels, the layers being at right angles to each other alternately, and the butt-ends being always towards the outside. The usual size is about 4 ft. 6 in. deep, 3 ft. 6 in. in diameter at one end, and 3 ft. 4 in. at the other, to enable the contents to be uncovered for examination without disturbing the mass. The packing is effected under considerable hydraulic pressure. Elsewhere all kinds of packages are employed, and their weights are very various.

Improving.—It is sometimes the custom to subject the tobacco-leaves to some sort of improvement. There is no doubt that, by proper application of ingredients, the value of tobacco may be much enhanced. The most costly tobacco often commands a high price, not so much on account of its inherent flavour, as from that given to it artificially. In most instances, the best course to be adopted is to leave the improvement of the leaves to the manufacturer. Many ingredients are employed to improve smoking-tobacco. They tend:—1, to make the tobacco more elastic and flexible; 2, to remove the coarse flavour; 3, to add a particular flavour; 4, to improve the burning quality; 5, to improve the colour. To make the tobacco more flexible and pliant, the leaves are macerated in, or sprinkled with, a solution of sugar. In hot countries, this process is often necessary, to give tobacco such an elasticity as to fit it for handling, especially when intended for wrappers. To remove the coarse flavour, it is often macerated in water, or in very dilute hydrochloric acid. In Holland, 4–8 oz. of hydrochloric acid, diluted with 25–30 measures of water, is applied to 100 lb. of tobacco. The coarser the flavour of the tobacco, the stronger is the solution used. The time of maceration varies between ½ and 1 hour. Sometimes tobacco is steeped in a mixture of sugar solution and diluted hydrochloric acid. To extract the fatty matter, it is macerated in alcohol or spirit of wine. To give a fine flavour, numerous substances are employed, some of which are kept secret. The following ingredients are mostly in use:—Water, cognac, vanilla, sugar, rose-wood, cassia, clove, benzoin, citron oil, rose-wood oil, amber, thyme, lavender, raisins, sassafras-wood, saltpetre, orange, and many others. The burning quality is improved by macerating in or sprinkling with solutions of carbonate of potash, acetate of potash, acetate of lime, or saltpetre, &c. Badly-burning cigars inserted for a moment in such solutions are much improved. Tobacco treated with acetate of lime yields a very white ash. The colour is sometimes improved by fumigating the leaves with sulphur, and by the application of ochre and saffron.

Although it may be said that fine tobaccos generally do not require any impregnation with foreign matter for the sake of flavour, yet the manufacturer frequently endeavours to give the leaf a particular aroma. An inferior tobacco, however, which often would not find a market, is sometimes so much improved by artificial means, as to compete successfully with the genuine fine article. It is said that in Germany indigenous tobacco is often so much "improved" that the cigars made from it, after being covered with a fine tobacco leaf, are sold as genuine Havanas. A special preparation of tobacco for snuff is seldom attempted by the cultivator. With reference to the preparation of tobacco for export, the sorting of the leaf is of the utmost importance; only first and second sorts should be exported. It would be well to remove the mid-ribs, whereby the cost of transport and customs duty would be greatly reduced.

The value of a cigar depends, not only on the intrinsic value of the leaf, but to a great extent on the mode of manufacture. Thus, the raw material may be of good quality, but if the maker does not classify the leaves properly, or if he rolls his cigars too hard, which must vary according to the qualities of the leaves, the cigar will burn badly. The best-burning leaves must always be used for wrappers. If this should be neglected, the inside of the cigar burns faster than the covering, the air has no access to the burning parts, and the empyreumatical substances are volatilized without being decomposed. Such cigars therefore make much smoke, and smell badly.

Production and Commerce.—Details concerning the different modes of cultivating and curing, and of the extent of the production and commerce in tobacco in the various countries, will best be given in the alphabetical order of the countries.

Afghanistan.—The tobacco grown at Kandahar is celebrated in all the neighbouring states for its mild and agreeable flavour, and is largely exported to Hindustan and Bokhara. Three kinds are grown, viz.;—Kandahari, Balkhi, and Mansurabadi. Of these, the last named is the most esteemed, and fetches the highest price, viz., 6 lb. for 2*s.*–4*s.* The Kandahari sells for a little less than half this price, and the Balkhi for a little more. The Mansurabadi is not much exported, being mostly consumed in the country. The cultivation is conducted with great care, and the same plants yield two crops of leaves in the year. Of these, the first, which is called *sargul*, is the best, the leaves having a mild and sweet flavour; it is mostly consumed by the wealthy classes, or exported. The second crop is called *mundhai*: the leaves have a tough and fibrous texture, and a strong acrid taste; it is usually smoked by the poor people, and is also made into snuff. The plants are raised from seed in small beds, prepared for the purpose by careful manuring with wood-ashes and stable-refuse mixed together. From these nurseries, the young plants are transplanted into the fields, previously prepared for their reception, the earth being laid out in regular ridges and furrows. The plants are fixed into the sides of these little ridges, and watered by means of the intervening furrows. Often the young plants, packed in moist clay, and bound up in straw, are conveyed to distant parts of the country; but the produce of these, it is said, does not equal that of the plants reared at Kandahar. About six weeks after transplanting, that is, about May–June, the first crop is reaped, the whole plant being cut away about 6 in. from the ground, and only some five or six of the lowest leaves being left. Each plant, as cut, is laid on the ridge, and here each side is alternately exposed for a night and a day to the effects of the dew and sun, by which their green colour becomes brown. After this, they are collected in large heaps in a corner of the field, and covered over with mats, or a layer of straw, &c., and allowed to remain so for 8–10 days, during which the stems shrivel, and give up their moisture to the leaves. At the end of this time, the heaps are conveyed away into the villages, where the stalks are separated from the leaves, the latter are then dried in the shade and tightly packed in bundles about 14 in. square, and in this shape are sold by the grower. After the first crop is gathered, the ground is turned with a spade, well manured, and freely irrigated. In due course, the old stems shoot up and produce fresh leaves, and in six weeks or two months, the second crop is cut. Sometimes, though seldom, a third crop is realized, but the quality of this tobacco is very inferior, and only fit for making snuff.

Africa.—The tobacco-plant extends throughout Central and E. Africa, wherever the equinoctial rains fall. It is cultivated to some extent in the Bondei of Usambara, but seems to be the special product of the Handei district, whence considerable quantities are sent to Pangani for export. Usambara also exports to Zanzibar stiff, thin, round cakes, which have been pounded in wooden mortars, and neatly packed in plantain-leaves. It is dark and well-flavoured. The Cape of Good Hope, in 1865, had 933 *morgen* (of 2·116 acres) under tobacco, yielding 1,632,746 lb.; in 1875, 1243 *morgen* afforded 3,060,241 lb. Tobacco is grown considerably in Oudtshorn and other districts of the Cape Colony, and on the warmer farms in the Transvaal, but to the greatest extent on the coast. The supply is already sufficient for local demands, and tobacco promises to become a staple of S. African agricultural industry.

Algeria.—Tobacco-growing is a very important industry in Algeria. The culture and manufacture are quite free, but the French Government buys all the best produce, for manufacture and sale by the State factory in Paris. The cultivation continues to increase, and is highly remunerative where the land is capable of irrigation. In 1876–7, the 1889 Europeans engaged in it cultivated 2471 *hectares* (of 2½ acres), and produced 2,782,500 *kilo.*; the 8021 natives cultivated 4154 *hectares*, which yielded 1,889,124 *kilo.* The year 1877–8 was less favourable, and the area decreased by 425 *hectares*. Still worse results were expected in 1878–9, owing to scarcity of water. The kind most grown is called *chebli*. The produce per *hectare* of fine and *chebli* is estimated at 6–8 *quintals*; the other kinds give 10–12. The exports in 1877 and 1878 respectively were as follows:—Manufactured, 121,090 *kilo.*, and 124,117 *kilo.*; unmanufactured, 3,445,441 *kilo.* and 1,509,266 *kilo.* In 1879, 1087 Europeans planted 3180 *hectares*, and gathered 1,226,181 *kilo.*; 11,079 natives planted 6584 *hectares*, and produced 1,384,802 *kilo.*; the exports were 2,481,218 *kilo.* unmanufactured, and 146,345 *kilo.* manufactured.

Australia.—In the year ending 31st March, 1879, New South Wales had 835 acres under tobacco, and the crop amounted to 7932 cwt. In the same year, Victoria cultivated 1936 acres, which yielded 15,662 cwt., valued at 43,853*l.* Queensland grew 36 acres of tobacco in 1879.

Austro-Hungary.—The manufacture and sale of tobacco is a Government monopoly in the Austro-Hungarian Empire, and the revenue thus derived is the most lucrative item of the indirect income of the State. The only tobacco-growing provinces of Austria are Galicia and Bukowina, producing about 4 million *kilo.* from 2900 *hectares*; and S. Tyrol, where 290 *hectares* yield almost 4 million *kilo.* of green tobacco. The respective approximate values of the two products are 18⅓ *florin* (of 1*s.* 11½*d.*) and 4⅝ *florin* per 100 *kilo.* The chief supplies are furnished by Hungary, which was once so noted for its tobacco, but the industry is now completely crippled by the fiscal regulations. The area (in acres) under cultivation fluctuates remarkably; in 1860, it was 679¼; in 1865, 68,141; in 1869, 843¾; in 1875, 26,817; in 1879, 7316. The total areas (in acres) under cultivation in the whole empire in 1876, 1877, and 1878 respectively were: 144,493, 148,126, 143,447; the yields in *kilos.*; 46,033,163, 44,164,038, 40,978,540; and the yield (in *kilos.*) per *joch* (of 1·43 acre): 445, 426, 408. Fiume, in 1877, exported by sea 2862 cwt. of manufactured tobacco; and by land, 31,200 cwt. of leaf, and 53,712 cwt. of manufactured. In 1879, it shipped 9900 *kilo.* of leaf tobacco direct to England.

Borneo.—Tobacco is grown in small quantities by the Dyaks and people of Bruni; but they are unskilful in its manufacture, though the flavour of the product of Bruni is much esteemed by Europeans. Under skilful management, and by introducing a better kind if necessary, it might become as profitable to this island as it now is to the neighbouring ones of the Philippines, Java, &c. The Dyaks might be more readily induced to cultivate this plant, the nature of which they know, than plants which are strange to them.

Brazil.—In Brazil, tobacco is chiefly cultivated in the provinces of Bahia, Minas, Sao Paulo, and Para. The town of Purificaçao, in Bahia, is the centre of an important district. The cultivation is increasing, and greater care is being taken in the preparation. The common up-country method is to pick the leaves from the stalks, dry them under the hut-roofs, remove the midribs, and spread them in superposed layers, amounting to 2–8 lb., for rolling together and binding with bark strips. These rolls are bound very tightly with cord, and left for several days, when the cord is replaced by strips of *jacitára*, the split stem of a climbing palm (*Desmoncus sp. div.*), and have a stick-like form 1½ in. in diameter. They are sold in *masas* of 4–6 ft. in length, but the tobacco is not considered good till it has fermented for 5–6 months, when it is hard and black, and shaved off as required for pipes, cigarettes, and cigars, the last made with wrappers of *tauari* bark (*Couratari guianensis*). The Tapajos tobacco is considered the finest in the Amazon valley. The export of tobacco from Bahia in 1877–8 was 17,272,678 *kilo.*, and in 1878–9, 18,149,201 *kilo.*, almost the whole being to Germany. Santos, in 1878–9, shipped 381,310 *kilo.* Bahia sends away immense numbers of cigars coastwise. Maceio exported 4336*l.* worth in 1876, but none in 1879.

China.—The chief tobacco-growing provinces of China are Chihli, Hopih, Hoonan, Szechuen, and Shingking. The use of tobacco is wide-spread and common, and considerable local trade is carried on in it. The exports from Amoy were 2573 *piculs* (of 133⅓ lb.), value 13,561*l.*, in 1877; and 3994½ *piculs*, value 17,936*l.* in 1878. Wenchow exported 27¾ *piculs* of leaf in 1878, and 321⅓ in 1879. The exports and re-exports from Hankow in 1878 were 65,070¾ *piculs* of leaf, and 46,241¾ of prepared. In 1879, Hankow exported and re-exported 63,180 *piculs* prepared, value 311,754*l.*, and 58,094 of leaf, value 118,534*l.* There is an immense supply from the provinces, and the leaf is fine in colour, texture, and fragrance, but though sent to America and England for cigar-making, the trade has not been remunerative. It is now used in cigarettes and various cut mixtures as "Turkish," but when better known, will be smoked on its own merits. Canton exported 1730¾ *piculs* in 1877, 1742¾ in 1878, and 2397 in 1879. The exports of leaf from Ningpo were 407 *piculs* in 1874, 571 in 1875, 211 in 1876, 530 in 1877, 378 in 1878, and 165 in 1879. Kiungchow exported 449¼ *piculs* of leaf in 1878; and 85½ *piculs*, value 136*l.* in 1879. Kiukiang exported 28,120½ *piculs* of leaf, value 35,678*l.*, in 1878; and 14,659 of leaf, and 802 of stalk, in 1879.

Chinkiang imported 13,328 *piculs* of leaf, and 1914 of prepared in 1879. Macao receives tobacco from the Hokshan district, and prepares it for exportation to Java, the Straits, and California, the annual export being about 10,000 *piculs*. The Newchwang imports of prepared native tobacco were 8052 *piculs* in 1877, 8354 in 1878, and 6630 in 1879. Shanghai, in 1879, imported 58,460 *piculs* of native leaf, 79,081⅓ of prepared, and 1187½ of stalk; and exported and re-exported 31,541 of leaf, and 29,672¼ of prepared. Taiwan imported 3017¼ *piculs* of prepared native in 1879. Tientsin exported 1047⅓ *piculs* native tobacco in 1878, and 693½ in 1879. Tobacco is grown in the hilly districts near Wuhu; the leaves are gathered in October, and sun-dried on wicker-work frames. The exports in 1879 were 597½ *piculs* of leaf, and 742 of prepared.

Cochin-China.—The culture of tobacco is extending in Cochin-China, and it is even said that a considerable quantity is exported to China, but it improves little in quality. The area reported to be under tobacco-cultivation in 1878 (including coffee) was 2361 acres.

Ecuador.—The tobacco-crop of Ecuador for 1879 was not so large as usual, owing to an unfavourable season. Esmeraldas, the most northerly port, and whence nearly all the tobacco shipments are made, despatched about 3000 *quintals* in 1879. Guayaquil exported 150 *quintals* in 1877, none in 1878, and 10 in 1879.

Fiji.—The Fiji Islands are well adapted to tobacco-culture. The natives produce a good deal, which nearly approaches the American leaf. With careful curing, it would find a market in England. The native product is rolled, which prevents its being made into cigars. Samples of leaf-tobacco in hands, raised from foreign seeds, exhibited very unequal qualities, and a tendency to revert to American forms, the Havana returning to the Virginian type. Cut up for smoking, they were deficient in flavour, but were considered satisfactory as a first experiment.

France.—The area occupied by tobacco in France in 1873 was 14,858 *hectares* (of 2½ acres), yielding at the rate of 12 *quintals* (of 220½ lb.). The amount of land authorized to grow tobacco in Pas de Calais in 1879 was 2100 acres, and the quantity furnished to the Government was 3,659,636 lb., the prices (per *kilo.*) paid by the Government being 1 *fr.* 45*c.* for 1sts, 1 *fr.* 12*c.* for 2nds, 88*c.* for 3rds, and 10–66*c.* for other inferior qualities. The number of plants grown per acre is about 17,000. The department Nord affords rather more than Pas de Calais.

Germany.—The total area of land engaged in growing tobacco in Germany in 1878 was about 44,520 acres; nearly two-thirds of this total was distributed among Rhenish Bavaria, Baden, S. Hesse, and Alsace-Lorraine. The total consumption of tobacco in the German empire in that year was 2,196,000 cwt. The home production was 596,776 cwt., the remainder being imported.

Greece.—The production of tobacco in Greece is about 4 million *okes* (of 2¾ lb.) annually. Patras, in 1878, exported 300 tons to Holland, Austria, and Turkey, at a value of 25–30*l.* a ton. The values of the exports from Syra, in 1879, were 3503*l.* to Great Britain, 2325*l.* to Turkey, 88*l.* to the Danubian Principalities, 236*l.* to France, 554*l.* to Austria, 436*l.* to Egypt, 1605*l.* to Russia; and in 1878, 1528*l.* to Turkey, 1875*l.* to Great Britain, 93*l.* to the Danubian Principalities, 441*l.* to Austria, 334*l.* to France, 266*l.* to Russia, 39*l.* to Egypt.

Holland.—There were 4117 acres under tobacco in Holland in 1878, which produced 3,132,875 *kilo.*

The imports of tobacco into Holland in 1878 were as follows:—Maryland, 5249, Kentucky, 500, and Virginian, 107 hogsheads; Java, 87,998, seed leaf, 100, Sumatra, 33,671 packages. In 1876 and 1877, there were 5900 and 3993 packages respectively from Rio Grande. The exports of leaf from Holland in 1879 were 3,900,000 *kilo.*

India.—An immense area is occupied in producing tobacco in India. In Madras, Dindigul is the great tobacco district, and cheroots are manufactured at Trichinopoli. The islands in the delta of the Godavari also yield *lunka* tobacco, the climate being suitable, and the plants being raised on rather poor, light soil, highly manured and well watered. Manilla seeds have been tried on the lower Palnai Hills, but the Wynaad has proved to be the best locality. In Bombay, the Kaira and Khandesh tobaccos are superior; altogether over 40,000 acres were under the crop in this presidency in 1871–2, and the exports were 3 million lb. Shiraz and Manilla seeds yield good plants in Gujrat, and Khandesh. The total areas under tobacco in 1871–2 were thus returned:—Bengal, about 300,000 acres; Punjab, over 90,000; Oudh, 69,500; Rungpore, 60,000 (affording the so-called "Burma cheroots"); Central Provinces, 55,000; Tirhoot, 40,000; Cooch Behar, 24,000; Mysore, 20,000; Dinagepore, 20,000; Purneah, 20,000; Behar, 18,500; Burma, 13,000; Monghyr, 9–10,000; Nuddea, 9–10,000. The best tobacco districts are said to be Sandoway and the island of Cheduba, in Arracan; Rungpore, in Bengal; and Bhilsa, in the Central Provinces. The results of many analyses of S. Indian tobaccos show that their ash seldom contains more than 5–6 per cent. of carbonate of potash, while American range from 20 to 40 per cent., indicating the poverty of the Indian soils in this important ingredient. It might, however, be supplied at moderate cost in the shape of saltpetre, which is actually exported largely from the tobacco-growing districts.

The bulk of the Indian tobacco exported consists of leaf, the kinds chiefly shipped being the "Bispah" and "Poolah" varieties of the Rungpore kind; the quantities of cigars and other manufactured tobacco exported are very small. The exports in lbs. for the last four years were:—

	1875–76.	1876–77.	1877–78.	1878–79.
Unmanufactured	22,861,711	10,508,720	10,594,604	13,279,158
Manufactured:				
Cigars	152,189	190,136	189,742	196,759
Other sorts	232,720	205,033	317,887	247,743
Total	23,246,620	10,903,889	11,102,233	13,723,660

On the other hand, a considerable quantity of manufactured tobacco, averaging over 1½ million lb. yearly, is imported, showing that India is still merely a producer of raw material, and is dependent upon other countries for the manufactured article in a condition fit for consumption. Even as regards the raw material, India might do a great deal more than at present, for there would be a large and constant demand on the continent of Europe for Indian leaf, if it could be obtained of somewhat better quality. The French and Italian tobacco departments are prepared to take Indian tobacco in large quantities, if it can be supplied of a quality suited to their purposes; and there would also be an extensive demand from Austria and Germany. Although the shipments consist mainly of leaf tobacco, and that not of good quality, tobacco-manufacture is now making a promising beginning. In the enterprise being carried on at Ghazipore, in the N.-W. Provinces, and at Poosah, in Bengal, both the cultivation and manufacture are under the supervision of skilled American growers and curers. Some of this tobacco sent to the *Administration des Tabacs* in Paris has been very favourably reported on. The factory at Ghazipore is now turning out about 500 lb. a day of all classes, the greater part being black cavendish and honeydew, for the army. The machinery is capable of turning out 3500 lb. a day, as soon as sufficient hands have been trained.

Hitherto no Indian tobacco has realized any valuation approaching that of American. The average price of the American "shipping tobacco" is 5–6*d.* a lb., higher classes of bright leaf from Virginia realize as much as 7–13*d.* a lb., while the price of Indian tobacco has generally been 1–2*d.* a lb. But the 15,000 lb. of Poosah leaf from the 1877 crop reached England when American shipping leaf was at 4–5*d.* a lb., or 25 per cent. below the normal rate. The consignment was, moreover, packed in rather damp order, and contained a quantity of moisture which caused it to be assessed under the highest rate of the new tariff, which imposes 3*s.* 10*d.* duty when the moisture is over 10 per cent., against 3*s.* 6*d.* under 10 per cent. This made a difference in the value, estimated at 1*d.* a lb. The price obtained was 3⅝*d.*, which would have been 4⅝*d.* had the tobacco been drier, and the sale has been followed by orders of large shipments.

The high prices, too, realized for the best samples of the 1876 and 1877 crops, indicate that Indian leaf can be turned out equal to the best shipping tobacco from America. A tierce of strips from the 1876–77 crop from Ghazipore sold for 7*d.* a lb., and the greater part of the rest for 5*d.* or more, while a portion of the Poosah leaf of 1877–78 was valued at 5*d.* when the market was 25 per cent. below normal rates. These facts seem to guarantee future success, since the quantity of the higher classes can be largely increased, and a greater portion of the crop be brought to the same higher level. The chief point to be ascertained was whether a sufficiently high level could be attained at all. It has been attained. The cured leaf of 1878 is very much superior to any hitherto turned out, especially that from Ghazipore. A new market is not unlikely to open in France. The French Government have already asked for a consignment for trial of 1000–1500 lb.

The reason why the manufacture of smoking tobacco for Indian consumption has occupied so large a share in the operations is, that the Indian market, though small, pays far more handsome profits than the English market. The price paid for reasonably good American manufactured tobacco in India ranges from one to three *rupees* a lb. Ghazipore and Poosah tobacco is sold at half that price, at a much higher profit than can be obtained by sending cured leaf to England.

While Indian cured leaf can find a sale in the English market at prices which will enable it to compete there with American cured leaf, Indian manufactured leaf is proved to compete successfully with American manufactured leaf in India itself, with a fair prospect of success in a similar competition in the colonies. It may be stated in general terms that 4*d.* a lb. for cured leaf in England, and 6–10 *annas* for manufactured leaf in India, will secure sufficient or even handsome profits. The opening for profits will perhaps be better understood if it is explained that 1*d.* a lb. represents an asset of about 5*l.* an acre. The one great advantage which India has over America is cheap labour. It is now proved that the leaf is, for all practical purposes, as good as the American leaf, and there is hardly any doubt that America cannot afford to send home leaf at the price at which India can sell.

The exports of tobacco from British India during the years 1874–5 to 1878–9 have been as follows :—

		1875.	1876.	1877.	1878.	1879.
Unmanufactured ..	lb.	33,411,504	22,861,711	10,508,720	10,594,604	13,279,158
Manufactured	lb.	425,040	384,909	395,169	507,629	444,502
	No.	2,999,940	..	..	..	..

Italy.—Tobacco is cultivated in Italy in the provinces of Ancona, Benevento, Terra di Lavoro, Principato Citeriore, Terra d'Otranto, Umbria, Vicenza, and Sardinia. The area and produce in the following years were :—in 1870, 9544 acres, 67,192 cwt.; 1872, 12,256 acres, 82,349 cwt.; 1874, 8202 acres, 90,300 cwt. The exports from Naples in 1879 were 2006 *kilo.*, value 401*l.*

Japan.—Japanese tobacco is well-known in the London market, but it is often in a soft condition, and then scarcely saleable. More care is needed in drying it before packing.

Java.—Tobacco, termed by the natives *tombáku*, or *sáta*, is an article of very general cultivation in Java, but is only extensively raised for exportation in the central districts of Kedu and Banyumas. As it requires a soil of the richest mould, but at the same time not subject to inundations, these districts hold out peculiar advantages to the tobacco-planter, not to be found on the low lands. For internal consumption, small quantities are raised in convenient spots everywhere. In Kedu, tobacco forms, after rice, by far the most important article of cultivation, and, in consequence of the fitness of the soil, the plant grows to the height of 8–10 ft., on lands not previously dressed or manured, with a luxuriance seldom witnessed in India. Cultivated here alternately with rice, only one crop of either is obtained within the year; but after the harvest of the rice, or the gathering of the tobacco-leaves, the land is allowed to remain fallow, till the season again arrives for preparing it to receive the other. The young plant is not raised within the district, but procured from the high lands in the vicinity, principally from the district of Kalibéber, on the slope of the mountain Diéng or Práhu, where it is raised and sold by the hundred to the cultivators of the adjoining districts. The transplantation takes place in June, and the plant is at its full growth in October. The exports in the year 1877–8 were 212,500 *piculs* to Holland, and 213 to Singapore; in 1878–9, they were 248,566 *piculs* to Holland, and 872 to Singapore. The value of the export to Holland in 1879 was stated at 1,250,000*l.*

Persia.—The whole of the eastern coast of the Black Sea, i. e. Mingrelia, Lazistan, Abkhasia, and Circassia, is admirably suited for tobacco cultivation. The country between Poti and Súkhúm Kalé contains admirable sites for tobacco-plantations, labour for which can be got from Trebizond. A great demand for tobacco of good quality exists in the country, and a practical planter should do well. A quantity of coarse, badly-cured tobacco, of no commercial value, is produced in Imeritia and Georgia. Great success has attended the culture in Ghilan. The first seed introduced was from Samsoun; since then Yenija seed has been tried, and some parcels attained the standard of the best Turkish tobacco. It can be produced at about 20*s.* a *pood* (of 36 lb.), giving a profit of

22*s.* a cwt. Hitherto the cultivation has been confined to the plains, where both soil and atmosphere are damp, but it might be worth trying the hill-skirts. About 2000 cwt. were produced in 1878. The exports of tobacco, the produce of Ghilan, from Resht to Russia were valued at 4615*l.* in 1878, and 6154*l.* in 1879. The values (in rupees) of the exports in 1879 were 13,000 from Bushire, 73,500 from Lingah, and 35,000 from Bahrein.

Philippines.—The soil and climate of the Philippines are eminently suited to tobacco-culture; but the unjust Spanish monopoly cripples the industry, and it is declining. Next to the Cuban (Vuelta abajo) and a few prime Turkish sorts, Manilla tobacco is admitted to be the best. Most of the Philippines produce it. According to the quality of the produce, the provinces rank as follows: —(1) Cayagan and Ysabel, (2) Ygorrotes, (3) Island of Mindanáo, (4) Bisayas, (5) New Ecija. On the average, over 400 million cigars, and a quantity of tobacco sufficient to bring up the total weight to 56,000 cwt., are annually exported. The advantage of the plantations in Cayagan lies in the annual deposit of alluvial matters by the overflowing of the large streams. The cultivation in Bisayas promises to become extinct, whereas if the natives were free to sell in the best market, the industry would increase immensely. The yield of the Cebu district in 1878 was 8780 *quintals*, the whole of which went to the cigar factories of Cadix and Alicante. The exports from Manilla were:—in 1877, 17,526,700 lb. tobacco, value 525,801*l.*; 87,007,000 cigars, value 243,619*l.*; 1878, 15,630,400 lb. tobacco, value 468,918*l.*; 136,835,000 cigars, value 383,136*l.*; 1879, 9971 *quintals* (of 101½ lb.) tobacco leaf to Great Britain, and 74,490 *quintals* to Spain; cigars, 10,571,000 to Great Britain, 6,557,000 to Australia, 44,586,000 to the Straits Settlements and India, 25,861,000 to China and Japan, 693,000 to the United States, 100,000 to California, 1,521,000 to Spain and the Continent; the total values amounted to 480,263*l.* The exports of tobacco from Yloilo were 25,454 *piculs* (of 133⅓ lb.) in 1878, and 20,600 *quintals* (of 101½ lb.) in 1879, all to Spain.

Servia.—It is estimated that there are 4000 acres under tobacco-culture in Servia.

Spain.—The port of Cadiz is a great centre of the tobacco industry. The imports here in 1878 were:—123 *kilo.* from Germany, 304,538 *kilo.* from the United States, and 6,776,900 *kilo.* from Spanish colonies; the exports were 15,600 *kilo.* to Germany, and 213,846 *kilo.* to France.

Turkey.—The Turkish Empire has long been known as producing some of the finest tobaccos in the world. In the sanjac of Drama, which forms the vice-consular district of Cavalla, tobacco is the staple article of production and industry, and some 75,000 acres were devoted to its culture in 1873. The whole crop of 1871 was reckoned at 11,200,000 lb., the exports having been 7,600,000 lb., value 37,825*l.* The tobacco of this district, though derived entirely from one species, is divided into two classes, known as *Drama* and *Yenidji*. The former leaf is larger, stouter, and more potent, and generally of deep reddish-brown colour; the latter is smaller, slighter, less narcotic, with a peculiarly delicate aroma, and the best is of a rich yellow colour, whence its name "golden-leaf." The *Drama* kind is principally grown in the western portion of the district, and is the class supplied to European markets. The differences in the two kinds seem to be due solely to the soil.

The plantations in the Drama district proper occupy both plain and hill-side. The produce of the former is much the more considerable, and superior. The best leaves, distinguished by a stronger and more substantial texture, and a dark-red hue, go to Constantinople; the inferior and lighter-coloured find a sale in Russia. The mountain product is much inferior in quality and is sent chiefly to Europe. When the leaves are petiolate, or furnished with stems, they are made up in *manoks* ("hands") of 10–15, and termed *bashi-baghli* ("head-tied"); when the leaves are sessile, or devoid of stems, they are simply pressed together in small numbers, and called *bassma*. The whole produce of this locality varies from 2,100,000 to 2,450,000 lb. yearly. The growth obtained in the Vale of Pravista is known as *Demirli*. It is inferior, unsubstantial, and dark-coloured, and usually made up as *bashi-baghli*. The annual production is about 2 million lb.; the exports to England were 1,600,000 lb. in 1871. Cavalla affords yearly about 300,000 lb. of inferior quality, chiefly as *bashi-baghli*, and mostly consumed locally. The shipping port for all these places is Cavalla.

The district of Sarishaban produces on the average about 2,000,000 lb. annually, but the crop of 1871 reached 2,800,000 lb. About ⅞ is as *bashi-baghli*. That grown on the plain and hills is termed *ghynbek*, and forms the bulk; that from the slopes, about 500,000 lb. a year, is the best, and is known as *ghubek*. All is packed up in small *boghchas* (parcels), of 30–50 lb., which are distinguished as *béyaz*, from the white cotton wrappers used for the best sort, and *kenavir*, from the canvas coverings of the inferior kinds. The best goes to Constantinople, secondary to Smyrna and other home markets, and the worst to Europe. The district of Yenidji, near the Gulf of Lagos, affords some 3,500,000 lb. per annum, chiefly as *bassma*, and bearing a very general resemblance to the produce of Sarishaban. The best goes to Constantinople and Russia. Ghiumirgina (Ghumurdjina, or Komuldsina), grows about 300,000 lb. yearly of dark-coloured *bassma*, of the *Drama* class, which is used locally; and Sultan-Yeri gives 400,000 lb. of still darker *bashi-baghli*. The produce of these districts is shipped at Lagos (Karagatch) or Cavalla.

The most delicate and valued of all the tobaccos raised in this portion of European Turkey is the celebrated "golden leaf" from the caza of Yenidji, on the Vardar (Nestus) river. After it, in declining order, come the products of Drama, Persocciso, Sarishaban, Cavalla, and Pravista. Of the whole Drama and Yenidji produce, it is estimated that Austro-Hungary takes 40 per cent. Italy buys annually about 150,000–200,000 kilo. France, Germany, and Switzerland receive very little. Russia is a large customer. Before the war, considerable quantities were sent to the countries on the Lower Danube. England imports every year some 10,000 bales, or 400,000 *okes* (of 2·83 lb.) of Pravista tobacco. The *refusa*, or waste leaves, &c., is sent everywhere for making into cigarettes, most largely perhaps to Egypt. A kind of tobacco known as *ayiasoulouk* is grown in considerable quantities in the opium districts, almost exclusively for export to Europe, the natives having a strong prejudice against it.

The necessity for manuring is well understood by the Turks. They dress the seed-beds with goat- and sheep-dung, and manure the fields during winter with horse- and cattle-dung. In the spring, sheep and goats are folded on the land. The soil of tobacco lands will be found quite impregnated with ammonia and nitrate of potash, both absorbed by the plant; the former is thought to influence the aroma, and the latter may be seen in crystals on the surface of the dried leaf. In order to keep the leaves small and delicate, the planting is performed very close, the usual distances being 5 in. apart, and 9 in. between the rows.

The district of Latakia, in the northern part of Syria, has long been celebrated for its tobacco, which is the chief product of the mountainous part. There are several kinds:—(1) *Abu Riha* or *Dgebeli*, found in its best state among the mountains of the Nesseries (Ansaries), which possesses a peculiar and much admired aroma, derived from its being exposed, from November to April, to the smoke of fires of *ozer* (*Quercus Ilex*, or *Q. Cerris*); (2) *Dgidar*, including a number of kinds, of medium strength, and in great favour locally on account of its low price; (3) *Scheik-el-Bent*, almost equal to *Abu-Riha*, and often substituted for it.

The plain of Koura is remarkable for its tobaccos, which are rather strong, but much admired. The villages of Lebail and Serai produce better tobacco than Koura. The district of Gebail (Gebel) in Kesrasan (Castravan) affords the best and dearest tobacco in Syria; it is very brittle, and its ash is quite white. The country south of Lebanon yields very ordinary qualities, known as *Salili*, *Tanoné*, and *Takibé*, or generically as *Berraoni*; these are mixed with stronger kinds for use. The best of the *Abu-Riha* is yielded by the plant called *Karn-el-Gazel*; the second quality is termed *Bonati*.

The exports of tobacco from Alexandretta in 1879 were:—To Egypt, 91 tons, value 6380*l.*; Turkey, 24 tons, 1920*l.*; England, 51 tons, 2550*l.*; France, 1 ton, 80*l.* The exports from Aleppo in 1878 were 30 tons, value 1200*l.*, to Great Britain. The yield of the crop in Thessaly was 1,116,000 *okes* (of 2·83 lb.) in 1877, 210,000 in 1878, and 890,000 in 1879. The crop of Prevess in 1878 was 4000 *okes*, value 215*l.* The exports from Dedeagatch were about 260 bales, value 1000*l.*, in 1878; and 600 bales, value 2400*l.*, in 1879. Considerable quantities are grown around Sinope. Tobacco is one of the principal products of the district of Samsoun, and is of good quality. The average yield is 7,000,000 lb. yearly. It is grown near the sea-shore, and not eastward of Yomurah, at Matchka and Trebizond, and especially at Akché-Abad. But the aggregate crop in these localities is hardly ⅓ of the quantity produced at Samsoun, and the quality is far inferior. The Samsoun product is usually purchased largely on account of the French Government. The exports from Samsoun in 1878 were:—To Turkey, 2,680,000 *kilo.*, value 160,800*l.*; France, 583,500 *kilo.*, 28,008*l.*; Russia, 575,000 *kilo.*, 57,500*l.*; Germany, 400,000 *kilo.*, 7200*l.*; Austria, 327,220 *kilo.*, 31,266*l.* Great Britain, 87,567 *kilo.*, 1576*l.*; total, 4,653,287 *kilo.*, 286,350*l.* The exports of Turkey-produced tobacco from Trebizond in 1879 were:—To Turkey, 14,864 cwt., value 44,592*l.*; Russia, 866 cwt., 2598*l.*; Great Britain, 490 cwt., 1470*l.*; Austria and Germany, 204 cwt., 612*l.*; total, 16,424 cwt., 49,272*l.*

United States.—The United States of America occupy the foremost rank among tobacco-growing countries. The areas and productions have been as follows:—1875, 559,049 acres, 379,347,000 lb.; 1876, 540,457 acres, 381,002,000 lb.; 1877, 720,344 acres, 489,000,000 lb.; 1878, 542,850 acres, 392,546,700 lb. The crop of 1875 (in millions of lb.) was thus contributed:—Kentucky, 130; Virginia, 57; Missouri, 40; Tennessee, 35; Maryland, 22; Pennsylvania, 16; N. Carolina, 14¾; Ohio, 13½; Indiana, 12⅔; Connecticut, 10; Massachusetts, 8½; Illinois, 8. The average yields (in lb. per acre) of the various districts in 1875 were:—Connecticut, 1600; Pennsylvania, 1600; New Hampshire, 1600; Massachusetts, 1350; Missouri, 850; Arkansas, 822; New York, 800; Florida, 750; Ohio, 700; W. Virginia, 680; Maryland, 675; Tennessee, 675; Kansas, 670; Texas, 650; Kentucky, 630; Virginia, 630; Illinois, 550; Georgia, 550; N. Carolina, 500; Indiana, 500; Wisconsin, 500; Alabama, 465; Mississippi, 317. The exports from New York in 1878 were:—37,484 hogsheads, 2561 bales, and 2,218,200 lb. manufactured, to Great Britain; 15,570 hh., 207 bales, and 14,800 lb. manufactured, to France; 35,700 hh., 78,331 bales, and 147,400 lb. manufactured, to N. Europe; 23,150 hh., 6058 bales, and 120,000 lb. manufactured, to other Europe; 4628 hh., 14,360 bales, and 4,780,200 lb. manufactured, to S. America, E. and W. Indies, &c.

Baltimore exported 66,039 hh. in 1878. The shipments from New Orleans in 1877–8 were:—1226 hh. to Great Britain, 743 to France, 4552 to N. Europe, 3222 to S. Europe, Mexico, &c., and 4500 coastwise. Philadelphia, in 1879, exported 9,564,171 lb. of leaf tobacco, 52,000 cigars, and 515 lb. of snuff. The total American export of unmanufactured leaf in 1879 was 322,280,000 lb.

W. Indies.—The Spanish possessions in the W. Indies are well known for their tobacco. The best is produced on the *vuelta abajo*, or low-lying districts of Cuba, near Havana, which are yearly flooded during the autumn, just before the tobacco is transplanted. To this fact, and the peculiar suitability of the seasons, the excellence of this particular product is attributed. The exports from Havana in 1878 were:—93,603 bales tobacco, 75,212,268 cigars, 203,581 bundles cigarettes, to the United States; 6169 bales tobacco, 66,795,330 cigars, 5,034,774 bundles cigarettes, to England; 32,582 bales tobacco, 9,541,498 cigars, 133,008 bundles cigarettes, to Spain; 582 bales tobacco, 3,861,700 cigars, 8206 bundles cigarettes, to N. Europe; 5671 bales tobacco, 18,327,025 cigars, 797,513 bundles cigarettes, to France; 41 bales tobacco, 900,850 cigars, 5,709,442 bundles cigarettes, to other countries. The totals for 1878 were 7,078,904 *kilo.* of tobacco, 182,356 thousand cigars, and 12,816,903 packets of cigarettes; in 1879, 6,371,014 *kilo.* of tobacco, 145,885 thousand cigars, and 14,098,693 packets of cigarettes. The tobacco exports in 1879 from St. Jago de Cuba were 9653 bales to Bremen, 4015 to the United States (chiefly for Bremen), and 1809 coastwise, total 15,477, against 10,249 in 1878. In the island of Puerto Rico, the tobacco-plant thrives well, and the quality, especially in the Rio de la Plata district, is very good. In 1878, the island exported 8 *quintals* (of 101½ lb.) to the United States, 32,109 to Spain, 4198 to Germany, and 18,123 to other countries.

The British W. Indies have only recently appreciated the importance of tobacco cultivation. Many portions of Jamaica seem as well fitted for it as the *vuelta abajo* of Cuba, and already Jamaica tobacco in the Hamburg market ranks next to the best Havana, and is considered superior to such Cuban growths as St. Jago, Manzanillo, Yara, &c. Tobacco-cultivation may now be said to have a place in the industries of Jamaica, a fact mainly due to Cuban refugees. The most extensive plantations in the island are Potosi in St. Thomas Parish, and Morgan's Valley in Clarendon. Much of the produce goes to the German market, the remainder being made into cigars for local consumption, and said to be quite equal to some of the best Cuban brands. Some experiments made with Bhilsa tobacco have given great satisfaction, on account of the robust habit and immense yield of the plant. It is especially adapted for very wet districts, and its cultivation will be widely extended, if justified by its market value. Tobacco is, and for very many years has been, grown by the peasantry in small patches; from this, they manufacture a smoke-dried leaf, which, twisted together in rope form, sells readily in the home market. The acreage occupied by the crop was 297 in 1874–5, 442 in 1875–6, 331 in 1876–7, and 380 in 1877–8. The slopes of valleys in many parts of Dominica, too, are eminently suited to this crop, particularly the district between Roseau and Grand Bay. The experiment of tobacco-culture in New Providence on a large scale has not proved satisfactory, owing to the difficulties encountered in curing and preparing the leaf; the cigars made are fit only for local consumption.

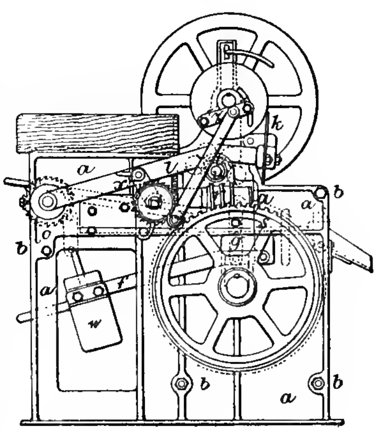
Preparation and Use. Manufacture of Cut-, Cake-, and Roll-tobacco; Cigars, Cigarettes, and Snuff.—It is impossible to indicate the precise form in which each kind of tobacco-leaf is manufactured for use; indeed, no well-defined line marks the qualifications of each sort, and the great art of the manufacturer is to combine the various growths in a manner to produce an article suited to the tastes of his customers, at a price suited to their pockets. But, in a general way, it may be said that Havana and Manilla are probably exclusively consumed in the form of cigars; Virginia is a favourite for cavendish, negrohead, and black twist, and is largely converted into returns, shag, and snuff; Kentucky, Missouri, and Ohio are used for cavendish, brown twist, bird's-eye, returns, and shag; Dutch and German make the commonest cigars, k'naster, moist snuffs, and smoking-mixtures; Java and Japan are selected for light cigars, mixtures, and light moist shag; Latakia, Turkey, Paraguay, Brazil, China, and the remainder, are used up in cigarettes, mixtures, imitations, and substitutes.

Damping.—The tobacco-leaves are received by the manufacturer in all kinds of packages, from a hogshead to a seron (raw hide), and of all weights from 1 to 12 cwt. The first process they undergo is "damping," which is necessary to overcome their brittleness, and admit of their manipulation without breaking. For this purpose, the bunches ("hands") are separated, and the leaves are scattered loosely upon a portion of the floor of the factory, recessed to retain the moisture. A quantity of water, which has been accurately proportioned to the absorbing qualities of the leaf used, and to the weight present, is applied through a fine-rosed watering-pot, and the mass is left usually for about 24 hours, that damped on one morning being ready for working on the following morning. In England, water alone is admissible (by legislative enactment) for damping, except in special cases to be noted subsequently; but abroad, many "sauces" are in vogue, their chief ingredients being salt, sal ammoniac, and sugar.

Stripping and Sorting.—Quantities of leaf-tobacco are shipped in a condition deprived of their stem and midrib, and are then known as "stripts." Those which are not received in this state, after having been damped, are passed through the hands of workmen, who fold each leaf edge to edge, and rip out the midrib by a deft twirl of the fingers, classifying the two halves of each leaf, and ranging the sorts in separate piles as smooth as possible. The value of the leaf greatly depends upon the dexterity with which the stripping is done, as the slightest tear deteriorates it. Stripts require sorting only. The largest and strongest leaves are selected for cutting and spinning; the best-shaped are reserved for the wrappers of cigars; broken and defective pieces form fillers for cigars; and the ribs are ground to make snuff. For the manufacture of "bird's-eye" smoking-tobacco, the leaves are used without being previously stripped.

Cutting.—Cutting is the process by which the damped leaves, whether stripped or not, are most extensively prepared for smoking in pipes and cigarettes. The tobacco-cutter which is in general use in this country is shown in Figs. 1001 (side elevation), 1002 (sectional elevation), 1003 (front elevation), and 1004 (plan). The main frames *a* are united by stretcher-bolts *b*; *d* is a wooden-surface feeding-roller, on which the tobacco is pressed and cut; *c* are the upper compressing- and feeding-rollers, mounted in *e*, carriage-plates extended backwards, forming the sides of the feeding-trough, and hinged to the axle *m*; *f* are levers; *g*, links by which the weight *w* presses down the upper rollers; *h*, a crank, and *i*, a connecting-link for working; *j*, the cross-head to which the knife *k* is fixed; *l*, side-levers or radius-bars for guiding the knife, hinged on the eccentric ends of the axle; *m*, an axle held in bearings at the back of the machine; on its middle part, which is concentric with its own bearings, are hinged the top roll carriage-plates *e*, whilst on its projecting ends, which are slightly eccentric, the knife-levers *l* are hinged; *n* is a worm-wheel segment; *o*, a worm; *p*, a hand-wheel for turning the eccentric spindle *m* through a part of a revolution in its bearings, for adjusting the contact of the knife with the nose-plate *q*; *r*, a worm; *s*, a worm-wheel; *t*, a worm-pinion for giving simultaneous movement to all the rollers; *u*, a spindle, "universal jointed" at both ends, for driving the upper rollers in positions varying with the thickness of the feed; *v*, a saw-toothed ratchet-wheel, moved intermittently by a catch *x*, link *y*, and stud-pin *z*, *v* being changeable, and the eccentricity of *z* variable, for the purpose of regulating the fineness of the cutting. Both ends of the knife move at the same speed, and its surface is made to clear the work by describing a slight curve. The knife is adjusted accurately to the nose-plate, while the machine is in motion, by varying the direction of eccentricity of the axis of the knife-levers to that of the roller-levers. The fineness of the cutting is regulated by varying the eccentricity of a movable stud-pin in a plate on the crank-shaft which gives motion, through a train of speed-reducing gear, to the several rollers. The

1001.



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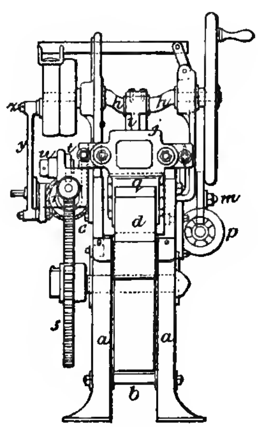
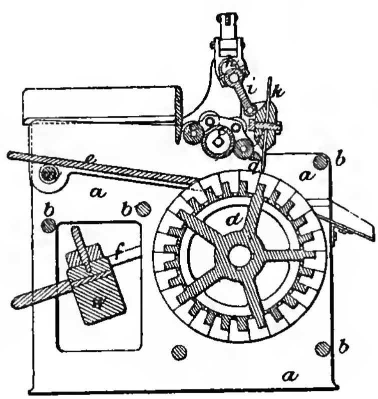
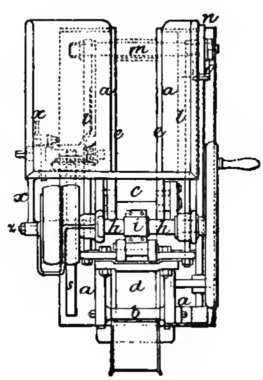




1002.



1004.

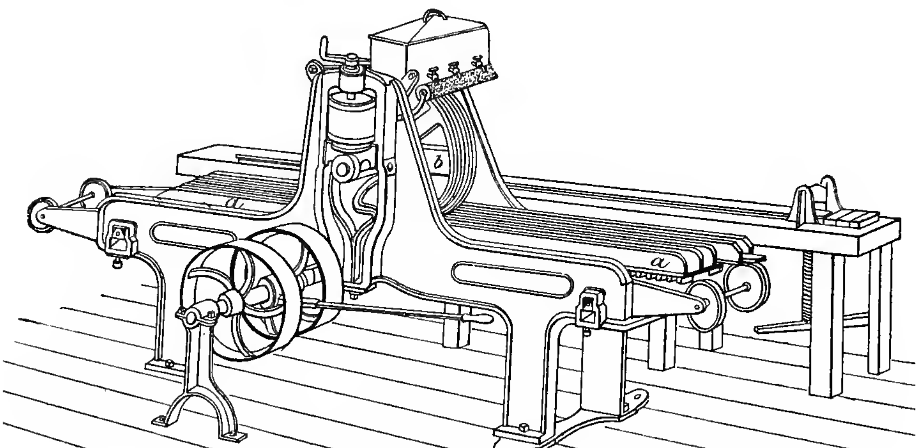
knives are easily removed and replaced, and require sharpening after every 4–6 hours' working. Two men attend the machine, one to keep the feed-rollers supplied, the other to watch that the knife is doing its work, and to remove the tobacco as fast as it is cut.

Drying.—The cut tobacco, as removed from the machine, is placed loosely in a layer several inches deep in a large trough, provided with a canvas false bottom; steam is introduced between the true and false bottoms, and finds its way up through the tobacco, which is thus rendered more easily workable. It is next transferred to a similar trough having no false bottom, but a steam-jacketed floor instead; here the tobacco is dry-heated, and at the same time lightened up by hand. Finally, it is taken to a third trough, where cold air is forced through the canvas false bottom, by means of a blower or fan. This last operation dries the tobacco ready for use in the course of some hours; but it has the disadvantage of dispersing part of the aroma, and is therefore generally resorted to only when time presses. In other cases, the drying is conducted on canvas trays. However performed, the drying operation needs the greatest attention, to prevent the moisture being extracted to such a degree as to destroy the profit which its presence confers upon the manufacturer. With drying, the preparation of cut tobacco for smoking in pipes is completed.

Cake or Plug.—The manufacture of "cake" or "plug" is little carried on in this country, as the Excise laws exclude the use of sweetening matters, except when carried on in bond. The process is sufficiently simple. Virginian leaf, with or without the addition of flavourings, is sweated for a day or two, to deepen the colour, worked into a soft mass, and next placed in moulds, and subjected to sufficient pressure to ensure the cohesion of the mass. Each cake is then separately wrapped in perfect leaf, and passes through a series of moulds, each smaller than the last, and under increasing pressure in steam-jacketed cupboard-presses, of which there are many forms. The combined effect of the heat and pressure is to thoroughly impregnate the whole mass with the natural juices of the leaf and the flavouring (if any has been used), and to produce a rich dark colour.

A machine for turning out plug-tobacco in ribbons, made by the McGowan Pump Co., New York, is shown in Fig. 1005. The tobacco is first weighed out in the proper quantities, and spread

1005.

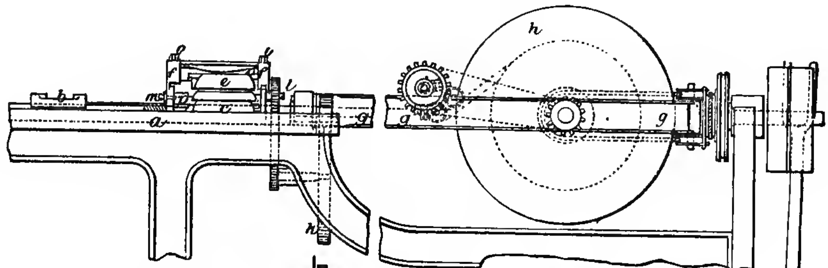


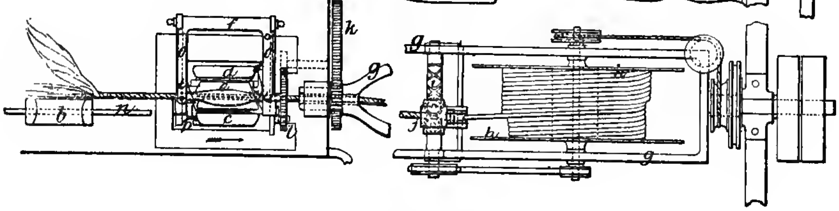
in a box placed in spaces in a heavy iron table *a*. When the latter is filled, it is passed to and fro under the heavy iron wheels *b*, which are loose on the shaft, and which can be adjusted to exert any desired pressure. Twice passing through suffices. The ribbon is made in lengths of 10 ft., and either $5\frac{3}{4}$ in. or $2\frac{7}{8}$ in. wide, as desired.

Roll or Twist.—Roll- or twist-tobacco is made by spinning the leaf into a rope, and then subjecting it to hot pressure. Until recently, the spinning was performed by hand, much after the manner of ordinary rope-making by hand. But this slow process is now superseded by a machine made by Robinson and Andrew, of Stockport; it is spoken of in very favourable terms by English manufacturers, and received a diploma of merit at the Philadelphia Exhibition. The machine consists of a combination of 3 rollers, whose surfaces are made of segments, to which lateral to-and-fro motions are given by cams attached to the stands on which the axles of the rollers rotate. The tobacco occupies the central space between the 3 rollers, and it is carried through the machine by the lateral to-and-fro motions given to the segments. The fillers and wrappers are laid on a table joined to the machine. The filler is placed in the cover, and they pass together between the rollers, whose action twists and compresses the tobacco into a roll; this is carried forward and wound on a bobbin, revolving in an open frame, and provided with a guide for equalizing the distribution of the tobacco.

The machine is shown in Figs. 1006 (elevation), 1007 (plan), and 1008 (end view). The tobacco is laid on the table *a*, provided with a rib *n*, on which the sliding rest *b* is free to move to and fro; *c d* are the two lower segmental rollers, the axles of which revolve in stationary bearings; *e* is the top

1006.



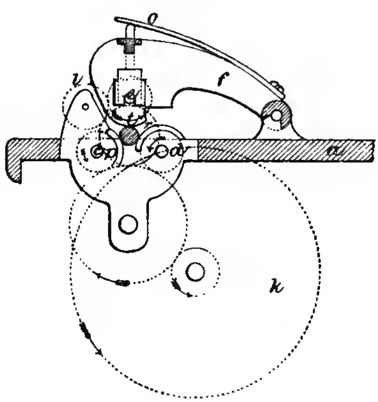


1007.

roller, the axle of which revolves in sliding bearings, fitting in the swing-frame *f*, and each acted upon by a spring *o*, pressing on a pin communicating with the bearing, and putting an elastic pressure on the tobacco.

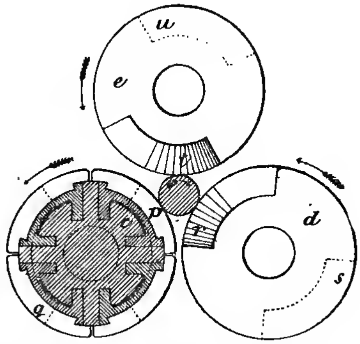
Each segment-roller consists of an axle with four segments, best shown in Figs. 1009 and 1010. The outer shell of the segments is made of hard wood, fitting an inner shell of malleable cast-iron, the projections on which suit grooves on the cast-iron axle. The segments of the rollers *c d* are moved laterally to and fro by the wedge-shaped cams *p q r s*, fixed to the bearings of the roller-axles; and the segments of the roller *e* are moved in the same manner by cams *t u*, fixed to the swing-frame *f*. The tobacco occupies the central space between the 3 rollers, and the cams *p r t* move the segments in the direction of the arrow where they touch the tobacco, while the cams *q s u* move them back. After the tobacco has passed beyond the segment-rollers, it goes through the hollow trunnion of the open frame *g*, in which the bobbin *h* revolves; the other trunnion of the frame *g* is provided with fast and loose pulleys, by which the whole machine is driven. To this trunnion, are also fixed an ordinary friction-break pulley, and a grooved pulley, around which latter passes a band for driving the pulley on the axle of the bobbin *h*. To the other end of the axle of the bobbin, is fixed a pinion, which, by means of a toothed chain, gives motion to another pinion fixed to the double screw *i*; this double screw gives a traversing to-and-fro motion to the guide *j*, for distributing the tobacco evenly on the bobbin, by means of a swivel T-headed stud, connected with the guide, and taking into the thread of the double screw. The guide is provided with two horizontal grooved rollers, between which the tobacco passes, and with two other rollers to guide the tobacco on to the bobbin.

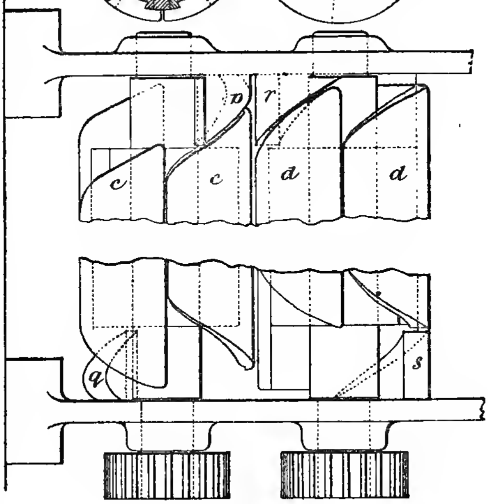
1008.



Rotary motion is communicated to the segment-rollers *c d e* as follows:—To the hollow trunnion of the open frame *g*, is affixed a pinion, which drives the wheel *k*, on the same shaft as the change-pinion that drives the wheel gearing into the pinions on the axles of the rollers *c* and *d*, and one of which pinions gears into the intermediate pinion *l*, which drives the pinions on the axle of the roller *e*. The-driving strap is held upon the fast pulley by a drop-catch acting on a weighted lever, one arm of which is connected by a link to the lower end of a strap fork-lever. When it is requisite to stop the machine, the attendant kicks the point of a catch off the end of the lever, which is then raised by the weight, and so moves the driving-strap from the fast to the loose pulley, the stoppage being virtually instantaneous. The mode of working is as follows:—The spinner and assistants stand at opposite sides of the table; the fillers and wrappers being placed on the table, one assistant spreads out the wrapper and pushes the end towards the filler, which the spinner supplies and holds against the sliding rest *b*; the rotary motion of the segment-rollers *c d e* twists the tobacco, and causes the wrapper to be wound over the filler, and the rest *b*, being movable, enables the spinner to regulate its position according to the quantity and quality of the filler and wrapper. The lateral motion of the segment-rollers passes the roll towards the bobbin, on which it is wound, as described. The combined rotary and traversing motions of the rollers consolidate the tobacco, and put the desired face upon the twist. The roller *e* is supported in a swing-frame, which is lifted off the tobacco when starting the machine. When the machine is at work, the swing-frame is held down by the stud *m* (Fig. 1006). The figures represent a machine suitable for manufacturing Limerick roll; for pigtail and other small descriptions, it is necessary to reduce the diameter of one or more of the segment-rollers.

1009.





1010.

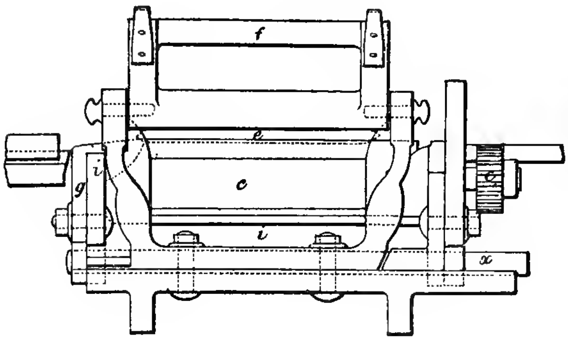
A more recent improvement in this machine, by J. E. A. Andrew, is shown in Figs. 1011 (side view), 1012 (transverse section), and 1013 (plan). The table *a*, rib *n*, and sliding-rest *b*, and two lower segment-rollers *c d*, are constructed as usual; but the axles of the segment-rollers revolve in bearings *g h*, bolted to the flanges of swivel-frames *i k*, hinged upon the fulcrum-shaft *x*; the object of thus supporting the bottom rollers *c d* is to be able to vary the distance between them according to the thickness of the twist of tobacco that is being rolled. When the distance between the rollers is fixed, the bearings are secured by bolts passing through segmental slots. The solid top roller *e* revolves in centres in sliding bearings fitting in the swing-frame *f*.

As the bobbin is filled, it is removed, and replaced by an empty one. The rope is then unwound, and formed into rolls, by the aid of a spindle with flanges at the sides, worked by a treadle, under a cushioned weight which squeezes the coils closely together as they are wound. The completed rolls are subjected to great pressure in steam-jacketed presses, in the same way, and with the same object, as the cakes or plugs.

Cigars.—Cigars are composed of two parts, a core formed of pieces of leaf placed longitudinally, known as "fillers," and a covering formed of perfect leaf, called the "wrapper." Probably all the best cigars are made by hand, the only tools required being a short-bladed sharp knife, a receptacle containing an emulsion of gum, and a square wooden disc or "cutting-board." A portion of perfect leaf is first shaped to form the wrapper of the cigar; then a bunch of fillers is moulded in the hand, and rolled up tightly in the wrapper, the taper end being secured by gumming. Expert workmen make the cigars remarkably uniform in weight and shape. When made, they are sorted according to colour, deftly trimmed at the thick end, and placed in their boxes in cupboards heated by gas-stoves to finally dry or season before being stored for sale.

In America, machinery is introduced wherever possible. Moulds for shaping the cigars are made of hard wood, sometimes partially lined with tin, and of every possible size and form. A machine is made by Dubrul and Co., of Cincinnati, for working 3 sets of moulds at once, 2 being kept filled up under pressure while the 3rd is being filled, or the bunches are being rolled up. A handy little machine for rolling the fillers for cigars is that known as Henneman's, made by Dubrul

1011.



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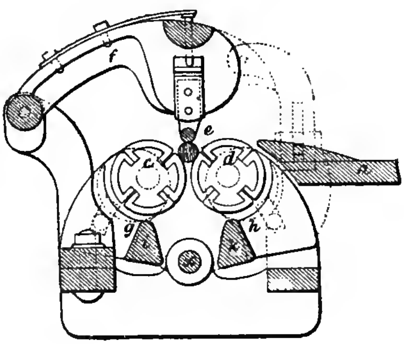

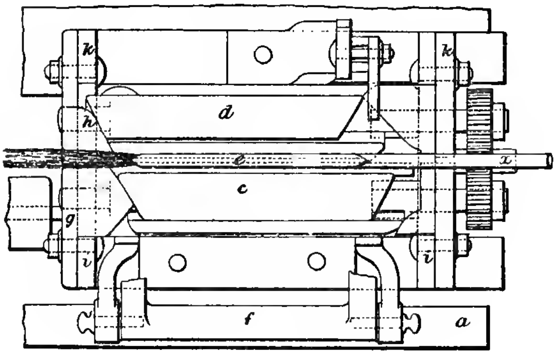

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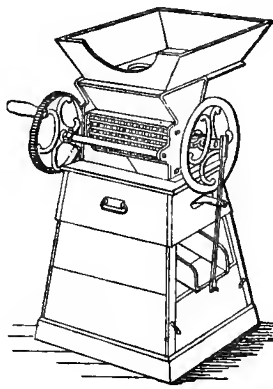


1014.

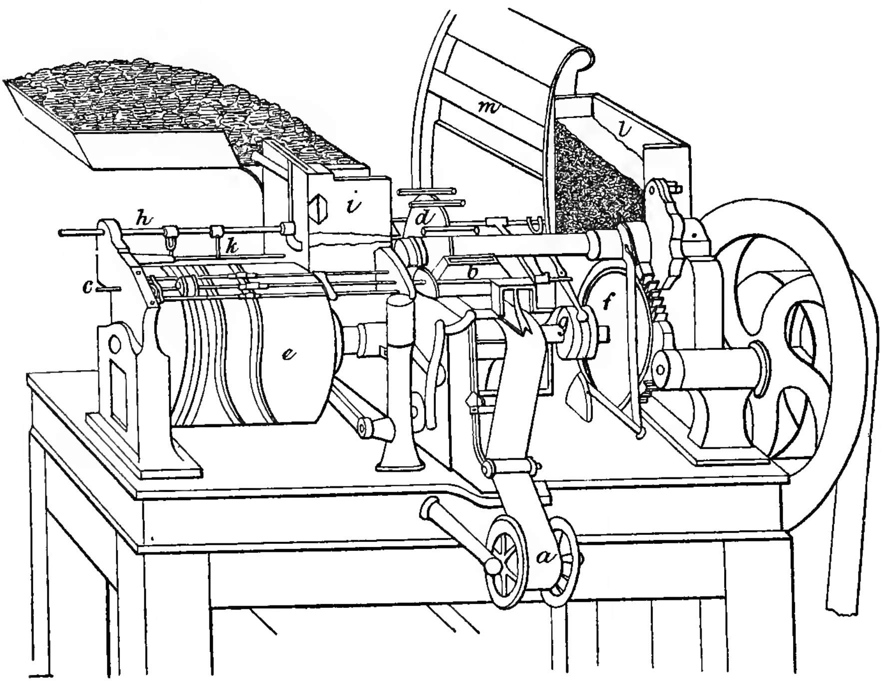
and Co. The demand for scrap-made cigars, or those manufactured with short fillers, has caused the introduction of machines for cutting and sifting scrap. One made by Dubrul and Co. is shown in Fig. 1014. It consists essentially of a cylinder formed of hook-shaped, double-edged steel blades, revolving against 3 series of fixed but adjustable steel blades, thus permitting the size to be regulated at will.

Cigarettes.—Cigarettes consist of paper tubes filled with cut tobacco, with or without an external wrapper of leaf tobacco. Preference is usually given to those made by hand, but machines have been introduced with some success for making the commoner kinds. A French machine for making cigarettes is shown in Fig. 1015. Its work consists in making the paper tubes, and filling them with tobacco. The paper, previously prepared, in a band about 3 in. wide, is unrolled from the coil *a* by means of the carriage *b*, and cut off in pieces about 1 in. long for presentation to the mandrel *c*, temporarily introduced into one of the tubes of the mould-carrier *d*. The mandrel has a clamp which grasps the paper and rolls it, and, at the moment when the latter escapes from the carriage, its free end is brought upon a rubber pad covered with gum, hidden in the illustration. The paper tube is left in the mould, the mandrel being extracted by means of the cam *e*; the mould-carrier is then turned $\frac{1}{8}$ rev. by the cam *f*, a new tube comes into line, and the operation is repeated. When 6 paper tubes are completed, the first one is pushed by a small piston, actuated by the cam *g*, upon the end of the filling-tube; and immediately the rod *h*, actuated by the cam *e*, drives into this tube a portion of tobacco already prepared in the compressor *i*. In preparing the tobacco, a workman, occupying the seat *m*, is necessary to dispose the material in regular layers on a carrier, by which it is transported into the compressor. When the cigarette-envelope is filled, the mould-carrier again makes part of a revolution, and the finished cigarette is pushed out of the mould by the rod *k*, also actuated by the cam *e*; a device finally lodges the cigarettes in the box *l*.

One workman is said to be able to turn out 9600 cigarettes in 10 hours by the aid of the machine.

Snuff.—Snuff is entitled to the last place in the series of tobacco manufactures, as it is largely made up of the scraps, cuttings, and rejections of the preceding processes. The materials are chopped very fine, placed in heaps in warm damp cellars, "doctored" with various flavourings, left to ferment for several weeks, and then ground to powder in edge-runner mills, some kinds even

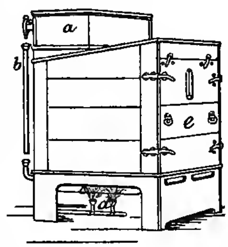
1015.



undergoing a slight roasting. When ground, the mass is passed through "mulls," wood-lined, bottomless bowls, let into a bench, where the snuff is softened and rendered less powdery by means of pointed pins, resembling domestic rolling-pins, which slowly travel around the sides of the bowls. Snuff represents a highly profitable article manufactured from materials that are otherwise useless, and depending for its favour chiefly upon the perfumes and flavourings used. Hence these last are kept profoundly secret by the manufacturer.

From refuse tobacco which is unfit for any other purpose, is made a decoction for washing sheep and destroying vermin; often the waste is ground very fine, and used by gardeners, presumably to keep noxious insects away.

1016.

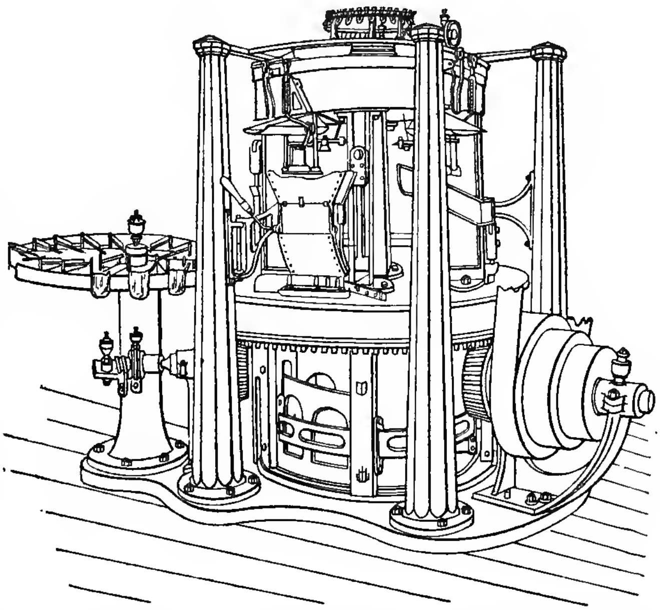


Miscellaneous Appliances.—The customary ingenuity of the Americans has invented a profusion of admirable labour-saving machines for almost all the operations of the tobacco-manufacturer. A few of these only can be noticed in the present article.

Fig. 1016 shows a portable resweating-apparatus, intended for darkening the colour of tobacco to suit the dealer's market. It measures 4 ft. long, 3 ft. wide, and 5 ft. high, being just large enough for one case (400 lb.) of tobacco, including the case; it consists of a water-tank *a*, a pipe *b* for conducting the water into the metallic pan *c* at the bottom of the apparatus, which is heated by gas-jets *d*. The tobacco is introduced by the door *e*, which is fitted with a thermometer. The roof is sloped so as to determine the flow of the water of condensation. The steaming occupies 3–5 days, and needs occasional watching. The apparatus is made by C. S. Philips and Co., 188 Pearl Street, New York.

Fig. 1017 illustrates a complicated machine, introduced by C. C. Clawson and Co., of Raleigh, N. Carolina, for putting up large quantities of tobacco in parcels of 2 oz. upwards. It consists of a central table provided with automatic scales for weighing out the portion; four equidistant guides which determine the form of the package; a plunger for packing, and a follower for raising the package; a side-table carrying tongs for holding the empty bags; and another to receive the packages, and hold them during tying. The hopper being supplied with tobacco, and the machine put in motion, each form takes a bag from the tong-table, and the article having been weighed, is carried to the form by a shute, when it drops into the bag, is packed by the plunger, and transferred to the tying-table. With 2 girls or boys, it is said to weigh, pack, and tie 30 bags a minute.

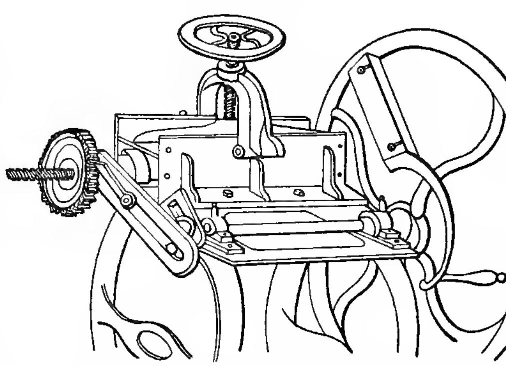
1017.



The New York Tobacco Machine Co. make two forms of machines for granulating tobacco, chiefly for making "Killickinick" and cigarettes, their working capacity ranging from 200 to 2000 lb. a day. The cutting-rollers are covered with cross-millings at right angles to each other, those running lengthwise being deep; the fixed cutters are adjustable, so that the cutting may be either coarse or fine. When working, the action is like that of a pair of shears, except that the cross-millings reduce the strips to a granular state. Both stems and leaves may be worked up. The great advantage claimed for these machines is that, though the tobacco should be dry, the percentage of dust escaping is reduced to a nominal figure.

A cutting-machine made by the same Co. is shown in Fig. 1018. It is adapted to cut leaf, stem, scrap, plug, or any form of tobacco, to any required degree of fineness, turning out 300–400 lb. a day. The action is almost precisely that of a chaff-cutter. The Co's. sifting-machine consists of an adjustable cylindrical wire sieve, with a rattan-broom screw-roller revolving inside. The stems are stripped and worked out at one end, while the remainder is broken up, and passed through the sieve, falling upon a perforated tray, through which pass the finest particles for snuff-making. A machine largely used in America is the stem-roller, for crushing and flattening the stems so that they may be used like leaves for making cigars. Great benefit is anticipated in the United States from the adaptation of Ryerson's "attrition mill" to snuff-grinding, owing to the fact that the pulverization is accomplished without the particles being heated in the least degree. Of cigarette-making machines, there are many kinds; the best are those which deal with the tobacco in a comparatively dry state, thus preventing shrinkage after packing.

1018.



Indebtedness is acknowledged to Hy. Archer and Co., Borough, S.E., and T. Brankston and Co., Carter Lane, Doctors' Commons, for opportunities of inspecting their thoroughly representative works, and for much information readily given concerning the manufacture in this country; to W. Jollyman, of W. D. and H. O. Wills' London house, for having revised these sheets before going

to press; and to Hy. A. Forrest, 61 Broadway, agent of the New York Tobacco Machine Co., for valuable material relating to American machines and processes.

Nature and Properties.—The active principle of tobacco is a volatile, highly poisonous alkaloid, called Nicotine ($C_{10}H_{14}N_2$). Although green tobacco-plants contain generally more nicotine than the leaves after they have been prepared for the market, yet the odour is only perceptible after the fermentation of the leaves has set in. It has been ascertained that young leaves 2 in. long contained 2·8 per cent., and leaves 10½ in. broad and 16 in. long, as much as 5·6 per cent. of their weight of nicotine. The amount increases as the plants become ripe, and decreases on their becoming overripe.

Though the narcotic effects of tobacco experienced by the smoker must partly be attributed to nicotine, it cannot be said that they are solely due to it. It is well known that the products of combustion of quite harmless substances are often stupefying. Good Syrian tobacco contains no nicotine, yet smokers consider cigars made from this tobacco to be strong. It is evident that the strength of a cigar, as judged by the smoker, depends greatly on the circumstance whether the tobacco burns well or not. If it burns well, a greater amount of nicotine is consumed and decomposed, and less of the narcotic products of combustion are created, than when it burns badly. Cigars of the latter description, containing little nicotine, are more narcotic in their effects when smoked than well-burning cigars containing much nicotine.

The amount of nicotine in tobacco varies very much, according to the sort of plant, the climate, the nature of the soil in which the plant grew, the treatment received during its growth, and the course adopted to prepare the leaf for the market. Dr. Nessler found that good Syrian tobacco contained no nicotine, Havana tobaccos between 0·6 and 2·0 per cent., and German tobaccos between 0·7 and 3·3 per cent. Schlösing found in French tobacco nearly 8·0 per cent. of nicotine. Fine tobaccos contain generally little or no nicotine. Broughton found that the amount of nicotine in Indian tobaccos varies very much. The conditions favourable to the development of nicotine in the plants are :—Soil in a bad physical state, strong nitrogenous manure, a dry atmosphere, and probably a low temperature during the growth.

According to Nessler, green and newly-cut tobacco-plants contain no ammonia; it is developed during the drying and fermentation of the leaves, especially when they assume a brown colour. Tobacco-leaves, which have undergone a strong fermentation, contain more ammonia than those slightly fermented. Fine tobaccos contain generally less ammonia than coarser ones. In various smoking-tobaccos, Nessler found :—Havana, 0·2 per cent. of ammonia; Cuba, 0·3; Syrian, 0·6; German, 0·9 per cent.. Schlösing found Havana tobacco to contain 0·8 per cent.

Nitric acid, consisting of nitrogen and oxygen, is formed in animal and plant substances when decomposed under the influence of atmospheric air and a sufficiently high temperature; whereas ammonia, consisting of nitrogen and hydrogen, is formed when those substances decompose in the absence, or nearly so, of atmospheric air. Organic substances decomposing under the latter condition emit an objectionable pungent odour, which must partly be attributed to the formation of ammonia. Tobacco, soon after harvesting, commences, according to the conditions under which it is placed, one of these decompositions. The extent of the decomposition the tobacco has gone through may be partly judged from the colour the leaves have attained. If leaves be dried so rapidly as to remain green, the decomposition is probably confined to the formation of carbonic acid. A yellow colour indicates the formation of nitric acid; and a dark-brown or black colour, that of ammonia. The conditions under which nitric acid and ammonia are formed being known, it is possible to control their development. When the tobacco is hung far apart, so that the air has free access, the formation of nitric acid will take place; but if the air be excluded more or less, by hanging the tobacco very close, or pressing it in heaps or pits, the formation of ammonia is engendered.

Nitric acid generally promotes the combustion of plant substances, by supplying a portion of the needed oxygen, and has undoubtedly a similar effect in tobacco; its occurrence in the tobacco is therefore a desideratum with the cultivator and manufacturer, and to supply any deficiency, the manufacturer often resorts to impregnating his tobacco with a solution of saltpetre. From this, however, it must not be concluded that every tobacco containing a large amount of nitric acid will necessarily burn well. Schlösing and Nessler have shown that the well-burning of a tobacco does not always correspond with a great amount of nitric acid, thus indicating that other substances or other conditions also affect the combustibility. The effect of the nitric acid will most probably vary with the base with which it is in combination.

The nitrogen in the forms of nicotine, ammonia, and nitric acid, constitutes only a small portion of the total amount present in tobacco; by far the greater portion ($\frac{5}{8}$–$\frac{7}{8}$) exists in the form of albuminoids. Nessler found that the nitrogen under this form varies from 2 to 4 per cent., which is equal to 13–26 per cent. of albuminoids. Substances rich in albuminoids generally burn badly, and emit a pungent noxious odour. On the condition of these albuminoids, and on the presence of other substances, as nitric acid, alkalies, &c., in the tobacco, mostly depend the burning qualities of the leaf, and the flavour of a cigar. The Eastern habit in smoking, from Malaysia, Japan and China, through India, Persia and Turkey, even to Hungary, is to inhale the smoke into the lungs, and natives of these countries maintain that a tobacco should be of full flavour without burning the throat or catching the breath. Western nations do not admit the smoke further than the mouth, and therefore require a strong, rank flavour.

Whilst drying and fermenting, the tobacco undergoes great changes. Some substances are decomposed, others are newly formed. The highly complicated compounds, the albuminoids, undergo first decomposition, and in doing so give rise to more simple combinations. Nitric acid, ammonia, and other substances less known are chiefly, if not entirely, derived from the products of the decomposition of albuminoids. The substances that cause the objectionable pungent smell in tobacco are formed from the broken-up constituents of these high combinations. The conditions under which these bad-smelling combinations originate are not properly known; but it is probable that they are developed with, and under the same conditions that cause the formation of, ammonia, as the disagreeable pungent flavour is found generally in tobacco that has undergone fermentation to a great extent. It is believed that the conditions that favour the development of nicotine are also conducive to the formation of albuminous substances in the leaf, viz. fresh nitrogenous manure, bad physical state of the soil, &c.

According to Nessler, the quality of tobacco depends to a great degree on the amount of cellulose it contains. He found that a good tobacco invariably contained more than a bad one, Havana yielding as much as 46 per cent. The fact that tobacco burns better after being stored for a time may be partly due to an increase of cellulose in it.

Every tobacco contains more or less fat, gum, ethereal oil, &c. It is not properly known in what way fatty matters affect the quality of tobacco. Many other organic matters exist in tobacco in combination with substances from which it is most difficult to separate them; they have not as yet been quantitatively ascertained, and are therefore little known. Most of them are only developed during the drying and fermenting of the leaf; their presence, however, considerably affects the quality of the tobacco.

The amount of ash constituents in the tobacco is considerable, varying between 16 and 28 per cent. There cannot be said to exist a definite relation between the total amount of ash in the tobacco and its quality, as tobaccos yielding much ash are sometimes of good, and at other times of bad, quality: a good tobacco may yield much or little ash. The relative proportion in which the ash constituents exist is, however, of the greatest importance. It has been ascertained that the presence of some special mineral elements modify to a great extent the quality of the tobacco. Of all ash constituents, potash (K_2O), more correctly speaking potassium carbonate (K_2CO_3), affects the quality of tobacco in the highest degree. Schlösing has pointed out that the good burning qualities of a tobacco depend on the presence in it of potash in combination with a vegetable acid; that a soil deficient in potash is unfit to produce tobacco of good quality. Numerous analyses have tended not only to corroborate the assertion made by Schlösing, but to demonstrate also, that it is not the total amount of potash, but the potash found as a carbonate, which existed in the plant in combination with a vegetable acid, that is the constituent chiefly affecting the combustibility of a tobacco. The complete analyses of Nessler have shown that, although a tobacco may contain a great amount of potash, it does not necessarily follow that the tobacco burns well. He found that some German tobaccos contained more potash than Havana, although the latter burned much better than the former; and that a great amount of potash did not always indicate a great amount of carbonate of potash. Although tobaccos yielding a great amount of carbonate of potash in their ash generally burn well, there may be conditions which neutralize the good effect of this combination, as a large proportion of albuminoids. It may therefore be said that the combustibility of a tobacco is improved in proportion as its ash yields more carbonate of potash, other conditions being equal.

Among the minor salts, the chlorides deserve most attention. It has been found that they generally retard the burning of tobacco, and that as they increase, carbonate of potash decreases. Lime is invariably found more or less in the ash, but it has not been ascertained to what extent its presence affects the quality of the tobacco; good tobacco may contain much or little, so that its presence is probably not of great importance. The same may be said of soda, magnesia, and phosphoric acid. According to Nessler, their proportions may vary thus:—Potash, 1·95–5 per cent.; lime, 6·5–9·2; soda, 0–1·63; magnesia, 0·12–0·99; phosphoric acid, 0·57–1·39.

In connection with the chemistry of tobacco, and the rational manuring of the crop, the name of Prof. S. W. Johnson, Chemist to the Connecticut State Board of Agriculture, must be placed in the foremost rank. Indebtedness is acknowledged to Prof. Johnson for a copy of his valuable report, quoted in the Bibliography at the end of this article.

Adulteration and Substitutes.—It is said that in Thuringia, over 1000 tons yearly of dried beetroot-leaves are passed off as tobacco. These leaves, and those of chicory and cabbage, are similarly employed in Magdeburg and the Palatinate. Many of the *Vevey* cigars of S. Germany are entirely composed of cabbage- and beetroot-leaves which have been steeped in tobacco-water for a long time. Other leaves, such as rhubarb, dock, burdock, and coltsfoot are also used. These are all principally for cigars. For smoking-tobacco, chamomile flowers, exhausted in water, then dyed and sweetened with logwood and liquorice, and dried, have been mixed with tobacco in such proportions as 70–80 per cent. In America, a specially-prepared brown paper, saturated with the juice expressed from tobacco-stems and other refuse, is most extensively used, not only for the "wrappers" of cigars, but also for "filling." Various ground woods, starches, meals, and pigments are introduced into snuff.

Imports, Duties, and Values.—Our imports of tobacco in 1879 were as follows:—

(*a*) Unmanufactured: From United States, 25,743,880 lb., value 682,253*l.*; Holland, 6,215,930 lb., 266,109*l.*; China, 1,444,192 lb., 36,265*l.*; Turkey, 1,214,319 lb., 32,627*l.*; Japan, 805,928 lb., 21,003*l.*; France, 651,350 lb., 14,585*l.*; Belgium, 515,009 lb., 15,501*l.*; Argentine Republic, 470,309 lb., 10,870*l.*; Germany, 426,139 lb., 25,602*l.*; Straits Settlements, 267,258 lb., 29,718*l.*; British India, 246,305 lb., 3605*l.*; New Granada, 241,638 lb., 9621*l.*; Canada, 121,920 lb., 3473*l.*; other countries, 497,043 lb., 14,256*l.*; total, 38,861,220 lb., 1,165,488*l.*

(*b*) Snuff: From all countries, 7719 lb., value 92*l.*

(*c*) Cigars: From Spanish W. Indies, 495,518 lb., value, 494,974*l.*; Germany, 150,460 lb., 46,318*l.*; Holland, 116,218 lb., 31,348*l.*; Philippines, 80,199 lb., 21,738*l.*; France, 73,348 lb., 24,071*l.*; Straits Settlements, 51,191 lb., 13,822*l.*; China, 48,762 lb., 11,240*l.*; Belgium, 46,536 lb., 14,211*l.*; British India, 33,208 lb., 10,898*l.*; United States, 14,625 lb., 5461*l.*; other countries, 43,978 lb., 19,184*l.*; total, 1,154,043 lb., 693,265*l.*

(*d*) Cavendish or Negrohead: From United States, 2,247,557 lb., value 84,422*l.*; other countries, 45,052 lb., 1964*l*; total, 2,292,609 lb., 86,386*l.*

(*e*) Cavendish, manufactured in bond: 33,069 lb., 7126*l.*

(*f*) Other sorts, including cigarettes: From United States, 52,206 lb., value 7999*l.*; Holland, 25,273 lb., 1372*l.*; Channel Islands, 15,470 lb., 1279*l.*; Germany, 14,474 lb., 4472*l.*; France, 9497 lb., 2368*l*; Belgium, 7939 lb., 2086*l.*; other countries, 12,328 lb., 3845*l.*; total, 137,187 lb., 23,421*l.*

The duties on unmanufactured tobacco are 3*s.* 6*d.* a lb. when it contains 10 per cent. or more of moisture; 3*s.* 10*d.* a lb. when it contains less than 10 per cent. of moisture. Snuff containing no more than 13 per cent. of moisture, 4*s.* 10*d.* a lb.; 13 per cent. and upwards, 4*s.* 1*d.* a lb. Cigars pay 5*s.* 6*d.* a lb. Cavendish of foreign manufacture pays 4*s.* 10*d.* a lb.; that manufactured in bond, 4*s.* 4*d.* Other sorts, including cigarettes, pay 4*s.* 4*d.* a lb.

The approximate relative values in the London market are as follows:—Maryland, fine yellow, fine, and good coloured, 7–9½*d.* a lb.; colory, 5–7*d.*; light-brown and leafy, 5–7½*d.*; ordinary and brown, 4–4½*d.* Virginia: Fine Irish and Scotch spinners, 7–10*d.*; good and middling, ordinary light and dry, 6–10*d.*; fine black sweet scent, and middling do., 6½–7½*d.*; part blacks, 5–6*d.*; ordinary and heated, 3–5*d.*; mixed parcels, ordinary and good, middling and fine, 5½–6½*d.*; stripped leaf, 4*d.*–1*s.* Kentucky: fine long light leaf, 7–11*d.*; good to middling do., 5½–7½*d.*; fine and middling blacks, 6–8*d.*; ordinary and mixed, 2–5*d.*; stripped leaf, fine, light leafy, middling and ordinary, 4½–11*d.* Negrohead, 11*d.*–1*s.* 6*d.* Cavendish, 4½*d.*–1*s.* Amersfort and German, 2¾*d.*–1*s.* 6*d.* St. Domingo, 5–7½*d.* Havana, Cuba, and Yara, 1*s.* 2*d.*–6*s.* Turkish and Greek, 2½–9*d.* E. India, Japan, and China, 2–9*d.* Java, 5*d.*–2*s.* Colombia (New Granada), 5*d.*–2*s.* 6*d.* Manilla, 8*d.*–4*s.* Manilla cheroots, 4*s.*–7*s.* 6*d.* Havana cigars, 5–40*s.*

Tumbeki.—This word, under a multitude of forms, is the common name in several Eastern languages (Bengali, Hindustani, Telugu, Sunda, Javanese, Malayan, Persian, Guzerati, Deccan) for ordinary tobacco. But in Asia Minor, it is applied to a narcotic leaf which is spoken of as distinct from tobacco, and is separately classified in the Consular Returns. Botanical authorities are at variance as to the plant which affords it, some attributing it to a *Lobelia*, while others consider it a kind of tobacco. The latter appears to be the more correct supposition. The flower resembles the tobacco in being trumpet-shaped; the leaf is broader, larger, and rounder than that of the tobacco raised in Turkey, and is also wrinkled like the inner leaf of the cabbage. The plant is raised from seed in nurseries, and when it has 4 or 5 leaves, is planted out in April in the prepared field, and watered sparingly. It is "set" in a day or two, and is then hoed occasionally to free it from weeds. After inflorescence, and when the plant is sufficiently "cooked," it is cut down, or pulled up bodily, and re-set in the ground till the leaves are wilted. These leaves are dried, and, after exposure to the dew, are pressed heavily, when they undergo a kind of fermentation which develops the aroma. It is exceedingly narcotic: so much so, that it is usually steeped in water before use, and placed in the pipe (a *narghilé* or water-pipe) while still wet. The exports of this article (the produce of Persia) from the port of Trebizond are considerable:—In 1877, they were 13,342 bales (of 1¾ cwt.), value 106,736*l.*, to Turkey; in 1878, 11,571 bales, 92,568*l.*, to Turkey; in 1879, 9659 bales, 77,272*l.*, to Turkey, and 866 bales, 6928*l.*, to Greece. Aleppo, in 1878, sent 4 tons, value 320*l.*, to Turkey, and 11 tons, 880*l.*, to Egypt. The exports of the article, the produce of the interior of Persia, from Resht to Russia, were valued at 5000*l.* in 1877, and 3846*l.* in 1878.

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(See Alkalies [Organic]—Morphine; Drugs—Belladonna, Cocculus Indicus, Duboisia, Henbane, Lactucarium; Poppy, Hops).

NUTS (Fr., *Noix*; Ger., *Nüsse*).

The term "nuts" as applied commercially embraces a good many vegetable products which do not strictly belong to nuts botanically so-called. The chief nuts of commerce are the following.

Areca- or Betel-nut.—This is the fruit of the areca palm (*Areca Catechu*), which is cultivated in the Malay Archipelago, the warmer parts of the Indian Peninsula, Ceylon, Indo-China, the Philippines, and some of the Pacific Islands. It thrives in high regions, and at a distance from the sea; begins to bear fruit after 5 years, and is productive for 25 years. It flowers in April–May, and the nuts ripen in October; those most esteemed are gathered before they are quite ripe. A fruitful palm is said to produce 850 nuts annually, but the average may be taken at 300; the mean annual yield of a plantation is 10,000 lb. of nuts an acre. The fruit is a drupe, about the size of a hen's egg; it does not fall when ripe. There are many varieties of the palm. The nuts are dense and ponderous, and very difficult to break or cut. When freshly broken, they have a weak cheesy odour, and a slightly astringent flavour. In the green state, before they are ripe, the nuts are pounded up and chewed with the betel pepper or kava-kava, for the narcotic effects produced (see Drugs—Kava-kava; Narcotics—Ava); this is by far the largest and most important use of the nuts. Their quality depends upon the natural appearance when cut, indicating the amount of astringent matter contained in them. If the white or medullary portion which intersects the red astringent part be small, and has assumed a bluish tint, and if the astringent part be red, the nut is considered good; but if the medullary portion is in excess, the nut is more mature, possesses less astringency, and is inferior. The astringent properties of the nut are made use of in dyeing and tanning (see Tannin—Catechu). The exterior of the nut affords a fibrous material (see Fibrous Substances—*Areca Catechu*). The nut itself has medicinal uses (see Drugs—Areca-nut). The ashes of the nut are used in making tooth-powders, but possess no advantage over other vegetable charcoals. The toughness of the nuts enables them to be used for articles of turnery, but their smallness confines this use within narrow limits. The Eastern trade in these nuts is very large. The exports from Ceylon in 1878 were 101,777 cwt., value 92,869*l.*; in 1875, of the total export of 94,567 cwt., 86,446 cwt. went to India. In 1872–3, Madras exported 43,958 cwt. of the nuts, and 2 millions of the entire fruit, to Bombay. Penang exports some 3000 tons annually; and Sumatra, 4000–5000 tons. The Chinese port of Shanghai, in 1879, imported 1700 *piculs* (of $133\frac{1}{3}$ lb.) from foreign countries, and $11,548\frac{1}{2}$ *piculs* from Hong Kong and Chinese ports; the re-exports left only 1455 *piculs* for local consumption. Kiungchow exported $335\frac{1}{2}$ *piculs*, value 450*l.*, in 1879.

Boma- or Booma-nut.—This nut much resembles an almond in shape and size, the fruit itself, with the fleshy covering, being about as large as a walnut. It is probably the fruit of a species of *Vitex*. It is a native of E. Central Africa, and is cultivated abundantly near the Victoria Falls; it is found also in the Shire Valley, but is said not to extend farther south than Lake Ngami. An oil is copiously afforded by it (see Oils—Boma).

Brazil- Castanha-, or Pará-nut.—The Brazil nuts of commerce, called *castanhas* in Brazil, are the produce of *Bertholletia excelsa*. The tree is a native of Guiana, Venezuela, and Brazil; it forms large forests on the banks of the Amazon and Rio Negro, and about Esmeraldas on the Orinoco. A large number of the nuts come from the rivers Tocantins, Xingú, Trombetas, and Curuá. The tree grows on low, rich *terra firme*, never on the flood-plains. The fruit is nearly round, and about 6 in. in diameter, with an extremely hard shell about ½ in. thick, containing 18–24 seeds, which constitute the commercial nuts. When the fruits ripen, they fall from the trees, and are gathered into heaps by troops of Indians, who visit the forests at this season for the purpose. They are then split open with an axe, and the seeds are taken out, sun-dried, and packed in baskets for transport to Pará in native canoes. They constitute a large article of export, some 90,000 bush., value over 35,000*l.*, leaving Pará every year. As they do not keep well in the Brazilian climate, they are shipped as soon as possible, largely to England and the United States, a few to France, Portugal, and Germany. They form a pleasant edible fruit, and yield an abundance of oil (see Oils—Castanha).

Bread-nut.—The seeds of *Omphalea diandra* and *O. triandra* are edible, and yield valuable oils (see Oils—Ouate, Bread-nut). They are cultivated, especially the former, in St. Domingo and Jamaica, under the names *noisettier* and "cob-nut."

Candle-nut.—The candle-nut, lumbang-nut, or country walnut (*Aleurites moluccana*, [*A. triloba*, *Jatropha moluccanum*, *Croton moluccanum*]), probably embracing several other varieties, is a native of the islands of the Pacific. It is found in N. Australia; abounds in the Moluccas, and most of the islands of the E. Archipelago, in the Malay Peninsula, Cochin China, and S. China; it occurs in California, Chili, and Venezuela; it is largely cultivated in Lower Bengal, and other parts of India; it is found in Bourbon and Mauritius; it has been introduced from Asia into the W. Indies, and has become naturalized in Jamaica. The fruit is the most valued product, and strews the ground beneath the trees at all seasons of the year. Each nut weighs about 160–170 gr., the kernel forming ⅓ of the total weight. The shell is covered with concretions of calcium carbonate. The juice is used for dyeing, and the calcined shells afford both a dye and a pigment. The kernels are eaten in most countries where the tree is common, usually after roasting or long keeping, or in combination with a condiment. Their flavour resembles that of walnuts or almonds. The nuts are commonly threaded on a reed or similar wick, and burnt for illuminating purposes. Analysis shows them to contain over 62 per cent. of oil, and more than 22 per cent. of nitrogenous substances; the proportion of phosphoric acid is 1·67 per cent.; and the ash contains 30 per cent. of potassium phosphate, 39 per cent. of magnesium phosphate, and 22 per cent. of calcium phosphate. These figures suffice to show its value as an ingredient of cattle-foods, could it be deprived of its purgative qualities. Tahiti exported 700*l.* worth of the nuts in 1875. Levuka (Fiji) sent nuts to London to the amount of 1562*l.* in 1876, and 3040*l.* in 1877. The oil has many uses (see Oils—Kukui).

Cashew-nut.—This is the fruit of *Anacardium occidentale*, a plant cultivated in the W. Indies, E. Indies, and other tropical countries. It grows on the W. African coast, from the Congo to Ambrizette, very abundantly. The plants yield a gum (see Resinous Substances—Cadjii). From the intermediate layer of the shell of the nut, is obtained a thick, black, oily, viscous juice, called *cardole* in the E. Indies. The kernels are eaten after having been roasted. They also yield an oil; and from them, an excellent wine is said to be prepared in Brazil. (See Oils—Cashew.)

Chestnut.—The edible fruit of *Castanea vesca* is well known. The tree is probably a native of S. Europe, from Spain to the Caucasus. In France, Italy, and Spain, it attains great size, and flourishes at 2500–2800 ft. in the Alps and Pyrenees. It is more abundant in Asia Minor, Armenia, and the Caucasus; and is also found in America as far north as lat. 44°. It ripens its fruit in the warmer parts of Scotland, but rarely, if at all, in Ireland.

It is very largely cultivated in Tuscany, where the method employed is as follows:—Plants are raised from the fruits, placed in earth which has been repeatedly worked. The plantations are generally situated near a stream, and the ground is shaded by hedges or trees. The space is divided into furrows, 6–7 ft. wide, in each of which, holes are dug about 3 in. deep, and at a distance of about 6 in. from each other. In these holes, the nuts are placed, with the germs downwards. The use of manure is not largely resorted to. After two years, the plants are transferred to another part of the plantation, where they remain four years, after which they are placed where they are to remain permanently. The season usually chosen for transplanting is after the falling of the leaves, though it is frequently done even as late as February–March. There are two methods of grafting the tree (which is done at the age of 5–6 years); one is the primitive method of inserting the bud in the end of a branch, with a slit in it, where it is retained by wax or other substances. The other, which has proved most successful, consists in cutting large rings of bark from the branches of the large or Spanish chestnut, and placing them on twigs of the ordinary kind; this is a very delicate operation, requiring great care, and is performed in the following manner:—The bark of the Spanish chestnut is cut into circles on the twigs, where marks of buds appear, care being taken to have one or more buds on each circle or cylinder, the bark is then slightly beaten to loosen it from its position, and gently twisted by hand, until a hollow cylinder of bark is obtained, which is then drawn up by the stem, that has been previously denuded of its bark in like manner. The cylinder of bark is then carried to the stem of the tree, which is grafted. This stem, having been previously denuded of its bark, and cut off down to the place where the ring is to be put on, is then covered with the ring, which unites with the growing bark, and sends out shoots of its own variety. In this manner, a tree is covered with these rings, and the natural branches being cut down, all the force of the tree is expended in throwing out the shoots of the large chestnut from the grafted branches. Great care is always taken to cut off all shoots of the common chestnut that may appear near the grafted part, as they will otherwise interfere with its full development. The operation of grafting by rings is practised in Tuscany from 10th April to 1st May, that being the time when the sap is running most freely, just before the leaves and buds come out. A method of preserving the grafting buds so that they may remain good even after a year, is to place them in tin tubes filled with honey, and hermetically sealed immediately on their removal from the tree. Another method of transporting the grafting buds is by putting them into hermetically sealed tubes filled with water; this method can only be used for transporting the buds for distances accomplished under forty days.

The nuts (to the number of 1–3) arrive at maturity in two months after flowering, that is to say in October, and then fall to the ground; they are also beaten from the trees by long poles, but this is only occasionally done, as it seriously injures future fruit-buds, and affects the yield of the tree for another year. The chestnut is pruned and trimmed every three years; this, while helping the tree to bear more abundantly, produces wood for fuel and other purposes, and small twigs and branches which are used for drying the nuts. After the nuts are gathered, they are deposited in huts, in the upper part of which deep trays are constructed, whereon the nuts are placed to the depth of 6 in.; in these huts, slow fires of green wood are kept up, until the nuts become hard and dry. They are then carried to a mill, where they are ground into flour, in the same manner as corn or wheat. From this flour, many preparations are made, such as "polenta," and various kinds of cakes, fritters, and even a heavy kind of bread.

There are many varieties of the chestnut, some of the best and largest not being adapted to the English climate; the most suitable are the Devonshire, the Prolific, and the Downton, the last remarkable for its short-spined husk. Chestnuts, after being well-dried in the sun, may be stored with dry sand in casks. In France, Spain, N. Italy, and Corsica, they form a most important article of food, and serve in a great measure as substitutes for potatoes and bread. The approximate export of these nuts from Spain in 1878 was 5,789,000 *kilo.* Italy, in 1874, had 1,224,711 acres under chestnuts, the produce of which was 11,351,282 cwt. The consumption in France is said to be 6 million bush. annually. Our imports have never reached 70,000 bush.; in 1870, they were 31,767 bush., about half from France, and the remainder from Spain and Portugal. (See Timber—Chestnut.)

The horse-chestnut (*Æsculus Hippocastanum*) affords a nut abounding in farinaceous matter, and though too bitter for human food, serves for feeding domestic animals. It yields a large proportion of starch (see Starch—Horse-chestnut), and a small quantity of oil (see Oils—Horse-chestnut).

The kidney-shaped kernel of the Tahiti chestnut (*Inocarpus edulis*) is roasted and eaten in the Pacific Islands, New Guinea, and the Moluccas, and forms a staple food in some districts. It is sweetish when boiled, or roasted in ashes, but is harder, and less pleasant and farinaceous, than the common chestnut.

The large seeds of the Moreton Bay chestnut (*Castanospermum australe*), a native of Queensland, are eaten by the Australian natives, but are hard, astringent, and little better than acorns.

Coco-nut.—The fruit of the coco-nut palm (*Cocos nucifera*) is too well known to need description. The tree flourishes with equal vigour on the coasts of the E. Indies, throughout the islands of the tropical Pacific, and in the W. Indies and tropical America. Its importance renders it an object of especially careful cultivation in many regions. On both the Malabar and Coromandel coasts of India, it grows in vast numbers; and Ceylon, which is peculiarly favourable to it, is estimated to maintain some 20 million trees. Many parts of the coast of Brazil teem with these palms; and in the W. Indies, great numbers are met with. The tree also occurs in considerable abundance on the coasts of tropical E. and W. Africa. But it seems most at home in the Pacific Islands. It is now attracting much attention from the colonists in Australia, where it is not yet established to any great extent.

Some 30 varieties of coco-nut are distinguished by the natives of the districts producing them, but many of these distinctions are obviously groundless. In preparing plantations, the nuts for sprouting are chosen fully ripe, with large eyes, and gathered from trees past middle age, and from clusters numbering few fruits. They should be gathered without injury, and neither be allowed to fall to the ground, nor to dry on the tree. They are carefully kept for not less than a month before planting, and are then set in an elevated plot, where water will not stagnate, and which is somewhat exposed to the influence of the sun. The planting may take place in January–April, also in August, provided the rains are not heavy. The seed-beds are dug 2 ft. deep, and the nuts are planted on their sides, 1 ft. apart at least, and leaving 2 in. unburied, some ashes, alone or mixed with salt, being put into the trenches. The beds are kept duly moist, but never made wet. In ordinary cases, the young shoots are transplanted in the 2nd–6th month after their first appearance; but in low-lying situations, it is preferable to wait till the 12th month. In low, damp spots, the transplanting may be done during the hot season; in salt-marshes, and on hill-sides, during the monsoon. It may be generally said that all sandy soils are suitable. Sunlight and sea-breezes are most beneficial.

Coco-nuts growing in mangrove soil on the side of creeks, and more or less saturated with salt, have their milk brackish, and the sap is saline also. These trees do not suffer from the attacks of the rhinoceros beetle, and are found to bear much sooner than those planted on a sandy soil. As an illustration of this, while trees planted at Penang 30 years ago, on sandy soil, have not yet borne fruit—although they are fine-looking trees—others in the same plantation, only 10 years old, but on low ground, where the sea tide comes up daily, washes their roots, and runs off again, are in full bearing, giving 50–100 nuts annually, and the kernel is as thick as that of nuts grown on sandy soil, and produces as much oil. The chief requisite with regard to a plantation in such a situation, is attention to the drainage. Longitudinal drains should be cut between the rows of trees, and cross ones at greater intervals. These drains must be kept clear, so as to allow the salt water to flow in and out freely. The tide is found to deposit amongst the trees a very fertilizing matter. If the drains are not attended to, and the water stagnates, the trees get dwarfed, and become thin towards the top, thereby preventing them from having a large crown.

The holes into which the shoots are transplanted should be 12 yd. apart on backwaters; but where a deep alluvial soil is found, 8–10 yd. are enough. In a level, loose soil, the hole should be a cube of 1½ yd.; on hill-sides, 2–2½ yd.; in low grounds, ½–¾ yd. deep, and 1 yd. sq. If the holes are not sufficiently wide and deep, the roots soon appear above the surface of the ground, their hold upon the earth is weak, sufficient nourishment is not obtained, and the monsoon storms will overturn the tree. In a cold clay, the holes are filled with sand, and the plant is deposited in it. In low marshes, banks or terraces should be thrown up and consolidated previous to planting. If, in any of these cases, plants 2–3 years old are used, the holes must be at least 2½ yd. every way. They should be dug 2–6 months before the planting, and be prepared first by having heaps of fuel and weeds burned in them, and subsequently by manuring. In low situations, new holes and quick planting may be preferred. No time should be lost in the removal from the nursery to the holes; indeed the day should not pass, in which case new roots and fronds may be looked for within the month; but where this proves impracticable, if the plants are kept cool and in shade, 4–8 days have been known to intervene, but to be followed by very great loss in the number of successful trees. Inside the holes, smaller ones are made, and filled with salt and ashes mixed with mould, in which the young plants are deposited, with the nuts just covered by the compost. Some shade must be afforded, and care taken that the plants are not shaken or removed from their first position; occasionally water should be sprinkled over them. The above compost must be used when there is but a small proportion of sand in the soil. Ashes will suffice on the sea-shore; and sand, in marshy and loamy soils. The broken roots of a plant under a year, and, according to many planters, all found on the nuts in the nursery, should have their ends cut, as new ones are supposed to be hastened by the process. Turmeric and arrowroot are often planted in the same pits with the coco-nut. After the plants are in, little *pandals*, or sheds, made of twigs and branches, should be erected to protect them, for the next six months, from too great sun-heat; this prevents the withering of the leaves and any check to the growth of the roots. On dry soils, the plants are watered twice a day for the first month, once a day for the next five, or until the monsoon showers come on, and once every 2–3 days during the dry seasons of three following years, according to circumstances. On hill-sides, it is usual to water during the hot weather, even till the first buds appear; on sandy plains on the sea-coast, when the trees are in full bearing, 8–10 ft. of bamboo (with the divisions at the joints broken to form the pipe) is often driven down by the side of the tree, and cool water from weed-covered tanks is poured down to refresh the roots and lower soil. The soil round the young plant is often kept damp by a bed of leaves, particularly such as will not be eaten by white ants. If the soil is naturally poor, or of a hungry nature, salt, ashes, paddy-husks, goats'-dung, and dry manures may be applied for the first year; but in after seasons, oil-cake, fresh ashes, decayed fish, and other refuse, are preferable.

If the soil at the foot becomes too rich, a large grub with a reddish-brown head, soon finds its way to the roots and into the stem, and though the foot of the tree may enlarge, the stem does not develop itself, the new leaf-spike at the crown becomes yellow, fades, and is not replaced, and does not open out into the usual frond, and in 2–3 months the whole tree-top is affected and drops to the ground. It would appear that fear of this evil is the reason why ashes alone are recommended by so many cultivators. As soon as the new fronds have divided into the long side leaflets, or lost their connected form, which is at the end of the first year, the soil should be dug up, and ashes be applied about once a month. When the tree is two years old, and henceforward at the commencement of every monsoon in May–June, the whole of the soil, for 1–2 yd. around the stem, must be opened out, and ashes and dry manure be applied and left open to the air; in October, when the rains have ceased, this freshened earth should be replaced and levelled. As the tree gets older, and the depression at the foot is gradually filled up, it may not in after years be necessary to dig so deep as for the earlier growths. If the opening-out of the roots, and the manuring, be thus annually attended to, the tendency to form a sort of bulb on the surface, and throw roots above the soil, will be checked; the old worn-out rootlets are cut away, strong roots from other trees and all weeds are removed, and the process acts both as a "wintering" and a "pruning." Cattle are most destructive during the first two years, in eating off the ends of the fronds, and stripping the leaflets; if the plants suffer often in this way, the growth is entirely stopped; sometimes the new leaf-spike is pulled out, and the tree dies. Should the heart of the stem and top not be injured, the tree will still remain unsightly, and often entirely profitless.

From the time when the leaflets become fully developed and distinct from each other, till the period for the spathes (or covers to the flower) to make their appearance, the fronds should be shaken and weighed or pressed downwards each month, so as to keep them from each other and make them spread; and careful and frequent examination should be made, lest rats, beetles, or worms have made nests upon the head, or bored into the cabbage heart of the palm. Some planters sprinkle ashes and salt about the spike-shoots to keep insects away. The dried fronds, old spathes, fruit- and blossom-stalks, and ragged fibres, should be removed at stated periods of perhaps a month, or as often as the nuts may be gathered. The application of salt and ashes to the tree-tops is usual at least in March and October, to keep off the swarms of insects, particularly red ants, which live upon the juices of the tree, and render them fruitless.

The tree is all its life endangered by the attacks of enemies. One beetle bores into the tender shooting leaf, and lays its eggs there, to be hatched into grubs which will eat their way in all directions; another bores round holes into the stem itself and lives there; rats climb up and make their nests in the hollows of the branching fronds, and eat the cabbage itself, or feast upon the young kernels; the common flying-fox or rousette (*Pteropus*) gnaws round holes through husk and shell of the mature nut, and will attack the young nut, biting away large pieces from the tender part under the capsule; the flying squirrel (*Pteromys*) also makes its abode in near woods or forest trees, and at nightfall attacks the nuts; the common striped palm-squirrel is also sometimes found destroying the nuts and blossom; while red ants and parrots attack the blossoms only. The most effective methods of obviating these evils are to shoot the flying-foxes and squirrels by moonlight, and to poison the others by a mixture of arsenic with grated coco-nut pulp, or of pounded glass, oil, and black sugar, in coco-nut-shells, left in the tree-tops. Rats may be taken in trap-falls. The red ant's nest should be sought out and destroyed. A large wasp will attack the very small nut, taking it for the material of its nest. When the spathe is cut for drawing toddy, the frequent visits of the men will tend to keep some intruders away, but the smell of the toddy is said to invite others. Grass should be kept down by feeding off with goats and cattle; in marshy lands, cattle are apt to make deep tracks, and break down the margins of the terraces, hence goats or calves only are allowed. The undergrowth may be annually cut for repairing paddy-fields, and this is another source of profit. Planting jack, mango, tamarind, coffee, and other trees close to the palm, is thought to be detrimental, as is also allowing pepper and betel vines to climb the tree, and even the sowing of maize, gram, or any of the dry pulses under the shade. But areca-nut trees and all other palms may be planted, and the ground may be dug, and various kinds of yams and tuberous roots cultivated with advantage.

Under ordinary conditions, distinct leaflets begin to show themselves at the end of the 1st year, and are completed at the end of the second, on each frond, which will be 3 in. thick in the stem or leaf-stalk next the parent trunk. In the 3rd year, the bottom of the frond assumes a horse-shoe form where it clasps the main tree; in the 4th year, the trunk of the tree appears slightly above ground, and has not less than 12 fronds. About the 5th year, the trunk is fully manifested, and there should be about 20–24 fronds; when a luxuriant well-grown tree begins to bear fruit, there will be no less than 36 of these branches or fronds. Spathes or shoots, whence eventually the flowers emerge, begin to appear in the 6th year. The height of the stems at this important period, in some kinds usually, and in all when influenced by the soil, will be only 1–2 ft. above the ground; in other cases, it may be 16 ft. For the first few months, these flower-shoots are deceptive, and only dry up; but within the year, they begin to retain their blossoms and bear a few fruit, yielding abundantly in 3–4 years after their first appearance. In six months from blossoming, the kernels of the nuts begin to solidify: in a year, the fruit is fully ripe—even sooner if the season is very hot and dry. The produce of the tree in full health and properly tended is much dependent on soil and climate. The average may be put down at 120 nuts in the twelve months; in a low and sandy soil, it will amount to 200; in gravel and laterite, not 60. The most productive months in India are from January to June, that is for ripe nuts, the heat bringing them quickly to maturity. It is calculated that where the roots of the trees can reach water, and the soil is alluvial, the trees will bear 8–10 bunches of fruit; in other and higher lands, not more than 6. The trees bear until they are 70–80 years old.

When the trees begin to show spathes, they are often tapped for toddy, during the monsoon, and for that season only, this being supposed to render future fruit-branches more numerous, and to give the sap a tendency to flow. In some places, the trees are never allowed to bear fruit, but toddy is always extracted. If toddy is drawn for 6 months, it should not be repeated till at least 5 years have elapsed, otherwise the trees become exhausted, and produce no nuts. While some of the spathes are cut for toddy, the others will grow nuts, provided the number cut is not too great. Gathering some of the tender nuts from the earlier bunches greatly develops the succeeding branches, and strengthens the whole tree: but it is not recommended to cut the spathes out before they are matured or dry. Some 8–10 spathes dry and fall from each in a year, chiefly in the hot season; these should be removed when turning brown, leaving a small portion of the foot-stalk on the tree. The percentage composition of the nut is said to be:—Water, 39·7; oil, 29·3; amygdalin, 14; woody fibre, 9·5; sugar, 3·6; gum, 2·1; emulsin, 1·1; albumen, 0·5; mineral matter, 0·2. The exterior of the nut affords a valuable fibre (see Fibrous Substances—*Cocos nucifera*); the nut itself is very largely consumed as an edible fruit; and it is expressed to yield an oil (see Oils—Coco-nut), the remaining solid portion being largely used for feeding cattle. The trade in coco-nuts is very extensive.

Many years since, the Malabar coast was estimated to produce 300–400 million nuts per annum, worth 50,000*l.*; and the exports of copra were reckoned to have a nearly equal value. Travancore grew 5½ million trees 30 years ago, and the number has much increased since. In Cochin, the cultivation is very rapidly extending. The Madras presidency has over 200,000 acres under coco-nut palms. The value of the coco-nut plantations of Ceylon is computed at 15,000,000*l.*; their acreage in 1865 was 332,890; and the situation is chiefly in the north-western, northern, and southern provinces. More recently, the area is stated at 200,000 acres, and the production at 700–800 million nuts annually, worth 2,000,000*l.* The production varies exceedingly. Thus in 1866, over 128 million nuts were recorded, and others to the value of nearly 25,000*l.*; in 1868, only 30 million nuts and 28,000*l.* worth. The exports in 1870 were 5,478,677 nuts (and 623 bags), value 17,185*l.*; and 40,638 cwt. copra, value 31,678*l.* In Cochin China, more than 33,000 *hectares* (of 2½ acres) are occupied by coco- and areca-palms. The former is very abundant in the E. Archipelago, and the annual produce of the trees is estimated to be worth 2,500,000*l.* In 1874, Amboyna possessed over 500,000 trees; Banca, about 123,000; Minahassa, 600,000; Gorontalo, 250,000. Java and Madura number over 20 million trees. Plantations in the Straits Settlements are small and scattered, yet no district seems better suited to the cultivation of the nut. In the Straits of Malacca, the chief natural enemy of the tree is a species of elephant-beetle, which begins by nibbling the leaves into the shape of a fan; it then perforates the central pithy fibre, so that the leaf snaps off; and lastly it descends into the folds of the upper shoot, where it bores itself a nest, and, if not speedily extracted or killed, soon destroys the tree. A similar kind of beetle is known on the Coromandel coast, and is extracted by means of a long iron needle or probe, having a barb like that of a fish-hook. By using this, and by pouring salt or brine on the top of the tree, so as to descend amongst the folds of the upper shoots, the evil may be prevented or got rid of; the natives of Keddah say that this insect appears at intervals of 2, 3, or more years. The common kinds of the nut, under very favourable circumstances, begin to bear at 6 years of age; but little produce can be expected until the middle or end of the 7th year. The yearly produce of one tree with another may be averaged at 80 nuts. The quantity of oil which can be manufactured from 400,000 nuts will be, as nearly as possible, 834 *piculs* (of 133⅓ lb.). The coco-nut is foremost in importance among the vegetable productions of Borneo. The wars of the inhabitants have almost exterminated the plant from the W. coast, but it is abundant to the northward; and the Natuna Islands on the west, and Sulus on the east, are said to be covered with this palm. The rugged coral rock (limestone soil) and salt breezes of the Ke Islands seem very favourable to its growth, and it abounds up to the highest points, and produces fruit all the year round.

In New Caledonia, the coco-nut palm is abundant on the N.-E. coast, but rare on the opposite coast, and while it flourishes in a northern aspect, it declines towards the south. At Tahiti, there are about 200,000 of these trees, which produced over 12½ million nuts in 1874; about 600,000 nuts, and nearly 2,000,000 *kilo.* of copra, were exported. The Marquesas shipped 19,000 *kilo.* of copra in 1873. From the Tuamotus Archipelago, 3000 tons of copra were exported in 1873; the single island of Anaa is said to possess more than 7 million of the palms. Large plantations were made in 1866, and must now be in full fruiting. From the island of Samoa, in the S. Pacific, copra is the main article of export, but is the production almost solely of the German-owned plantations. In 1879, there were 12,921 acres of coco-nuts cultivated by whites in the Fiji Islands. Tahiti exported 174,400 coco-nuts, value 698*l.*, and 2113 tons copra, value 29,582*l.*, in 1878; and 150,000 nuts, value 600*l.*, and 875 tons copra, value 12,250*l.*, in 1879.

Coco-nuts are the chief production of the Seychelles, and the plantations are constantly increasing and extending from the beaches up to 1000–1500 ft. on the mountain-slopes. In 1879, 5278 coco-nut trees were recorded as growing in Curieuse Island, and 16,369 on Félicité Island. The best land is said to be already occupied by them. The method of extracting the oil is very primitive. Mauritius ships 40,000–50,000 nuts yearly.

In Jamaica, some thousands of the palm have been planted on sterile spots, such as the Palisadoes, running from Kingston to Port Royal. Several of the parishes possess over 100,000 fruiting trees each, and the number is constantly increasing. The tree abounds around nearly the whole seaboard of the island, but is singularly neglected. The annual export of 2 million nuts, worth about 5000*l.*, from the colony, gives no true index of the importance of the palm, nor the value it might have.

Trinidad possesses similar undeveloped resources, and the cultivation of the nut can be extended indefinitely on the eastern coast. The trees are in bearing all the year round, but some planters confine the plucking to three periods,—April, August, and December. The shipments in 1864 averaged only 250,000 nuts, but in 1876, they were 4½ million, and the total value was 18,000*l.*

The cultivation might be developed in Dominica with certain and immense advantage. The nut begins to bear in the 3rd year, the produce of the 4th year is very considerable, and that of the 6th is a "full crop." The cost of planting and cultivation are merely nominal, for in such situations as the valleys on the sea-coast, having extensive frontages of stony, barren, or swampy soil, the palm completely outstrips weeds and every other kind of vegetation. The number of coco-nut trees in the island is already considerable, and the nuts are of excellent size and quality, so that an extended production might easily be effected. It is receiving increased attention, being found to be one of the most easy and profitable cultivations. The exports from Dominica were 2,262,927 nuts in 1871, 2,660,905 in 1872, 2,380,871 in 1873, 3,974,400 in 1874, and over 4 million in 1875. Surinam exported 82,236 nuts in 1877, and 54,864 in 1878.

British Guiana had 10 estates under coco-nuts in 1879; the exports in 1880 were 1,197,908 nuts from Demerara, and 1050 from Berbice. British Honduras exported 381,680 coco-nuts in 1876, 604,399 in 1877, and 688,164 in 1878. The Bahamas have recently entered upon this industry, and there is promise of its attaining respectable proportions in a few years. The export of the nuts was 9518 in 1879. Some 80,000 trees have been planted in the colony since 1875.

Groves of coco-nut palms extend for about 280 miles along the coast of Brazil. From Para alone, about 7½ million of the nuts, worth 130,000*l.*, are annually shipped to the United States and Europe. The yearly produce of the island of Itamarca, on that coast, is about 400,000 nuts. Maceio exported 263*l.* worth of coco-nuts in 1876, and 138*l.* in 1879.

Coquilla-nut.—This is the produce of *Attalea funifera*, one of the palms affording piassaba fibre (see Fibrous Substances—*Attalea funifera*). It is of a dark-mahogany colour, oval, and 3–4 in. long, and is used for ornamental turning, and making the handles of doors, umbrellas, &c. The supplies have been curtailed by indiscriminate destruction of the trees, and the quality has much deteriorated.

Corozo- or Corosso-nut, or Vegetable Ivory.—The fruit of the *antá* (*Phytelephas macrocarpa*) forms the *marfil vejetal*, or "vegetable ivory" of commerce. The plant is confined to the northern part of S. America; and though yielding so useful a product, no serious attempt has been made to introduce it into any of our tropical colonies, despite the great promise of profit attending such a venture. In Jamaica, Trinidad, and Dominica, the plant would thrive along the banks of the rivers and streams, which run through many of the estates. The "nuts" are the seeds found in the interior of the fruit. They are collected by the natives, and shipped in large quantities to Europe, where they form the chief substitute for elephant-ivory (see Ivory), and are very extensively used for small articles of turnery, such as buttons. The exports of these nuts from Panama are constantly increasing, and at enhanced prices; the shipments to the United States in 1879 were of a value of 28,370*l.* The exports from Guayaquil have increased from 71,482 *quintals* in 1874, to 193,432 *quintals* in 1879; the province of Manabi also shipped 107,986 *quintals* in 1878. The consumption of the nuts despatched from Guayaquil is almost equally divided between England and Hamburg; but the cargoes sent from Manta and other Ecuadorian ports are chiefly for the latter market. Their value is 15–30*s.* a cwt.

The kernels of *Hyphæne crinita* and *Raphia Hookeri* have been imported as substitutes, but unsuccessfully. Those also of *Sagus amaricum* have been largely received from the Friendly Islands. It is probably this plant which is so abundant in the Solomon Islands of the S. Pacific, though the fruits are called "corosso-nuts." An ivory-nut palm belonging to a new species of *Phytelephas* is a native of Venezuela, and has been provisionally called *P. orinocensis.* The nut is like that of *P. macrocarpa;* but the plant, called *timiti* by the natives, has an erect trunk 8–10 ft. high. It may lead to ivory-nuts being exported from Bolivar and Trinidad.

Ginkgo-nut.—This is the seed of *Salisburia adiantifolia*, which is largely cultivated in China and Japan. The seeds are eaten, and yield an oil.

Ground- or Pea-nut.—This nut, called also earth-nut, monkey-nut, Manilla nut, and *minyak-katjang* or *katchang-tanak* (in Java, &c.), is the produce of *Arachis hypogæa.* The plant is extensively cultivated in all tropical and subtropical countries, especially India, the Malay Archipelago, China, Africa, and America. It might with great benefit be introduced into Australia. In W. Africa, it is cultivated in greatest abundance at a few miles inland, where the comparatively arid country is succeeded by better land and climate. It requires a good soil, and is therefore chiefly grown in the bottoms of valleys, or near rivers and marshes. The cultivation is exceedingly simple: the ground is cleared of weeds, &c., which are burnt, and after being hoed a few inches deep, the seeds are dropped in and covered over. Sowing takes place at the beginning of the rainy season, October–November; the first crop of nuts for eating green is ready about April, but they are not ripe till 9 months after sowing, or about July–August. The greater part of the crop of Angola and the Congo is grown in the Mbamba country, parallel with the coast, and 30–80 miles inland. The Indian-grown nuts are chiefly used locally as food, while some oil is obtained from them, mostly for adulterating other oils. Recent figures state the area occupied by it in India at 112,000 acres, and this is capable of very great extension. In Java, the nut is planted in high grounds, that are unfit for wet rice cultivation; after extraction of the oil, the refuse is used as manure. In Senegal and on the Gambia river, these nuts form a staple production, Cayor and Casamanco furnishing the largest quantities. The American crop for 1880 was estimated as follows:—Virginia, 1,600,000 bush.; Tennessee, 1,100,000: N. Carolina, 120,000; total, 2,820,000 bush. Jamaica had 5 acres under ground-nuts in 1874–5, but only 2 in 1877–8. The important alimentary value of ground-nut meal may be judged from the following analysis:—Moisture, 9·6; fatty matter, 11·8; nitrogenous compounds, 31·9; sugar, starch, &c., 37·8; fibre, 4·3; ash, 4·6 per cent. It is thus far superior to both peas and lentils. The chief use of the nuts at present in Western commerce is for the oil which they afford (see Oils—Ground-nut); for the sake of this oil, they are largely imported to Marseilles, London, and Hamburg. The exports from the Gambia were 15,729 tons in 1858, and 13,000 tons in 1872; they fell to 10,000 tons in 1876, but reached the unprecedented figure of 29,396 tons in 1879. The exports from Sierra Leone in 1870 were 350 tons and 713,524 bush., all for France. Senegal exported 11,483,080 *kilo.* to France in 1874. The exports of ground-nut cake from Kiungchow were 17,600 *piculs* (of 133⅓ lb.) in 1877, 7942 in 1878, and 14,612⅓, value 5989*l.*, in 1879. The exports of the cake from Pakhoi were 250,000 *piculs* in 1879. Taiwan exported 10,619 *piculs* of the cake in foreign bottoms in 1879. The exports of the nuts from Amoy were 1666 *piculs* in 1877, and 695 in 1878. The exports from Grenada Island (W. Indies) were 451 barrels and 216 bags in 1878.

Hazel-nut.—The fruits of the wild *Corylus Avellana* are the common hazel-nuts; several species and varieties are distinguished, the principal being var. *barcelonensis*, affording the Spanish and Barcelona nuts, *C. Colurna*, yielding the Turkish kind, *C. tubulosa*, filberts; and *C. Avellana* var. *grandis*, the Kentish cob-nut. Some of the species are probably mere varieties produced by cultivation. The common wild nut is a native of all the cooler parts of Europe, N. Asia, and N. America. Of these nuts, our importations never exceed 300,000 bushels. The bulk comes from Spain. These, though afforded by one variety of tree only, are classified separately as—(1) Spanish: coming from Gijon, said to be sulphured, and will not keep for any time, arrive in bulk; and (2) Barcelona: kiln-dried, shipped from Tarragona in bags of 128 lb. The production of hazel-nuts is an important industry on the Turkish coast districts, extending from Athina to a little westward of Kerasund, and they constitute the chief riches of Kerasund, Tireboli, Ordos, Keureli, Yomurah, and Surmeneh. The best qualities are those of Kerasund and Tireboli. Since 1876, the nuts have been shipped from these places directly to Great Britain, and their yearly value is now upwards of 20,000*l.* The exports of nuts (including a few walnuts) from Trebizond in 1879, in sacks of 1½ cwt., were:—To Turkey, 11,862, value 17,793*l.*; France, 1924, 2886*l.*; Austria and Germany, 612, 918*l.*; Russia, 1150, 1725*l.*; Greece, 552, 828*l.*; Bulgaria and Roumania, 2004, 3006*l.*; total, 18,104, 27,156*l.* Filberts are of three kinds, white, red, and frizzled. The first is most commonly grown in this country. Hundreds of acres are planted with it in Kent, whence the London market is chiefly supplied. It is said that 30 cwt. an acre is sometimes raised on suitable land, affording a higher money return than probably any other crop grown in this country. Hazel-nuts afford a bland oil (see Oils—Hazel-nut).

Hickory-nut.—Several species of hickory-tree, all natives of N. America, afford edible nuts. The fruits of the Peccan or Illinois hickory (*Carya olivæformis*), a common tree on the Ohio and Mississippi, are light-brown in colour, and shaped like an olive; they are much superior in flavour to the nuts of any other species of the genus, and occasionally are found in English fruit-shops. The nuts of the shell-bark hickory (*C. alba*) are second in point of edible qualities. The nuts of nearly all these trees are valuable for their oleaginous properties (see Oils—Hickory-nut).

Kola-, or Guru-nut.—This name is applied to the seeds of *Cola* [*Sterculia*] *acuminata*, a tree indigenous to W. and central tropical Africa, and introduced by the negroes into Brazil and the W. Indies. These nuts are held in the highest estimation among the African races, for promoting digestion, and rendering stale water potable; and they form a most important article of commerce from the Angola to the Mediterranean. Chemical examination of the nuts has proved them to contain an alkaloid, similar to that of tea or coffee, and they are habitually used as substitutes for our ordinary dietetic beverages by foreigners residing in the localities producing them. They are said to promote digestion, support fatigue, and produce a generally bracing effect upon the system. When better known, they will doubtless be cultivated in our tropical colonies, especially as they flourish both on the sea-coast and inland.

Palm-nut.—The well-known palm-oil of commerce (see Oils—Palm) is the product of the outer fleshy coating of the seed of *Elæis guineensis*, a palm indigenous to W. tropical Africa, where it is found in great abundance, and whence it has been introduced into the W. Indies. Some oil is also yielded by the seed. The shell of the nut takes a fine polish, and is made into ornamental articles by the negroes. The geographical range of this palm in Africa extends from the coast of Guinea to the south of Fernando Po, and into the interior as far as Zhern, 400 miles from the sea, and the mouth of the Min, a tributary of the Niger. It flourishes also on the islands of Zanzibar and Pemba; occurs on the mountains of Usagona; and is plentiful around the lakes of Central Africa. Its limits are probably far from being yet defined. Strangely enough, beyond a successful attempt to introduce this most useful tree into Labuan, virtually nothing has been done to extend its range, and we remain absolutely dependent upon the W. African ports for our supplies of the oil. The following notes convey all that is known about the cultivation of the palm. The ground is first well-raked, and the ripe nuts selected for sowing are scattered broadcast over the prepared ground, and lightly covered with earth, or 6–10 nuts are dropped together into holes at various distances, and covered with earth. The planting is effected during the rainy season, as moisture is essential. When the young shoots are about 1 ft. high, they are carefully removed in the evening, and transplanted at distances of at least 15 ft. from each other; the best plan is to let them remain during 12 months, before performing the transplantation. The tree grows luxuriantly, and bears abundantly when it is 10–12 ft. high, if in a damp, semi-marshy soil, where water does not stagnate; but in dry, arid soil, it becomes stumpy, growing very slowly, and sometimes bearing fruit when only 4 ft. high. To ensure healthy trees, and a full crop of "fat nuts," the trees must be at least 20 ft. apart, and well supplied with water. The harvest of nuts fit for use is biennial, but the chief quantity of commercial oil is obtained from nuts gathered during the rainy season. The kernels now form a distinct article of trade, not less important than the oil itself: 27,873 tons were shipped from Lagos in 1878; 100,000 tons from Sierra Leone in 1870; 104 tons from the Gambia in 1877, and 87 tons and 91 bags in 1878. The meal left after expressing the oil from these kernels is one of the most valuable fat-producing foods for cattle, its analysis showing:—Moisture, 7·49; fatty matters, 26·57; albuminous compounds, 15 75; starch, mucilage, sugar, and digestible fibre, 37·89; woody fibre, 8·40; ash, 3·90 per cent.

Physic-nut.—This name is applied to the seeds of *Curcas purgans* [*Jatropha Curcas*], from the powerfully purging qualities of the oil expressed from them. The plant is indigenous to tropical America, and is very generally found in warm climates, being cultivated in Brazil, the E. and W. Indies, W. Africa, the Cape Verde Islands, the Philippines, &c. It is readily increased by cuttings, which rapidly take root, and is invaluable as a hedge-plant, the leaves being refused by all cattle. The Cape Verdes produced 16,672 tons of the seeds in 1869. The wider cultivation of the plant in our tropical colonies would be amply repaid by the oil (see Oils—Pulza).

Pistachio-nut.—Pistachio-nuts are the produce of *Pistachia vera*, a native of W. Asia, whence it has been introduced into S. Europe, and has there become very largely cultivated. The nuts are very generally eaten by the Turks, Greeks, and natives of S. Europe, either simply dried as a dessert-fruit, somewhat resembling almonds, or made into articles of confectionery. We import them in small quantities, both shelled and unshelled. The exports from Aleppo in 1878 were:—7 tons, value 420*l*., to France; 32 tons, 1920*l*., to Turkey; and 8 tons, 480*l*., to Egypt. Bagdad in 1878 exported 9 cwt, value 52*l*., to India and Europe.

Sapucaya-nut.—The seeds of *Lecythis Zabucajo* occasionally come in small quantities to this country. The tree is a native of Venezuela, Guiana, and Brazil, and grows indifferently on the *terra firme*, in the swamps, and on the edge of the flood-plains. The nuts are likely to supersede the closely-allied Brazil-nuts as a dessert-fruit, being far superior in flavour, and easier of digestion. They are more than 2 in. long and 1 in. wide. Our supplies are drawn from the Brazilian forests, and are shipped at Pará. The seeds of *L. ollaria*, whose fruits are known as "monkey-pots," and sometimes used in ornamental turnery, are less palatable.

Singhara-nut.—The singhara-nut of India is the produce of two species of water-chestnut, *Trapa bispinosa* and *T. quadrispinosa*, which flourish in the lakes of Cashmere, and in the ordinary water-tanks all over the upper provinces of Bengal. In Cashmere, the cultivation of these nuts is a most important industry, and it is estimated that they feed 30,000 people for 5 months in the year. Their more extended growth in all lakes, jheels, and inland waters in all parts of India is strongly urged as a step towards preventing future famines. The harvest or season when the nuts are mature lasts for 3 months, and the nuts may be stored for years in their horny outer skin, or the kernels may be taken out and sun-dried, and will then remain good for a long time. Another species, *T. natans*, is cultivated in S. Europe, and its nuts are often ground, and made into bread. Yet another species, *T. bicornis*, is the *ling* of the Chinese, whose seeds also form a considerable article of food.

Soap-nut.—The name "soap-nuts" or "soap-berries" is applied to the seeds of several species of *Sapindus*, from the fact of their being used in the tropics as a substitute for soap, their outer covering or shell containing a saponaceous principle in sufficient quantity to produce a lather with water. Among the species thus used are *S. Rarax* and *S. emarginatus* in the Old World, and *S. Saponaria* and *S. inæqualis* in the New. The round, hard, black seeds are used for small articles of turnery, and *S. emarginatus* affords a medicinal oil in India (see Oils). The seeds of *Acacia concinna* are used in India in the same manner as the soap-nuts proper. Soap-seeds figure largely in Chinese commerce. Hankow exported 1183 *piculs*, value 344*l.*, in 1879. Shanghai, in 1879, imported 1788 *piculs* from Chinese ports, of which, 744 were retained for local consumption.

Walnut.—The fruit of the common walnut (*Juglans regia*) is too well known to need description. The tree is found native from Greece and Asia Minor, over Lebanon and Persia, along the Hindu Kush to the Himálayas, and from the Caucasus almost throughout China, besides having been introduced generally throughout temperate Europe. In portions of the Alps and Apennines, it is very abundant, and is fairly plentiful in the forests of Lazistan, on the Black Sea, but is perhaps most common in Cashmere, whence come the walnuts imported into the plains of India. The green nuts form an esteemed pickle, and the ripe ones an equally favourite dessert-fruit, while in some places they are treated for the extraction of a valuable oil (see Oils—Walnut). Our supplies come mostly from the Continent. China produces immense quantities: the exports from Hankow in 1878 were 10,560 *piculs* (of 133⅓ lb.), and in 1879, 9766 *piculs*, value 12,829*l.*; the exports from Chefoo fell from 5001 *piculs* in 1870 to 1693 in 1879.

Preparations of the walnut are included among medicinal agents on the Continent, notably an extract of the dry leaves. From experiments made with preparations from leaves collected in June, and in October, and leaves 12 months old, it would appear that the full-grown leaves may be collected at any period during fine weather, even as late as October, when they can be removed without injuring the tree. The extract should be prepared with such leaves recently dried. The leaves falling in autumn should not be used, though there is reason to suspect that they are often employed in preparing the commercial extract. When the leaves are of good quality, they have a fine green colour on the upper surface, and a darker green beneath, with brown petioles. They have a parchment-like texture, an aromatic odour, and a freely bitter and astringent flavour. Altered leaves lose most of their odour and flavour, and assume a brownish tint. Fallen autumn leaves sometimes show yellow spots.

Imports.—Our imports of nuts and kernels, mostly used for expressing oils therefrom, in 1879, were as follows:—From the W. coast Africa (foreign), 11,629 tons, value 158,571*l.*; Gold Coast, 9666 tons, 131,094*l.*; Australia, 4845 tons, 95,319*l.*; Pacific Islands, except Fiji, 3041 tons, 61,413*l.*; British W. Africa, 2748 tons, 33,994*l.*; other countries, 2437 tons, 41,379*l.*; total, 34,366 tons, 521,770*l.*

Bibliography.—P. L. Simmonds, 'Nuts, their Produce and Uses' (Jour. Soc. Arts., Vol. xx., No. 1014, London: 1872); P. L. Simmonds, 'Tropical Agriculture' (London: 1877).

OILS AND FATTY SUBSTANCES (Fr., *Huiles et Corps Gras*; Ger., *Oele und Fettwaaren*).

The dual heading "oils and fatty substances" is rendered necessary by the fact that, in everyday language, the specific terms "oil" and "fat" are very widely, and often erroneously, applied. The name "oil" is made to embrace three distinct classes of bodies:—(*a*) "fixed" or "fatty" oils, (*b*) "volatile" and "essential" oils, and (*c*) "petroleum" and other "mineral" oils.

The first class comprises a number of organic bodies, composed of carbon, hydrogen, and a little oxygen, viscid liquids, communicating a permanent stain to paper, insoluble in water, and, as they occur in nature, mostly mixtures of different simple fats, which, by saponification, are resolved into fatty acids and glycerine. For further information upon the subject of saponification, the reader is referred to the articles on Candles and Soap; the identification of the fatty acids is discussed under the section of the present article entitled Detection and Analysis. The term "fat" is applied to these oils when they are in a solid state; thus the same product may be an "oil" in one climate, and a "fat" in another.

The second class, volatile and essential oils, consist either wholly of carbon and hydrogen, or of these elements supplemented by less proportions of oxygen, nitrogen, and sulphur. They have a thin, oily consistence, volatilize completely at high temperatures, possess powerful and peculiar odour and flavour, are very inflammable, and sparingly soluble in water. Many of them occur ready formed in organic bodies, chiefly of the vegetable kingdom, and are then true essential oils; others, which are volatile but not essential, are produced by dry distillation, fermentation, and other changes.

The third class, mineral oils, belong strictly to the preceding, being true volatile oils; but their immediate sources, preparation, and application, differ so widely, and they form, moreover, such an important branch, that it will be best to consider them separately. Neither essential nor mineral oils can be spoken of as "fatty substances."

The arrangement adopted in this article is as follows:—Oils and Fats derived from Animals, Fish, and Insects, whether fixed or volatile (p. 1361); Fixed Oils and Fats derived from Plants (p. 1377); Volatile and Essential Oils derived from Plants (p. 1415); Mineral Oils (p. 1433). These main sections will be followed by various General Considerations bearing upon the whole subject, and embracing Improved Modes of Extraction (p. 1447); Refining, Clarifying, and Bleaching (p. 1459); Detection and Analysis (p. 1462); Illuminating Values (p. 1477); Heating Values (p. 1478); Lubricating Values (p. 1479); Boiling, Oxidizing, and Vulcanizing (p. 1482); Imports (p. 1482); Prices (p. 1483); Bibliography (p. 1483).

ANIMAL, FISH, AND INSECT OILS AND FATS.

Blackfish-oil.—The term "blackfish" is very promiscuously applied by whalers, and includes the common black whale of the Australian seas (*Balæna australis*), *Physeter microps*, and *P. Tursio*, besides the pilot whale (*Globiocephalus Svineval*), the American *G. intermedias*, and the killer (*G. macrorhyncus*) of the South Sea whalers. The two species of chief importance as oil-yielders are *G. intermedias* and *G. macrorhyncus*. The former is pursued by the Tasmanian whalers, and affords an average of 30–35 gal. of dark, unpleasantly odorous oil. This fishery, in 1869, produced 13 tuns; in 1873, 12½ tuns; and the exports in 1875 were 25 tuns, value 965*l*. The American cetaceans appear about the shores of Cape Cod and Barnstaple Bay from early summer till early winter. They are surrounded by boats, and frightened till they beach themselves in endeavouring to escape. They are then lanced, and when the tide leaves them, their blubber is cut out, and "rendered." The product is about 30 gal. of oil. In addition, a portion of the head, reaching from the spout-hole to the end of the nose, and from the top of the head to the upper jaw, and forming a piece weighing about 25 lb., affords some 6 qt. of a very limpid oil, which is commonly termed "melon-oil." This oil is said to have an unusually low congealing-point, and to have no corrosive effect on metallic surfaces; it is specially prepared by a few firms in the United States as a superior lubricator for delicate mechanisms. (See also Spermaceti, p. 1371; Whale-oil, p. 1374).

Bone-fat (Fr., *Suif d'os*, *Graisse d'os*, *Petit suif*; Ger., *Knochenfett*).—A fat of varying quality is obtained from slaughter-house and kitchen bones, by boiling them in water, previous to their utilization for articles of turnery, manurial purposes, &c. The conduct of the operation and the nature of the products are described in the article on Bones (p. 521). Some improved methods of separating fat from bones will be found under another section of this article (see p. 1448).

Bone-oil, Dippel's Oil, Animal Oil.—In the dry distillation of animal gelatinous substances, the oil known by these various names is produced, it being a result of the decomposition of gelatinous tissue. That first introduced into pharmacy was obtained from stags'-horn, but all now found in commerce is recovered as a product of distillation during the calcining of bones for the preparation of animal charcoal or bone-black. The operation is described and illustrated on p. 1450. The crude oil is dark-brown to black; its sp. gr. is 0·97; it consists chiefly of a mixture of volatile organic bases, with lesser proportions of acids and neutral hydrocarbons.

Butter (Fr., *Beurre*; Ger., *Butter*).—The fatty portion of the milk of all mammalian animals is called "butter," but the term in a commercial sense is restricted to that from the cow. The methods adopted for making butter vary widely throughout the world, but the object of the operation is always the same, viz. to rupture the thin membranous sacs in which the butter is disseminated through the milk, and to enable their contents to coalesce. Butter is produced in most countries which possess pastures, but in some much more extensively than in others. The quantity made annually in the United Kingdom is estimated at 1½–2 million cwt. Much of this is Irish, Munster being the great butter-producing province. The chief ports for its shipment are Cork, Waterford, Limerick, and Belfast. Cork monopolises the foreign export trade, and the butter shipped there is usually more heavily salted, with a view to its longer preservation. The supplies from the other three ports are less strongly cured, and better adapted for immediate consumption. About ⅓ of the total exports go to foreign markets, principally to Brazil, smaller quantities to the Mediterranean, W. Indies, and Australia. Irish butters are divided into six qualities, and are esteemed inferior to good Continental butters. France is noted for its butter, the foremost quality being from Isigny, and including not only that made in the district, but also the best produce from Normandy and Calvados. The Gournay butter, made in the departments of Eure and Seine-Inférieure, ranks second. French salted butter comes from Brittany, especially Morlaix, Rennes, Nantes, and Vannes. Dutch butter is of three kinds—(1) "grass" butter, made from cream when the cows are at grass; (2) "hay" butter, made from cream when the cows are being stall-fed; (3) "whey" butter, made from the whey of new-milk cheese. A peculiarity in the Dutch way of making cream butters is the cooling of the new milk by cold-water troughs for a couple of hours, the milk being stirred meanwhile. This hastens and perfects the separation of the cream. American butters are now said to be largely adulterated with powdered soapstone or steatite (a natural silicate of magnesia), which increases the weight without affecting the bulk. For shipment to warm climates, butter should be packed in 1-lb. or 2-lb. glass bottles, with mouths about 2 in. across, and fitted with glass stoppers with a cement that will keep air-tight. A spoonful of the very best salt should be added at the top before stoppering. French butter is thus sent to the E. Indies.

The commerce in butter is extensive. The exports of butter from European Russia have risen from 112,925 *poods* (of 36 lb.) in 1873, to 174,110 *poods* in 1878; in 1871, they amounted to 237,401 *poods*. The exports from Sweden have grown from 69,815 *centners* (of 93⅝ lb.) in 1873, to 89,908 *centners* in 1878. The Danish exports have increased from 35,547 *tönder* (of 3·82 bush.) in 1868–9, to 102,140 *tönder* in 1878; they were 142,703 *tönder* in 1876. The exports from the German Empire were 258,000 *centners* (of 110¼ lb.) in 1872, and 244,000 *centners* in 1879. The exports from Holland have risen from 15,246,000 *kilo.* in 1872, to 36,451,000 *kilo.* in 1879. The exports from Belgium have grown from 3,784,000 *kilo.* in 1871, to 5,231,000 *kilo.* in 1879. The exports of butter and cheese together from France rose from 21,309,000 *kilo.* in 1870, to 43,081,000 *kilo.* in 1876; but fell to 31,598,000 *kilo.* in 1879. The exports from the United States have increased from 2,019,000 lb. in 1870, to 38,248,000 lb. in 1879; Philadelphia shipped 605,529 lb. in 1879. The exports from Canada fell from 170,254 cwt. in 1872, to 82,752 cwt. in 1875, then rose to 138,210 cwt. in 1877, and were 129,787 cwt., value 445,510*l.*, in 1879. The value of the butter exports from Natal fell from 8403*l.* in 1869, to 689*l.* in 1876, and was 1724*l.* in 1878. These statistics include all substances declared as butter to the Customs authorities. Large quantities of artificial compounds help to swell the figures, notably those of Holland and the United States.

The quality of butter depends upon the season, and upon the breed, health, and diet of the animal. It is a complex compound of glycerides, of non-volatile acids (fats), and of volatile acids. It should contain at least 85 per cent. of pure fat, the remaining constituents being 3–5 per cent. of caseine or curd, imperfectly washed out; 5–12 per cent. of water, according to whether it is fresh or salt butter; and 4 per cent. of salt in fresh, and 8 in salt butter. Its true melting-point, as determined by Hassall, ranges from 32°·8 (91° F.) to 34°·9 (95° F.), the mean being about 33°·5 (92°·3 F.). It dissolves in 28 parts boiling alcohol of 0·82 sp. gr. Dr. Hager has fixed the sp. gr. of butter at 15°–16° (58°–60° F.) at 0·938–0·940 when clarified by settling, and at 0·936–0·937 when several months old. It is most extensively adulterated (see Butterine). The most reliable tests for the detection of admixtures of foreign fatty substances in butter will be found in the section devoted to detection and analysis (see p. 1465).

Butterine, Bosch, Oleomargarine, or Artificial Butter (Fr. *Margarine-Mouries*).—Within the last decade, a new and important manufacture has sprung up in consequence of the dearness and scarcity of butter. It was initiated in France, and the product was called *Margarine-Mouries*, from the name of its inventor; in this country, it is variously styled "butterine," "bosch," "oleomargarine," and "artificial butter." It originated from a surmise of the eminent French chemist Mège-Mouries, that the formation of butter contained in milk was due to the absorption of fat contained in the animal tissues. This led to the experimental splitting-up of animal fats, with the result that a process was devised by which the oleine and margarine contained in the fat could be almost completely separated on a commercial scale from the stearine. This process consists in heating finely-minced beef-suet with water, carbonate of potash, and finely-chopped fresh sheep's-stomachs, at a temperature of 45° (113° F.), when the combined influence of the pepsine of the sheep's-stomachs, and the heat, causes the separation of the fat from the cellular tissue. The fatty matters are removed, cooled, and submitted to powerful hydraulic pressure in the cold, which effects their determination into a solid and a liquid portion, the former being stearine, a commercially valuable article, and the latter the oleine and margarine, or oleomargarine, required for making the artificial butter. This is the process patented by Mège-Mouries, and under which a large proportion of the butterine is made.

A method that is very extensively employed in the United States consists in thoroughly washing the picked beef-suet in water, and placing it in a steam-jacketed pan; the contents are never allowed to experience a temperature exceeding 49° (120° F.). The pure fat that runs off is "seeded" (i.e. allowed to cool very slowly, which facilitates the mechanical separation of the stearine) and pressed. The resulting stearine is sold for candle-making purposes, while the liquid portion (oleomargarine) is used in the manufacture of butterine.

Another arrangement is adopted by W. Cook and S. Hall of the E. London Soap-works, Bow. The freshest beef-suet is first thoroughly disintegrated and reduced almost to a pulp. A wooden chamber is provided, of sufficient height to accommodate a workman, and with a passage up the centre. At the two sides, are inclined racks; upon these, shallow iron trays are slid in from the outside, and rest with a slight slope towards the central passage. Along the lower free edge of each row, is an open iron gutter, leading to a receiver outside. The comminuted fat is laid in thin layers upon the trays, and the temperature of the chamber is raised by steam-pipes to such a degree as will just suffice (and no more) to liquefy the fat, which then escapes by the gutters to the receiver, leaving behind such shreds and portions of tissue as are not liquefied by the heat. The temperature should never exceed 54°–57° (130°–135° F.), and a much lower degree will be equally effective by prolonged time. The product (oleomargarine) is remarkably fine and fit for food.

The residual matters, still containing 6–7 per cent. of tallow, are mixed with kitchen-stuff, and rendered by the ordinary process described in another section (see pp. 1447–8).

The oleomargarine obtained by either of these processes is too limpid for use alone. It is mixed, either in the locality of production, or after exportation (in barrels or tierces, under the name "oleomargarine," "butter-fat," or simply "oil,") to butter-producing districts, with proportions of milk, water, and colouring matter. The usual proportions are 10 lb. oleomargarine, 4 pints milk, and 3 pints water, with a little annatto and salt. It is important to remark that (in America at least) the milk is invariably used in a slightly sour condition. The whole is churned up with the greatest care as to the temperature at which the operation is conducted, and is then suddenly run out in thin layers upon sheets of ice to cool it rapidly. It is finally made up in "pats" and packed, in every respect the same as genuine butter. The characteristics which distinguish it from true butter are described at p. 1465. A compound termed "creamy butterine," recently put upon the market in large quantities, has the taste, appearance, and odour of butter, and yields 92 per cent. of insoluble fatty acids. New York manufacturers state that, when the retail price of genuine butter falls below 23 cents (say 11½*d.*) a lb., it does not pay to make butterine. The average wholesale prices of the oleomargarine oil and the manufactured butterine ruling in New York since 1876 have been 13 cents and 15 cents a lb. respectively. As to the nutritive value of butterine, French official reports pronounce it superior to butter. On the score of its liability to contain organic germs likely to produce dangerous or fatal results in persons eating it, there is a marked want of agreement among scientific men. Much probably depends upon the care used in the selection of the fat and in the conduct of the manufacturing process; where inferior fats are employed, as it is to be feared is sometimes the case, it seems impossible to avoid a dread of evil consequences. Complaints are made that quantities of Chicago pig-lard are being introduced by some makers.

The manufacture of butterine has assumed very large proportions in the United States; it is chiefly carried on in New York, but factories also exist in Philadelphia, Pittsburg, Chicago, Cincinnati, and other cities. It is estimated that at least 6 million lb. of oleomargarine are exported annually from New York. The shipments take place almost entirely to the Continent, Havre, Hamburg, Bremen, and Rotterdam being the most important destinations. In the warm months, the oil is the main export, although the prepared butterine is also shipped in refrigerators by steamer. During the winter months, both oil and butterine are exported, the latter chiefly to the United Kingdom, but its proportion is comparatively small in relation to the oil sent to the Continent. After the oil has been converted into butterine in Germany and Holland, it is re-shipped to England and France, mainly the former.

Cod-liver-oil (Fr., *Huile de Foie de Morue*; Ger., *Leberthran*).—A valuable oil is afforded by the liver of several fish of the genus *Gadus*, notably that of the common cod, *G. Morrhua*. The chief seats of the cod-fishery are the coasts and banks of Newfoundland, Nova Scotia, the Gulf of St. Lawrence; the W. coast of Norway, from Stavanger nearly up to Hammerfest, and including the Loffoden Islands; the coasts of Denmark and Germany, commencing at Römö on the W., passing through the Skager Rack and Cattegat, and extending E. to Dantzic; the coasts of Shetland, Færoe, and Iceland, and the Dogger Bank in the North Sea.

The methods in vogue for extracting the oil from the cods' liver are not everywhere the same. The common plans at the less advanced fisheries, as in Iceland and the Finland ports, are as follows. The clear oil is obtained by throwing the livers, directly they are brought ashore by the fishermen, into large wooden reservoirs or barrels, where, after having been subjected to uniform stirring, they remain till decomposition has taken place. The effect of this is to cause the rupture of the cells containing the oil, which latter then escapes, and collects on the surface. It is drawn or ladled off as it rises, and conveyed into larger vessels for clarification by settlement of the impurities, afterwards being filled into casks for sale. The oil will be observed to darken considerably in colour as the decomposition progresses, and is somewhat deteriorated thereby. The burnt, brown, or tanners' oil is obtained from the solid remains left from the preceding process, which are placed in iron kettles, and boiled till all the water contained in the liver is evaporated; this also liberates the oil, which is strained, clarified, and barrelled like the first quality.

These crude processes have been considerably modified in Newfoundland and Norway. The livers reserved for the preparation of medicinal oil are taken as fresh as possible, always within 12 hours of the capture of the fish. They are very carefully examined, and those which are poor or injured, or have pieces of gall adhering, are rejected. The selected livers are then thoroughly washed and dried. They are immediately put into open barrels, where the oil slowly exudes, and is ladled from the surface. When quite cold, it is filtered several times through blotting-paper, and put up in tin cans or oak barrels. It is of a straw-yellow colour, almost devoid of taste and smell, and is known as "natural medicinal." The livers are then placed in tinned sheet-iron pots, suspended in water contained in a larger pot—a kind of water-bath; the heating of the water causes the oil to exude from the livers. Sometimes the heating medium is steam, and in other cases, the steam is directly applied to the livers themselves. The temperature at which the operation is conducted appears to differ most materially. At some works, it is not allowed to exceed 44½° (112° F.); while at others, it is raised to 82° (180° F.). The occurrence requiring to be specially guarded against is the breaking-up of the livers before the oil has been removed from the vessel, otherwise infinitesimal portions of animal matter mingle with the oil and subsequently putrefy in it, thus lowering its value. The exuded oil is skimmed off, and "reduced" or "boiled away" till all the water has evaporated from it. It is then filtered four times through filter-paper or very fine muslin, to free it from all remaining solid impurities. The yield of oil depends upon the condition of the fish, which varies exceedingly with the season. Early in the season, they are rich in liver, so that 250-300 fish may give a barrel of liver; as the season advances, they become poorer, till 600–700 are required to give the same quantity of liver.

The classification of the product naturally depends upon the systems which are in vogue for its preparation. The most usual subdivision is threefold:—(1) The palest and purest, termed "steam-boiled medicinal" or "ordinary bright," used only in medicine; (2) a somewhat redder after-yield, called "light-brown," inferior for medicinal purposes, but largely used for such; (3) the "dark-brown," or "tanners'," obtained by roughly boiling down the livers remaining from the foregoing processes. The last is settled in large receiving-tanks, racked off, and barrelled. It is largely used by tanners and curriers. The best is said to be from Newfoundland; that from Labrador fetches 2–4 cents a gal. less in the market. The refuse solid materials remaining after all the oil has been extracted are added to other offal for making fish guano (see Manures). The chemical and physical characteristics of the three qualities of the officinal oil as classified by de Jongh are as follows:—(1) Palest and clearest: colour, golden-yellow; sp. gr., 0·923 at 17½° (63½° F.); soluble in 40 parts cold and 22–30 parts boiling absolute alcohol; deposits a white fat at −13° (9° F.); (2) pale-brown: colour, that of Malaga wine: sp. gr., 0·924; soluble in 31–36 parts cold and 13 parts boiling absolute alcohol; (3) brown: colour, dark-brown, greenish by transmitted light; sp. gr., 0·929 at 17½° (63½° F.); soluble in 17–20 parts cold or hot absolute alcohol; deposits no solid fat at −13° (9° F). The oil consists chiefly of oleine and margarine, and contains small proportions of iodine, bromine, and free phosphorus, besides peculiar constituents. It is very largely prescribed in medicine, its efficacy being probably due to the bromine, iodine, and phosphorus present, though opinions are not uniform on this point. Many other oils are substituted for true cod-liver-oil. That obtained from the ling (*Gadus* [*Lota*] *Molva*) is recognized by the London pharmacopœia. The liver-oils of the dorse (*G. cellarius*), and the coal-fish (*G. carbonarius*) were formerly supplied to Great Britain from Bergen, and are still chiefly used in Germany and Scandinavia. The burbot (*Lota vulgaris*) also contributes to the liver-oil prepared in the Shetlands, &c. Besides these, the oils extracted from the livers of the haddock, hake, cat-fish, conger-eel (p. 1375), ray (p. 1376), shark (p. 1370), and probably many others, are surreptitiously mingled with the cod-liver-oil of commerce.

The trade in cod-liver-oil and its substitutes has attained considerable dimensions, and is of great importance to the population of certain districts. The annual production of Newfoundland is said to amount to 1¼ million gal., value 200,000*l.*; the exports of unrefined cod-liver-oil were 2275 tuns (of 210 gal.), value 113,757*l.*, in 1864, and 2946 tuns, value 49,618*l.*, in 1878; the highest figure reached during that time was 4140 tuns, 138,000*l.*, in 1869; the lowest was 2268 tuns, 75,600*l.*, in 1876; the exports of refined cod-liver-oil were 171 tuns, 26,380*l.*, in 1864, and 63 tuns, 2520*l.*, in 1878; the highest figure reached during that time was was 419 tuns, 27,944*l.*, in 1865; the lowest was in 1878. The French cod-fisheries on the Newfoundland coast were said to have yielded an average of 560,000 *kilo.* of oil in the five years ending 1871. The Norwegian fisheries exported 130,600 barrels, value 386,600*l.*, in 1877; the estimated exports in 1878 were 66,000 barrels (of 100 *kilo.*), of which, 4000 were white steam-prepared oil, 12,000 yellow medicinal, 12,000 common oil for industrial purposes, 8000 brownish-yellow, and 30,000 brown tanning, considerable quantities of which are still used medicinally on the Continent. The Loffoden fisheries, in 1879, afforded about 2750 barrels of medicinal oil, and 33,500 barrels of blubber; the Finmarken fisheries, in the same year, produced 3080 barrels of medicinal oil, and 25,000 barrels of coarser oil; the Söndmöre fisheries also gave some 2700 barrels of medicinal oil. The total exports of cod-liver-oil from Sweden and Norway in 1879 were 143,165 *hectol.* (of 22 gal.).

To the foregoing account, R. G. Clements, of Hackney, has been good enough to add remarks substantially as follows. For many years the Newfoundland oil was considered the only sort safe for medicinal use. Norway attempted the extraction, but the imperfect method of its preparation caused it to be neglected in the London market. Of late years, however, great improvements have been made, and now that the Norwegian oil comes in tin-lined casks instead of simply wooden ones, it has quite superseded the Newfoundland brand. An exceedingly fine oil may be prepared on a domestic scale by selecting the quite fresh livers, washing and drying them, puncturing them all over with a pen-knife, and placing them on a dish before a fire. In Norway, three industrial methods are in use:—(1) Exposure to the sun, then boiling in water, and skimming off the oil; (2) packing into vats provided with three taps, when, after remaining long enough, the oil floats, and is let off by the taps, the uppermost giving the best; (3) cutting into slices, and exposing to a temperature of 82° (180° F.). All livers which have yielded cold-drawn oil are afterwards exposed to moderate heat for the extraction of straw-coloured oil, and then to stronger heat for brown oil. The property demanding chief attention in oil for medicinal purposes is the presence of free iodine (not added), and all wholesale dealers determine its proportion (by the usual sulphuric acid test) before purchasing the oil.

Crocodile-oil.—The oil of the Indian crocodile contains a larger proportion of solidifiable fat than either neats'-foot or any fish oil. It solidifies at the melting-point of ice, while the others only thicken. In comparison with the softening qualities of other animal oils on leather, it has been found that leather treated with crocodile-oil remained much stiffer than when other animal oils were used. It has been inquired after for leather-dressing in this country, but is not yet a commercial article here. It is prepared by the Sanif tribe, in the Punjab, who eat crocodile-flesh, and it is said to be abundantly procurable at Agra.

The fat of the alligator (*Alligator lucius*) is largely utilized. The tail of an alligator of 12 ft. in length, on boiling, furnishes 50–70 pints of excellent oil, which, in Brazil, is used for lighting, and in medicine. The alligators of Central America and the United States might be similarly turned to account.

Dugong-oil.—Of the "dugong," "sea-hog," *yungan*, or *mooda hoora*, there are two species, *Halicore australis*, and *H. indicus*, each yielding an oil of great value in medicine and cooking. The latter species is distributed throughout the Indian Ocean, abundantly in the Gulf of Manaar, on the W. coast of Ceylon, between Adam's Bridge and Kalpentyn; also in the Straits Settlements, and the Eastern Archipelago. The former species is found on the Australian coasts, from Brisbane northwards along the Great Barrier Reef; in the Gulf of Carpentaria; in Shark's Bay, W. Australia; and along the N.-W. coast. The pursuit of the animal by Europeans on an industrial scale is almost confined to the Queensland coast, chiefly in Moreton Bay, Wide Bay, Hervey's Bay, Cleveland Bay, and the mouth of the Pioneer River. Only one vessel is said to be engaged in this fishery at Shark's Bay, W. Australia; in Ceylon and the Straits, this industry seems to be totally neglected, except by the Malays, who hunt the animal for food.

The animals frequent shallow waters, where the depth does not exceed 2–4 fathoms, and feed on the sea-grasses found in such localities. Their habits are essentially gregarious, and they are sometimes met with in immense herds. The method of capture adopted by the Australian blacks is to surround the creatures on their feeding-grounds, and drive them landwards, where they kill them by spears. Netting is sometimes successful on a retreating tide; and harpooning is also practised from boats, which requires great skill and caution. The wariness of the animals places an obstacle in the way of a development of the industry, as they suddenly desert a feeding-ground and appear elsewhere, where no provision has been made for boiling them down. The assistance of a tender carrying the necessary apparatus will probably have to be brought into requisition.

The size of the Indian animal varies from 6 to 10 ft.; the Australian sometimes reaches a length of 15 ft. The weight of an average specimen is 4–6 cwt., though they occasionally attain to 10–12 cwt.; the yield of oil ranges between 6 and 14 gal. usually, but exceptionally amounts to 18 gal. It is obtained from the adipose matter of the cellular substance under the skin, which is boiled down for its extraction. It is free from odour, and has no unpleasant flavour; when well refined, it is clear and limpid. It loses its fluidity at low temperatures. It is so palatable as to be readily taken by stomachs which reject cod-liver-oil; in Australia, it is widely used as a substitute for the latter in medicine, though it differs from it in containing no iodine; it is also employed in lieu of butter, both as an article of diet, and for cooking. Its wholesale value at Perth, W. Australia, is 10*s.* a gal.

Egg-oil (Fr., *Huile d'œufs*).—There are several methods of preparing an oil from the yolk of eggs. (1) The yolks of new eggs are evaporated in a silver saucepan with constant stirring until the oil exudes on pressing the mass between the fingers; this is then enclosed in a bag made of ticking, promptly pressed between heated plates, and filtered while hot. This process is preferable to all others when the oil is to be applied to chaps on the skin; the product is very sweet. (2) The yolks are cooked in a water-bath, with unceasing agitation to hasten the evaporation; they are kept over the fire till, the oil commencing to separate, they have assumed the appearance of broth; they are then left to cool; they are next put into a flask with some ether, and after 24 hours, are poured into a displacer; the mass is there left to drain, and is exhausted with fresh ether; the etherized liquors are distilled; the product is a yellow oil, mixed with viscous matter; the mass is heated to separate the latter, which isolates itself, and the oil is pressed through fine linen, or filtered hot. The oil thus prepared is sweet, provided that well-rectified ether has been used. As it turns rancid very easily, it is kept in small bottles, tightly corked, stored in cellars. (3) Two parts of fresh yolk of egg are diluted with 5 parts of water; the liquid is introduced into a vessel with a ground-glass stopper, and 1½ part sulphuric ether is added; the vessel is occasionally well shaken during 7–8 hours. On standing, the ether charged with oil comes to the surface; it is decanted and distilled; the residue retains a little ether and animal matter; it is treated with concentrated boiling alcohol, and filtered; the alcohol is distilled, and to ensure the removal of every trace of alcohol, ether, and water, the oil is kept in the water-bath; it is filtered hot; it is sweet, and of a yellow colour. If the ether solution of the oil does not separate well from the rest of the liquid, a very slight heating will effect the purpose.

Egg-oil is semifluid at ordinary temperatures, and of a beautiful deep-yellow colour. It has an agreeable odour, and a very pronounced sweet flavour of yolk of egg. It commences to solidify at 8°–10° (46½°–50° F.). It easily becomes rancid, and loses its colour by long keeping. It has been used for application to chapped skin, and on the pustules of small-pox. It is most largely prepared probably in Russia, whence many samples were shown at the Exhibition of 1862. The best qualities are considered far superior to olive-oil for cooking purposes; the impure and very yellow qualities are chiefly manufactured into the celebrated Kazan soap, used by the luxurious classes as a cosmetic. It is sometimes adulterated by means of a fatty oil coloured with turmeric. The fraud is discovered by the mass remaining solid at 8° (46½° F.), and by its giving a soap wanting in consistence.

Herring-oil.—A species of herring (*Clupea pontica*), which is sold in Russia as "Astrakan herring," is turned to account for its oil in Russia and Japan. It is estimated that on the Volga about 100 million of these fish are sacrificed annually for their oil, no use being made of the flesh. During the 3–4 weeks that the fish are arriving in shoals, some 100,000–250,000 *poods* (of 36 lb.) of oil are made. The herrings are placed in open casks containing about 1000, and boiling water is poured over them. After several days, putrefactive fermentation sets in, and the oil commences to escape from the cells; a day's duration of this fermentation suffices to determine the separation of the oil, which floats on the surface of the mass, and is skimmed off. The Japanese extract oil from the herrings caught on the coast of Yesso and the north of Nipon. The principal market for it is Hakodadi, where the value is about 48–56*s.* a *picul* (133⅓ lb.).

Horse-grease or Mares'-grease.—Quantities of this article are shipped from S. American ports. It has about the same consistency as ordinary commercial American lard, and has practically a like value for the purposes of the soap- and candle-maker.

Houlican- or Oolachan-oil.—An oil, which forms an indispensable necessary to the aboriginal inhabitants of British Columbia and Vancouver's Island, is afforded by a little fish (*Thaleichthys pacificus* [*Osmerus* sp.]) closely resembling a smelt or sprat. The fish appear on the coast in April and May, and ascend the rivers in millions to spawn. During their run, which lasts about 3 weeks, countless numbers might be caught. By warming over a slow fire, or heating in water, they yield an abundance of oil, which, when properly filtered, is pellucid, of pale-yellow colour, odourless, and possesses a pleasant flavour. The natives consume it in immense quantities, as we do cod-liver-oil, and with great benefit in the consumptive diseases to which they are subject. It is just coming into general commerce, is of great importance in local trade, and might be procured in very large quantities. The fish are said to be so rich in oil as to burn like a candle when ignited.

Lard (Fr., *Axonge*, *Saindoux*, *Graisse de Porc*; Ger., *Schmalz*) **and Lard-oil.**—The fat of the pig, freed from the cellular tissue in which it is contained, is known as "lard." The pieces of adipose tissue are sometimes salted a little to keep them sweet, and are stored in barrels. They are scored and sliced till they do not exceed about 1 in. in diameter, and thrown into caldrons. The common method of "rendering" the lard among very small fat-melters is by means of boiling with water in an open cast-iron vessel exposed to the direct heat of a fire. The use of a steam-jacketed pan and injected steam, as described on p. 1447, is universal in the great American centres. Whatever plan be pursued, the oil is liberated from the tissues, and forms a layer on the surface of the mass; it is drawn off while still warm and liquid, and received in the vessels in which it is to be stored and transported. These vessels are bladders in the case of superior qualities, and little wooden kegs for inferior sorts. The fat immediately surrounding the kidneys yields the best and purest lard. This, and that which is obtained in flaky layers between the flesh and the skin of the animal, is known as "leaf" lard, and is kept separate from the rest, being much more valuable—harder and less fusible. Second-quality lard (which in reality, is the ordinary commercial first quality of wholesale quotations) is used for the production of lard-oil; the third quality, from trimmings which have become slightly tainted, is employed for making low-grade oil or for soap. The best pure lard should be moderately firm and white; the degree of firmness entirely depends upon temperature and the molecular condition [unless stirred while cooling, or exposed to very great cold in a refrigerating-room, it is usually "seedy" and sloppy, even at as low a temperature as 10° (50° F.)]; when melted, as clear and transparent as water; completely free from taste and smell; liquefiable at about 100° (212° F.) without ebullition, or affording a particle of deposit; and containing never more than 2 per cent. of either water or salt (good American lard has no salt, and not above 0·5 per cent. of water). Its melting-point ranges from 42°·6 (108°·6 F.) to 44°·6 (112°·2 F.), and averages 43°·6 (110°·4 F.). Its composition, according to Braconnot, is 38 per cent. of stearine and margarine, and 62 per cent. of oleine; 100 parts of it by saponification yield 9 parts glycerine and 94·65 parts margarie and oleic acids. The solidifying-point of the fatty acids of lard is about 41° (106° F.). Lard dissolves in 36 parts boiling alcohol at 0·816 sp. gr. According to Dr. Hager, the sp. gr. of lard is 0·931–0·932 at 15°–16° (58°–60° F.) when fresh, and 0·940–0·942 when old.

Lard is extensively adulterated, particularly keg-lard manufactured in England, Irish being seldom so treated. American lard seems to be commonly selected for adulteration after its arrival in this country. It is melted with a little water in false-bottomed copper pans, through which circulates steam. The dirt and foreign matters fall to the bottom, and the clear fat is withdrawn into a wooden vessel, where it is stirred in contact with cold water; it is then ground with a thick paste of potato-starch, mixed with a little potash-alum and quicklime, which seem to facilitate the absorption of the water and starch by the fatty matter. The quantity of alum used is such as to leave a small excess, to prevent the mildew attacking the starch. It also helps to increase the lightness and whiteness of the pastry in which the lard is used. Other saline matters, as salt, and the carbonates of soda and potash, are likewise used. The addition of a little mutton tallow to lard is very common, especially in warm weather, to correct the softness of the article. Really good lard is seldom sophisticated, as its market value is much more likely to be reduced than augmented thereby. The frequent adulteration of American lard is owing to its inferior quality and excessive softness, much of it being the entire fat of the pig melted down; some means of rendering it firm is actually necessary.

"Lard-oil" is prepared by placing the lard in woollen bags between wickerwork and the plates of hydraulic presses, where it is left for about 18 hours under a pressure of about 10 cwt. a sq. in. in the cold. The oil or liquid portion (oleine) is thus expressed in a pure, colourless, and limpid state, in the proportion of 62 per cent. of the weight of lard. It remains liquid even in the presence of great cold. It is largely used for adulterating olive-oil in France, and sperm-oil in the E. States of America; it is esteemed as a lubricant, and is said to be also used for illuminating. In Cincinnati, there are some 40 manufactories, turning out about 1½ million gal. of this oil annually. The production of lard-oil in the United States in 1875 was 8,552,583 gal.

The lard produced in the United Kingdom is chiefly Irish. Of European countries, Russia, Hungary, and Servia hold the foremost position. Hungarian lard is supplied to the whole Continent; many of the pigs are so lean as to be useless for food, and some establishments in Budapest boil down ½ million yearly for the lard alone. Pig-keeping is the leading industry of Servia, and large supplies of lard may be expected from that country in the near future. At present, America is the chief producer. In the United States, the average yield of lard from each pig was 25 lb. in 1862, and 37½ lb. in 1874. The total exports of lard from the United States in 1870 were but 35,809,000 lb.; in 1878, they reached the enormous figure of 342,668,000 lb., value 30,014,000 dollars (of 4*s.*), but fell to 326,659,000 lb. in 1879. The exports of lard from New York in 1879 were 2,412,395 cwt.; and of lard-oil, 1,236,442 gal. Philadelphia exported 12,915,027 lb. of lard, and 268,479 gal. of lard-oil, in 1879. Baltimore exported 21,262,610 lb. in 1878, 26,950,519 lb. in 1879, and 34,797,502 lb. in 1880. New Orleans despatched 1350 tierces in British ships in 1880. The Canadian exports of lard have fallen from 38,048 cwt., value 94,509*l.*, in 1876, to 4509 cwt., 7801*l.* in 1879. Denmark, in 1878, exported 160,066 lb. of lard and grease to Great Britain.

Malabar oil.—The ambiguous term "Malabar" oil is applied to a mixture of the oils obtained from the livers of several kinds of fish frequenting the Malabar coast of India, and the neighbourhood of Kurrachee. The species chiefly caught are *Rhyncobatus pectinata*, *R. lævis*, *Galiocerda tigrina*, and *Carcharias melanopterus*. This last is found in considerable numbers, and is taken principally in October–November, the livers being then much more developed, though the quality of the oil is about the same at all seasons. The most esteemed livers are firm and rosy-coloured, the white and flabby ones are inferior. The livers are cleansed, cut up, placed in earthen vessels with enough water to cover them, heated for 15–20 minutes, and then allowed to cool. The oil is skimmed from the surface, poured into earthenware jars, then passed through a sieve; 3-4 days later, it is filtered through a thick strainer, to separate the abundantly deposited stearine, and this operation is repeated 4 times, at intervals of 20–25 days, after which, the oil remains clear, exhibiting a fine straw colour, and smelling much like cod-liver-oil. Thus prepared, it is employed medicinally. The inferior oil is compounded with that obtained from the livers of the other kinds by heating, without previous washing or picking, and without any subsequent purification; the whole is used for lighting, and other domestic purposes, and might be utilized for soap-making.

Manatee-oil (Fr., *Huile de Lamantin*).—There are several species of *Manatus*, found in the rivers of Central and S. Africa, and in the estuaries, bays, and inlets of the W. Indies, and the coasts of Mexico, Brazil, and Guiana. Beneath the skin of these animals, is a layer of fat, generally about 1 in. thick, and which is boiled down to afford an oil used for lighting and cooking, each animal yielding 5–25 gal., according to its size and condition. By exposing the oil to the sun, it acquires a fine odour and flavour, and does not become rancid. The fat of the tail has a harder consistence, and, when boiled, is more delicate than the other.

Menhaden-oil, Straits or Bank Oil.—A fish eagerly sought for its oil on the Atlantic coast of America is the "menhaden" or "porgie" (*Alosa* [*Brevoordia*] *Menhaden*), a member of the herring family, about 8–14 in. long. The fishery is carried on all along the coast from Maine to Maryland. The fish leave the Gulf Stream and strike the coast of New Jersey in April, reaching the coast of Maine in May–June, and remaining till October–November. They migrate in enormous schools, and are caught in seines, carried by the fastest and smartest yachts. Very few of the fish are sent to table; nearly all are boiled down for their oil. This is performed in the following manner. The fish are shot into receiving-tanks situated outside the building; thence a sliding door opens into the boiling-tanks, which are long, watertight, uncovered boxes, of varying capacity, provided with a coil of perforated pipe for the admission of steam, and a plug-hole for the exit of the liquid after boiling. Some water is put into the tanks ready for the fish, and as soon as the latter have been introduced, steam is turned on, and the whole mass is boiled for 20–40 minutes. When the cooking is completed, the liquor, containing a portion of the oil of the fish, is drawn off into settling-tanks, for the recovery of the oil. The "pomace" or cooked fish is raked into "curbs," perforated cylinders fitted with hinged bottoms, and these, when full, are placed under hydraulic presses. Pressure is applied so long as water and oil continue to escape from the mass. The remaining solid matters, called "scrap," are treated for the preparation of a fertilizing compost (see Manures, p. 1257). The oil and water pass by gutters into settling-tanks, where the oil soon rises to the surface, and is skimmed off, or allowed to escape over a separating partition.

The oil is still crude, and requires clarifying and bleaching before it becomes a saleable commodity. This is effected in several ways. It is first boiled, to free it completely from water. It is purified from solid matters by running it into filter-bags suspended over casks, and then subjecting it to pressure in bags, the oil escaping while the sediment remains in the bags. This refuse, termed "foots," is bleached, and used for soap-making. The oil thus refined is termed "straits," and is ready for barrelling. "Bank" oil is an inferior grade. Bleaching is sometimes performed by exposure to the sun in shallow tanks, having glass covers to exclude dust when a superior quality is desired. The yield of oil is at its maximum in September, when a barrel (250) of fish gives about 4½ gal. of oil. The average product of 1000 fish is 13–14 gal. of oil. The total catch in 1878, an average year, gave 80,000 barrels of oil, 23,815 of which (644,762 gal.) were exported under the denomination of "fish-oil," and 45,000 were locally consumed. The exports in 1879 were 613,663 gal. Its principal application in America is for tanning and currying purposes. In France, it is largely employed as a substitute for cod-liver-oil, costing at Havre only about 45 *fr.* a 100 *kilo.*, while the latter fetches 50–53 *fr.* In this country, it is said to be often passed off as olive-oil, and that considerable quantities of it are mixed with linseed-oil for painters' use. The rapidity with which it oxidizes, and its good body, render it not unsuitable as a vehicle for paint; the same causes make it inadmissible for lubricating.

Neats'-foot-oil (Fr., *Huile de pieds de bœuf*).—From "ox-feet," the feet and hocks of neat cattle cut off about 18 in. above the hoof, is obtained a valuable oil, known as "neats'-foot." Its preparation, which is usually performed by tripe-dressers, is as follows. The "feet" as received are denuded of skin, and slit up longitudinally, by a knife passed between the sections of the hoof and continued between the long bones. Near the hoof, is a small mass of soft fat, which is scooped out with the knife, and set aside for the preparation of the best quality of oil. The hoofs are washed in cold water, and then boiled in open pans set in brickwork, and heated by a fire beneath. A certain quantity of oil is thus boiled out of them, and when skimmed off, forms an inferior grade of neats'-foot-oil. After about 3 hours' boiling, the tissues between the horny hoof and the last digit bone are sufficiently softened to allow of the latter being easily scooped out of the hoof with a knife. These "cores," consisting of bone, gelatinous matter, and fat, together with the small pieces of fat previously alluded to as being removed by the knife before boiling, are put into a separate pan of fresh water, and all boiled together for the extraction of the oil. This forms the best kind of neats'-foot-oil. It is reckoned that 10 "feet" will give about 1 qt. of oil. It is made in most large towns, and some quantities are shipped from the River Plate and the Falkland Islands. Philadelphia exported 1125 gal. in 1879.

This oil is usually yellowish or greenish in colour, but that from Buenos Ayres is often colourless. It is odourless when fresh, and of agreeable flavour. It is limpid, and remains so below a temperature of 0° (32° F.). Its density at 15° (59° F.) is 0·916. On standing for a short time, a proportion of solid fat separates out, and may be filtered off. Its limpidity, which is intensified in the oil obtained from Buenos Ayres, causes it to be largely employed for lubricating, especially clocks and bearings exposed to the cold. It is very rarely found pure.

Niin-oil.—An insect belonging to the genus *Coccus*, and which has been named *C. adipofera*, affords an oil having considerable economic use in Central America. It feeds on the resinous sap of a species of *Spondias*, whose local cultivation is so easy that even thick cuttings germinate quickly in almost any soil. The breeding of the insect is dependent simply upon the multiplication of this tree, which is already under extensive cultivation all over the tropics of continental and insular America. The female insects, which yield the oil, adhere to the trees by means of their beaks, existing in such large numbers that they frequently cover every portion of the plant. The oil is extracted from the insects by broiling or boiling them, and amounts to 26–28 per cent. of their weight. It is bright-yellow to yellowish-brown in colour, and possesses a peculiar odour. When recently melted, it is homogeneous, but soon becomes granular and lighter-coloured. Its melting-point is about 49° (120° F.); when melted, it remains fluid at even 27°–29° (80°–85° F.). Cooled to −12° (10° F.), it becomes hard and brittle, like suet. At ordinary temperatures, it is thick and pasty, like lard, and its sp. gr. is about 0·92. It is insoluble in alcohol, but freely soluble in hot and cold ether, forming a yellow oily liquid; it is very soluble in turpentine, producing an oily liquid of special value for mixing delicate oil-colours; it is also freely soluble in benzine and chloroform. It is a thorough drying oil, though its absorption of oxygen is slow, and is not hastened by boiling with oxide of lead. Its composition resembles that of ordinary animal fats. Its saponification is unusually difficult, and only effected after prolonged boiling with strong soda-lye. When melted in a porcelain dish, and the resulting oil is exposed to a temperatere of 121°–177° (250°–350° F.) for an hour, or till a considerable part has evaporated, the residue assumes a tough, flexible, varnish-like condition, is no longer soluble in turpentine, and but little affected by heat and cold. This, ignited with turpentine, affords a thick, yellow gum or oleo-resin closely resembling a thick solution of indiarubber, possessing remarkable adhesiveness, and retaining the semi-fluid consistency for several days. When the turpentine solution of the oil is exposed in thin strata to the air for some days, it acquires the properties of a resinous varnish, almost equal to fine shellac varnish, very elastic and hard.

The present native uses of this remarkable oil, which has yet to find its way into general commerce, are almost confined to its admixture with the pigments employed by the Indians and Mestizos of the peninsula of Yucatan, and in the vicinity of Vera Cruz, for adorning small household articles; it is also kept as a drug by the apothecaries of Yucatan, and is generally employed as a drying oil. In the industrial arts, its drying solution in turpentine will make it valuable to artists; it remarkably brightens colours prepared with it. Of greater commercial importance, perhaps, is the resinous varnish which it affords when treated as described above. The turpentine solution of niin-oil renders even the most porous filter-paper absolutely impervious to water. Articles to be waterproofed with it might be saturated in the solution, and then heated in an oven till the grease volatilizes. The coating then defies most solvents of oils.

Porpoise-oil (Fr., *Huile de Belouga, de Marsouin*).—The term "porpoise-oil" embraces the oils obtained from the black porpoise (*Delphinus phocœna* [*Phocœna communis*]), the white whale (*Beluga catodon* [*Phocœna leuca, Delphinapterus leucas*]), the grampus (*Phocœna orca*), and the black-fish, which last name is very variously bestowed (see Blackfish-oil, p. 1361).

The first is very abundant in the Atlantic, and is found in considerable numbers in the Mediterranean and Black Sea. Its systematic pursuit is carried on by the natives of Lazistan, who generally take it in nets, but occasionally shoot it. This fishery has its centre at Trebizond, and commonly affords 700,000 lb. of oil in a year. A portion is used locally for illuminating purposes, and the remainder finds a ready sale. The quantities exported by steamer from Trebizonde in 1878 were:—1400 cwt., 1750*l.*, to Constantinople; 524 cwt., 655*l.*, to Austria and Germany; 514 cwt., 642*l.*, to Russia; total, 2438 cwt., 3047*l.* Large schools of porpoises are met with on the Danish coasts, and frequently 1500–2000 are caught in the Little Belt.

This creature and the white whale are taken together in great numbers in the St. Lawrence, Canada, and occasionally in the Bay of Chaleur, parts of New Brunswick, and the Hudson Bay territories. They are surrounded by enclosures made of light flexible poles driven into the beach, within which they are speared and harpooned from boats. In the bays of the Polar Sea, on the coast of Kanin, near Meson, in the White Sea, and at the mouths of the Petschora, they are killed most numerously by harpoons in June–July, whole fleets of boats being engaged. The full-grown animal attains a weight of 2500–3500 lb., and gives some 400–450 lb. of oil, which is more esteemed than that of either the seal or the walrus. The oil is inodorous, and gives a brilliant light; it congeals only in intense cold, and its softness renders it valuable for lubricating and leather-dressing.

The oil from the head of the grampus is thought to be a superior lubricator to any yet obtained from the porpoise and the black-fish. This cetacean occurs much more rarely than either of the animals just described.

Sardine- and Louar-oils (Fr., *Huile de Sardine, de Louar*).—Several species of sardine afford an abundance of oil. The ordinary sardine (*Clupea Sardinus*) of the Mediterranean is too important as a food-fish to be generally sacrificed for its oil, yet a large quantity of the latter is made from damaged and refuse fish. More important as oil-producers are the *louar* (*C. Neohowii*), *C. lemuru*, and *C. palasah*, of the Indian and Malayan Seas. They are migratory, reaching the shores in immense shoals in August–September, and becoming sufficiently fat in October–November. They are taken in nets, and treated with boiling water to separate the oil, the exports of which, from Cochin, sometimes amount to 150,000 cwt. in a year.

Seal-oil (Fr., *Huile de Phoque*; Ger., *Seehundsöl*).—The principal species of seal are *Phoca fœtida*, *P. vitulina*, *P. barbata*, *P. annelata*, *P. groenlandica*, and *Cystophora cristata*. *Phoca caspica* is found only in the Caspian Sea, where it is hunted for the sake of its oil, which is consumed in Russia. All the other species are widely distributed throughout the north polar regions of both hemispheres, and their chase, for the value of their oil and skin, forms the most important branch of the so-called "Arctic fishery," extending from Iceland eastwards to Scandinavia, along the northern coast of Russia, especially about the mouths of the Dvina and Mesen, and the eastern shores of the White Sea, across to Alaska, throughout the bays and inlets of arctic America, and on the coasts of Greenland and Spitzbergen.

Newfoundland may be considered the centre of the seal districts, and stands foremost on the list in point of production. The species chiefly resorting to this coast are the two largest—the hooded seal (*Cystophora* [*Stemnatopus*] *cristata*), and the harp seal (*Phoca groenlandica*). Their whelps are born in January–February on the Labrador ice-fields, and this "whelping ice" is floated southwards, and appears off the Newfoundland coast after the middle of March. The young seals, not taking to the water till they are three months old, are easily caught; their skins are stripped off with the blubber attached, and the carcases are left on the ice. The produce is sorted into five qualities:—"young harp," "old harp," "young hood," "bedlamer" (1-year-old hood), and "old hood"; the most rich in oil is "young harp."

The average take of successful vessels is about 2000 seals, though it sometimes reaches 8000, and, in extraordinary seasons, individual ships have secured 10,000–20,000. Out of 400 vessels yearly engaged in sealing, not more than 60 make remunerative voyages. It is thus a speculation rather than a steady industry. So soon as the vessels have disembarked their first cargo, they start on a second hunt. This time they rarely take many young seals, as these have escaped to the water by about the 1st April; but they pursue the old ones, sometimes shooting them on the ice "pans," sometimes finding a herd cut off from the sea, and knocking them on head with clubs. The exports of seal-oil from Newfoundland have risen from 1605 tuns, value 76,247*l.*, in 1864, to 5905 tuns, value 147,625*l.*, in 1878; in 1871, they reached 6943 tuns, value 202,504*l.*

On the Greenland coasts, and especially between latitudes 60° and 61° N., *P. fœtida*, *P. vitulina*, *P. groenlandica*, *P. barbata*, and *Cystophora cristata*, are abundant, more particularly the last-named. The catch amounts to some 89,000 annually. The total production of blubber, including that from white whales, &c., is estimated at 2050 tuns yearly, of which 500 are used by the natives for lighting, and 100 for food. Harpoons, lances, guns, and nets are employed in the chase.

The 15 Norwegian vessels engaged in sealing in 1879 procured 30,000 crested seals or "hoods" (*Cystophora cristata*), and 55,000 of other kinds, old and young. The yield of oil was reckoned at upwards of 17,000 barrels. The price was as low as 36–48 *kroner* (of 1*s.* $1\frac{1}{2}$*d.*) a barrel, whereas a few years since it was 70 *kr.* in the German markets. The exports of seal-blubber from Sweden and Norway in 1879 were 16,938 *hectol.* (of 22 gal.). It is hardly possible yet to judge of the effects of the lately made law for the protection of the seals in the Arctic Seas during the season after they have cast their young; but there is good reason to expect that it will somewhat postpone their extermination, which at one time appeared immediately imminent.

Of the extent of the Russian seal-harvest in the White Sea and thereabouts, no accurate statistics are procurable, but the catch is approximately said to be only half that of the Caspian. In the latter, about 140,000–160,000 *poods* (of 36 lb.) are obtained every year.

The average quantity of oil afforded by 1000 seals is roughly estimated at 10 tuns. In the Russian fisheries, *Cystophora cristata* is reckoned to yield 360 lb. of blubber; *Phoca groenlandica*, 160–240 lb.; *P. annelata*, 120 lb. In Newfoundland, *P. groenlandica*, old, gives an average of 288 lb. of blubber, producing $22\frac{1}{3}$ gal. of oil; same species, young, 225 lb. of blubber, 22 gal. of oil; *Cystophora cristata*, young, 230 lb. of blubber, 21 gal. of oil; same species, bedlamer, 246 lb. of blubber, $21\frac{1}{2}$ gal. of oil. The skins and blubbers brought in by the hunters are stripped apart, and undergo separate treatment. The latter are generally put into wooden cribs, with pans beneath to catch the exuding oil, no artificial heat being employed. The oil which runs out during the first 2–3 months is called "pale seal," and forms 50–70 per cent. of the whole. As putrefaction sets in, the oil becomes darker and more offensively odorous. The solid refuse and the clippings of the skins are boiled to yield further quantities of "boiled seal-oil." This old process, though still widely surviving, is superseded in the best factories by steaming the blubber, by which all the oil, of a uniform and much better quality, is extracted in 12 hours. (For Fur-seal-oil, see p. 1375).

Shark-oil (Fr., *Huile de Requin*).—The seas of N. latitudes are inhabited by four species of shark—the "Greenland shark" (*Scymnus borealis* [*Squalus glacialis*]), the "basking shark" (*Selache maximus*), the "picked dog-fish" (*Squalus acanthias*), and the *kulp* or *hoastorsk* (*Squalus spinax niger*); the livers of these fish afford valuable oil.

The first-named numerously frequents the banks which may be traced in a line for nearly the whole length of the W. coast of Norway, at distances varying from 50 to 100 miles from the land; in greater abundance, however, on that portion which fringes the coast of Nordland and Finmark, as far as the North Cape, and between the latter and Cherry or Bear Island. They are met with, moreover, throughout the whole North Sea and Arctic Ocean, as well as in most of the fjords on the W. coast of Norway, at 100–200 fathoms, and their pursuit forms an important and remunerative branch of the Icelandic fisheries during a portion of the year. Formerly the Norwegian shark-fishery was confined to the immediate vicinity of the coast; but of late it has been more especially and lucratively prosecuted on the banks commencing at about 68° N. lat. Shark-fishing is now carried on vigorously by the Russians in the bays about the peninsula of Kola, Lapland. The fish are taken by means of large, strong hooks, baited with fish or about 1 lb. of seal-blubber, taken from seals caught at Spitzbergen and then salted while fresh. In Iceland, horse-flesh is preferred before all other bait. Porpoise-blubber sometimes replaces seal. The fishery begins about the end of September, and continues through the winter till the end of February. From N. Iceland, it recommences as soon as the drift-ice will permit, say March–April. The length of the fish varies from 10 to 18 ft. The value depends almost solely upon the size, quantity, and quality of the liver, which yields 15–60 gal. of fine oil. In summer, the livers are almost valueless. The flesh and skin are usually thrown away, though possessing considerable value.

The "basking shark" is found all along the Norwegian coast, from Ryvarden (59° 31′ N. lat.) to Finmark. Its pursuit was long followed with such activity and success as to afford the staple support of those engaged in it, but of late years decreasing numbers have much reduced its importance. Its chase resembles that of the whale rather than of other kinds of shark, as it cannot be baited nor enticed. Towards the conclusion of the dog-days, when the sea and the air are at their highest temperature, this fish makes its appearance on the coast; it lies perfectly still near the surface of the water, apparently basking in the sun, and follows leisurely after the boats which are in quest of it. It is thus struck by harpoons, such as are used for taking sturgeon. In size and condition it varies much; the prevailing length is 30–35 ft., increasing occasionally to 40 ft. The size of the liver depends mostly on the condition of the fish; the usual quantity of liver taken from a fish is 4–7 barrels, occasionally 10–16, and in very rare instances 24; 6 barrels of good liver should yield 5 barrels (of 30 gal.) of oil. The same fish is found in Indian waters, and is there called *mhor*. It is harpooned in great numbers by the Kurrachee fishermen, one estimate stating the annual catch at 40,000. The size here varies from 40 to 60 ft. in length, and the usual yield from one liver is 8 barrels of oil, of very low sp. gr.

The picked dog-fish, which was formerly very abundant along the whole coast from Gothenburg, is now pursued during the entire summer, from the Naze to the North Cape, in the Norwegian fjords as well as along the coast. About midsummer it swims near the surface, and is taken either by nets or lines. The liver is exceedingly rich in very fine oil.

The *kulp* or *hoastorsk* is met with in all the deep fjords along the Norwegian coast, where it does much mischief by nibbling off the baits from the deep-sea cod-lines. It is taken in numbers at a time, by lines with 10–12 hooks baited with tainted fish, in 60–100 fathom water. It travels in shoals, and feeds at night. Its liver is unusually rich, and yields a superior oil.

Sharks are caught in great numbers on the shores of New Zealand, during November–January, by the natives, who use them for food. A premium for the capture of sharks offered by the Victorian Government has promoted this branch of fishing among the sailors of Hobson's Bay, and very large numbers are now taken. They are also very common in Sydney Harbour, New South Wales.

Shark-oil is largely used in tanneries. It is also extensively passed off surreptitiously as cod-liver-oil and is probably but little less efficacious; the oil and liver are both esteemed as food by the Icelanders.

Sod-oil.—The term "sod"-oil is applied to the oil which has been fulled into skins during the operation of tanning, and has been subsequently washed out with soda. English sod-oil comes chiefly from deer- and sheep-skins, and is largely adulterated with gelatine from green sheep-skins. The purest and best sod-oil is from France, where olive-oil is employed in the tanning; the next is English, where cod-oil has been used; then comes American, where the currying has been done with "fish-oil" (menhaden-oil). This last now fetches the highest price. Sod-oils are much esteemed for lubricating delicate watches, &c.

Spermaceti or Head-matter (Fr., *Spermacéti*, *Blanc de Baleine*; Ger., *Spermaceti*, *Walrath*).—"Spermaceti" is chiefly the solid wax-like portion of the sperm-oil, or so-called "head-matter," found in the head of the "sperm-whale" or *cachalot* (*Physeter macrocephalus*), an inhabitant of the Pacific and Indian Oceans. On the right side of the nose, and upper portion of head of this species, is a triangular-shaped cavity, termed the "case," enveloped by an enormous mass of sinewy gristle called "white horse," which resists even a sharp axe. The case is filled with liquid "head-matter," consisting of spermaceti and oil; the whalers make an opening into the case, and remove the contents by a bucket, as many as 45 barrels being occasionally filled. This matter is carefully boiled alone, and placed in separate casks, and is commonly known as head-matter. It is of a yellow colour, and its consistence varies with the temperature. It undergoes a purification for the purpose of candle-manufacture, in which it is employed (see Candles, p. 589). The refined article is transparent, smooth, brittle, insipid, inodorous, and very difficultly saponifiable; its sp. gr. is 0·943 at 15° (59° F.); it is fusible at 45° (113° F.); it is insoluble in water; 100 parts of alcohol of 0·821 sp. gr. dissolve 3½ parts of spermaceti, but deposit about $\frac{9}{10}$ on cooling; it is also soluble in both fatty and volatile oils. It is said to be adulterated commonly with fatty matters, such as tallow, margaric acid, &c. Such falsifications are easily discovered by the saponification of the mass, and by the reduction of the fusing-point.

Similar products are obtained in lesser quantities from the head-cavity of *P. Tursio* and *Delphinus edentulus*, from the bladder of *Balæna rostrata*, and from the oil of *Delphinus globiceps.*

The Tasmanian whale-fishery produced 558 tuns of sperm-oil in 1873, and 342 in 1874. The exports in 1876 were 513 tuns, value 45,248*l.*; and in 1878, 279 tuns, value 17,577*l.* The production in 1869 was 643 tuns. The exports of sperm-oil from New York in 1878 were—911,975 gal. to Great Britain, 49 gal. to N. Europe, and 579 gal. to S. America, E. and W. Indies, &c., total 912,603 gal.; in 1879, they were 1,089,137 gal. The production of spermaceti in the American whale-fisheries was 1,300,959 gal. in 1878, and 1,285,454 gal. in 1879.

Tallow (Fr. *Suif*; Ger., *Talg*).—The cellular tissues of man and quadrupeds contain a concrete fat, the whole mass of tissue and fat being known as "suet." The term "tallow" is applied to this fat when it has been liberated from the tissue. Commercially, tallow is obtained almost solely from the ruminant animals, sheep and neat cattle, and is produced chiefly in the essentially pastoral portions of the globe. In many cases, the animals are (or were) reared more for the sake of their tallow than their flesh, and, in Australia, millions of them have been boiled down as they were killed, the boiled flesh being used for pig-feeding or manure. Recent improvements in transporting meat will doubtless prevent the recurrence of such a wasteful process, though the tallow may retain its importance as a commercial product, and will be prepared at the places where the animals are killed for transportation in cold chambers.

The "rendering" of tallow, or its separation from the cellular tissues in which it is confined, is performed on the large scale exactly the same as lard-rendering, described at length under the section on improved methods of extraction (see p. 1447). Occasionally mechanical power is employed to facilitate the operation, the suet being first passed through a specially constructed chopping-machine. The rendering is also greatly assisted by the addition of dilute sulphuric acid to the mass, say 1 per cent. of the acid and 20 per cent. of water on the quantity of tallow present; but there is a great, and to some extent well-founded, commercial prejudice against tallow in which any chemicals have been used during its preparation. The melted tallow is strained to free it from membrane. The nature and qualities of tallow vary greatly. The constituents are stearine, oleine, and possibly margarine; stearine predominates, but its proportion fluctuates with the species, age, and sex of the animal, and the portion of its body which afforded the suet. Beef-tallow usually contains less stearine than does either mutton- or venison-, and mutton-tallow is always whiter than beef-tallow, but S. American beef-tallow presents the curious exception of containing *more* stearine than S. American mutton-tallow. The hardness and melting-point have an equal influence upon the value of the tallow, and exhibit the same want of constancy under similar changes of condition. The degree of solidity much depends upon the food, increasing as the latter is drier. Pure tallow is white and almost tasteless, but that imported has a yellow tint. It is classed according to its suitability for candle- or soap-making, for which purposes it requires to be refined (see Candles, p. 579).

The term "beef"-tallow includes that of oxen, cows, and bulls; the former is much softer than the two latter. After melting, it commences to solidify at 37° (98½° F.), and its temperature then rises to 39° (102° F.); it dissolves in 40 parts alcohol of 0·82 sp. gr. Veal-tallow melts easily in the fingers, is very soft, and quickly becomes stale. "Mutton"-tallow comprises that of rams, ewes, bucks, and she-goats. On remaining some time exposed to the air, it acquires a peculiar odour. After melting, it commences to solidify sometimes at 37° (98½° F.), when its temperature rises to 39° (102° F.); at other times, it solidifies at 40° (104° F.), and its temperature rises to 41° (106° F.). It dissolves in 44 parts boiling alcohol of 0·82 sp. gr. Dr. Hager thus states the sp. gr. of tallows at 15°–16° (58°–60° F.):—Beef, 0·925–0·929; mutton, 0·937–0·940; beef and mutton mixed in equal proportions, 0·936–0·938. "Town tallow," "kitchen stuff," or "pot-grease," is the waste fat produced in culinary operations, and is consumed by soap-makers. Tallow is largely adulterated with starch, china-clay, ground limestone, and sulphate of barium; also with fats having a lower degree of hardness, especially "bone-fat" (see p. 1361). Mineral adulterants are easily discovered by simple solution of the mass; starch is detected by the iodine test; and inferior fats lower the appearance and consistence of the sample, and thus indicate their own presence.

In commerce, tallow occupies a very important place. Russia exports immense quantities, chiefly from the ports of Cronstadt, Odessa, and Taganrog. A dozen years ago, Russia's annual production was reckoned at 160,000 tons, half of which was consumed locally. The home consumption has since much increased. Thus the exports were 3,249,802 *poods* (of 36 lb.) in 1866; they gradually fell to 411,585 *poods* in 1875, recovered to 1,110,729 *poods* in 1877, and dropped back to 619,301 *poods* in 1878. Russian tallow is nearly all beef, and comes chiefly from Siberia and the Ukraine. It is transported in casks of 300–400 *kilo.* The commercial quotation of "P.Y.C. tallow" is a fiction, and does not regulate the market-price of tallow; it is a mere speculative medium, thousands of casks being bought and sold that have no existence whatever. Russian tallow has lost much of its hold on the market, and now forms but a small item in the total consumption in this country, notably in the case of the soap- and stearine-makers, for whose purposes it is less suited than for "dips." The States of S. America afford very large quantities of tallow from the carcases of animals slaughtered principally for the sake of this product and their skins, bones, and horns. It is generally known as "River Plate" tallow, and is mostly shipped from the Rio de la Plata. It has a strong-yellow colour, but is of good quality; it first arrived in serons of hide, but now comes in old wine-casks—pipes and half-pipes. The United States ship considerable quantities of tallow to Europe, chiefly from New York and New Orleans, in barrels of various sizes. The total exports were 85,506,000 lb. in 1878, and 99,964,000 lb. in 1879; in 1869, they were only 20,535,000 lb.; in 1874, 101,756,000 lb. The shipments from New York were 70,807,600 lb. in 1878, and 67,016,100 lb. in 1879. Of the shipments in 1878, 31,775,300 lb. went to Great Britain, 18,474,500 lb. to France, 16,687,100 lb. to N. Europe, 2,288,000 lb. to other Europe, and 1,582,700 lb. to S. America, E. and W. Indies, &c. Philadelphia exported 9,201,599 lb. in 1879. Excellent tallow is obtained from Algeria and Morocco, and chiefly consumed in the soap-works of Marseilles. The Chinese port of Kiungchow shipped 924 *piculs* (of 133⅓ lb.), value 1850*l.*, in 1877; 1906 *piculs*, 4007*l.*, in 1878; and 2688 *piculs*, 6225*l.*, in 1879. The exports and re-exports from Hankow in 1878 were 2776 *piculs;* the exports thence in 1879 were 564¾ *piculs*, value 1114*l.* Pakhoi, in 1879, exported 324*l.* worth. Shanghae, in 1879, imported 301½ *piculs* of foreign tallow from foreign countries, and 1423½ from Hong Kong and Chinese ports, none being re-exported; and of native tallow, the imports from Chinese ports were 815⅓ *piculs*, and from Hong Kong 433¾, all being re-exported to Chinese ports. Newchwang exported 415 *piculs* in 1877, but none is recorded since. The annual exports (chiefly re-exports) of tallow from Holland amount to 4½–7½ million *kilo.*; in 1879, they were 6,829,000 *kilo.* The Belgian exports (chiefly re-exports) fluctuate between 17 and 26 million *kilo.* yearly, and were 25,871,000 *kilo.* in 1879. The shipments of tallow from New South Wales have fallen from 190,575 cwt., value 311,339*l.*, in 1871, to 61,326 cwt., 98,018*l.*, in 1878; they were 100,390 cwt., 164,561*l.*, in 1877. In the case of Victoria, they have fallen from 13,582 tons, 469,069*l.*, in 1871, to 3298 tons, 103,879*l.*, in 1878. From New Zealand, they have increased from 828 cwt., 1661*l.*, in 1867, to 100,380 cwt., 178,502*l.*, in 1878. From Queensland, they fell from 124,180 cwt., 139,181*l.*, in 1871, to 19,194 cwt., 50,899*l.*, in 1873, and were 43,164 cwt., 73,006*l.*, in 1877. The exports of tallow from Honolulu in 1879 were 239,941 lb., to Germany. The value of the tallow shipped from the Falkland Islands to Great Britain was 4874*l.* in 1878, and 5940*l.* in 1879. The exports of tallow from India fell from 3540 cwt. in 1878, to 870 in 1879. The E. Indian tallow is very strong in stearine, but of bad colour. A similar tallow comes from Turkey; Japan also sends a good quality. The tallow production of the United Kingdom has been estimated at 100,000–120,000 tons yearly.

Tunny-oil (Fr., *Huile de Thon*; Ger., *Tunfischöl*).—The tunny (*Thynnus vulgaris*) is second in importance only to the sardine among the fish caught in the Mediterranean. During May and June, endless shoals of these fish migrate from the Mediterranean, through the Straits of Gibraltar, to the Atlantic, returning in July–August. Those caught during the exodus are much fatter and more valuable than those taken on the homeward passage. The coasts frequented by this fish are chiefly within the Mediterranean, extending without interruption along the Spanish and French coasts from the Straits to Nice, reappearing on the Italian coast between Camogli and Spezia, off the W. side of Elba and Sardinia, near Palermo and the Straits of Messina, around Malta and the Karkaneh Islands, and in the Gulf of Tunis. Outside the Mediterranean, the fish visits the European coast, from the Straits westward to Cape St. Vincent, and occurs less abundantly along the French coast from Yen northwards to Belle Isle. The tunny fishery in the Bay of Biscay is most important at Rochelle, Ile de Ré, and Sables d'Olonne, commencing in July, and lasting till mid-September. The Portuguese fishery is confined to the province of Algarve, the tunny not being found farther west than Sagres; the fish is chiefly taken in the space between the mouth of the Guadiana and Cape Santa Marta from the end of May till the beginning of August, and from the latter point to Albufeira from April till June. The Spanish tunny fishery is concentrated at the mouth of the Guadiana, around Cristina Island, and at Veger, Conil, Chiclana, Rota, Mojarra, and Portil. The catch begins in May, and ends in the last days of August. The Italian tunny-harvest lasts from April till the end of July, and is distributed chiefly thus:—Gulf of Palermo: S. Flia, Solanto, S. Nicola, Trabia; Sea of Milazzo: Oliveri, S. Giorgio, Vaccaro Pepe; W. Coast: Capo Passero; Sardinia: Portoscuso, Portopaglia, Isola piana, Calavinagra, Flumentorgiu, Alghero, Trabucato, Asinara; Elba: Porto ferrajo, Anfola, Marciana; on the mainland: Birvona and Pizzo, Porto S. Stefano, Camogli, and S. Margherita. It is estimated that in the Gulf of Tunis, some 10,000 tuns are taken yearly.

The fish yields a very large quantity of oil, which is extracted from it by boiling, the operation being performed at the fishing-stations, in the crudest possible manner, and often with sea-water. Generally only the heads, bones, and entrails of the fish are used, in varying stages of decomposition, and it is rare that any trouble is taken to prevent the oil being burnt and smoky. Good tunny oil is of a pale amber colour, and has an agreeable flavour; it possesses more body than any other fish oil, but contains no iodine. By boiling, it assumes a rich broom-yellow hue; and when left at rest in shallow open vessels, it undergoes a peculiar condensation (doubtless an oxidation), commencing about the end of August or beginning of September, and gradually extending till the whole mass becomes solid, and remains so unless heated. It is very commonly adulterated with Bergen and Hamburg inferior cod-oil, with sardine-oil, and with cotton-seed-oil; the presence of each and all of these is manifested by their remaining liquid while the tunny-oil solidifies. It is highly esteemed for leather-dressing, even in its impure and sophisticated state, and is said to be employed as a lubricator, though that must be regarded with doubt. It is put up in casks, and forms an article of trade in Genoa, Sardinia, Spain, and Tunis. The last-named country produces some 30,000–35,000 *kilo.* of the oil annually, and the value of its export in 1871 was 1600*l.* That prepared at Genoa is said to be superior to all others. The industry deserves much greater attention, and is capable of indefinite extension and improvement.

Walrus-oil (Fr., *Huile de Morse*; Ger., *Walrossöl.*—The walrus or sea-horse (*Trichecus Rosmarus* [*Rosmarus obesus*]) is pursued by the Arctic whalers. Some 50,000 are killed every year, but it is reckoned that 3 out of 4 struck are lost through the inefficiency of the projectiles used. On the coast of Danish Greenland, the walrus is met with between 66° and 68° N. lat., but the number killed yearly does not exceed 200. From 20 to 30 gal. of much-esteemed oil are obtained from each animal.

Whale-oil, Train-oil, and Blubber (Fr., *Huile de Baleine*, *de Nordcaper*, *de Rorqual*, *de Jubarte*; Ger., *Walfischspeck*, *Thran*).—The competition of mineral oils for illuminating, and animal and vegetable oils for industrial purposes, and the substitution of various articles for the once almost indispensable whalebone, have caused a gradual and general decline in the whale-fishery. The United States now take the lead in it. Their whaling fleet on 1st January, 1880, numbered 178 vessels, with a total burden of 39,433 tons, nearly all hailing from New Bedford. In the Behring's Straits waters, in 1869, 43 American ships secured 38,275 barrels of train-oil; in 1879, 18 obtained 17,118 barrels. In the Pacific, 40 ships in 1879 got 15,000 barrels. On the Californian coast, are some half-dozen whaling stations, for the capture of "grey-backs" mostly, which are difficult to secure, and not very rich in oil. The best catch is from November to February, when the whales are going south near the land; from May to October, they travel northwards farther at sea. In Hudson's Bay, 7 American vessels in 1870–6 procured 3048 barrels of train-oil. The exports of whale-oil (in gal.) from New York in 1878 were:—348,028 to France, 77,905 to Great Britain, 3050 to S. America, E. and W. Indies, &c., 2228 to Europe, 540 to Scandinavia; total, 431,751. Philadelphia exported 76,636 gal. in 1879. The production of whale-oil in the American fisheries (excluding spermaceti) was 1,091,930 gal. in 1879.

Next to America, ranks Scotland, and afterwards Norway. France and Germany have quite retired from the whale-fishery. The Scotch vessels hail from Peterhead, and Dundee. From the former port, 13 obtained 19 whales, 737½ tuns of train-oil, in 1869; in 1879, 7 secured 11 whales, 234 tuns of oil. Dundee, in 1869, despatched 11 vessels, which took 9 whales, 576 tuns of oil; in 1879, 15 captured 55 whales, and had a total of 1746 tuns of oil; in 1874, the figures were 190 whales, 1994 tuns oil. The fishing takes place partly in the European polar sea, partly in the Cumberland Gulf. The Norwegian whalery is almost confined to the Waranger Fjord, where 130 head, chiefly "finners," were taken in 1878. The Danish Greenland fishermen secure only 2 or 3 whales annually. The polar whale is found off the coast here and there between 65° and 70° N. lat. A station still exists in Holsteinborg. The chase lasts from December to March. In summer and autumn, they also meet with the humpback whale, in years when there is little or no drift ice. New Zealand had a whale-fleet of 13 vessels in 1877, hailing chiefly from Otago; the value of their take was 41,740*l.* Tasmania had 12 vessels engaged in 1877, whose catch was valued at 31,605*l.* The exports of whale-oil from Honolulu in 1878 were 7254 gal. to Germany. The Bay of Panama was very productive in whale-oil during 1878, the number of sperm-whales and humpbacks captured considerably exceeding that of previous years. In 1877, the number of barrels (of 30 gal.) of oil obtained was 727; in 1878, it amounted to 2710. The industry is carried on by American vessels from San Francisco and New Bedford, and by Chilian vessels from Valparaiso the latter being owned chiefly by English firms there. From the St. Vincent (W. Indies) whale-fishery, the exports were 610 barrels, 1830*l.*, in 1876; 750 barrels, 2259*l.*, in 1877; 581 barrels 1264*l.*, in 1878; 370 barrels, 315*l.*, in 1879. From Barbados, they were 1108*l.* in 1877, and 1887 in 1878. The value of Norwegian exports has fallen from 913,200 *kroner* (of 1s. 1½*d.*) worth of train-oil, and 66,000 *kr.* of whale-blubber, in 1875, to 450,900 *kr.* of train-oil in 1879. The quantity of train-oil in 1879 was 143,065 *hectol.* (of 22 gal.). Denmark, in 1878, exported 193,514 lb. of train-oil to Great Britain. Archangel, in 1878, exported 615 tons of train-oil, value 11,630*l.*, to Germany.

The "Greenland" or "right" whale (*Balæna mysticetus*) inhabits the Arctic Seas of both hemispheres; it usually affords about 125 barrels of blubber, which is converted into the so-called "train-oil." The "polar" whale (*B. glacialis*) is abundant around Greenland, Iceland, and the North Cape; it yields about 90 barrels of blubber. The "southern" or "Cape" whale (*B. antarctica*) is found in the South Seas. The "humpback" whale (*Balænoptera Boops*) inhabits the northern seas; it is less rich in oil than the "right" whale. The "finner" (*Balænoptera Gibbar*), a native of northern seas, is difficult to take, and furnishes a small quantity of oil, but of excellent quality. *Balæna rostrata* is met with on the coasts of Scotland. The thickness of the "blubber," or oleaginous cellular membrane, in a whale varies from 8 to 20 in. It is very coarse in texture, and harder than pork. The oil is drained from it by cutting it into pieces and placing these in racks, through which the oil drips down into casks. It is then heated at 107° (225° F.) to remove the unpleasant odour, and to assist the clarification. It is next pumped over with water, left to cool, and finally barrelled. (For Spermaceti, see p. 1371).

Miscellaneous.—Besides the oils and fats mentioned under the preceding headings, all of which are important commercial articles, there are many others obtained from members of the animal kingdom, some identified, others not yet referable to exact species, which, though not deserving of such prominent notice as the former, still cannot be altogether overlooked. They are as follows:—

Alpaca-tallow, the fat of some species of *Auchenia* (see Hair—Alpaca, p. 1093), is used in pomades in portions of S. America.

Anabas scandens, in the Malay Archipelago, gives a fish oil.

Ant-grease is obtained from white ants or termites on the Gaboon, by boiling them in large vessels, and skimming off the fat which floats; it is used as food. Another yellow or reddish-brown fatty oil is produced by expressing the residue left on distilling ants.

Badger-grease was formerly used in medicine, and is now employed in Austria for carriage-grease; melting-point, 30° (86° F.).

Barbus Chola, in the Malay Archipelago, gives a fish oil.

Bat-grease (Fr., *Graisse de Roussette édule*) is obtained from the "kalong" or (erroneously) "flying-fox," a large bat (*Pteropus edulis*) of New Caledonia, the Moluccas, and the Sundas; it has the properties of lard.

Bear-grease, from N. America, was formerly used in medicine and perfumery.

Beetle-oil, obtained from *Carabus saponarius*, of Senegal, is used as soap.

Cochineal-fat, from the cochineal-insect (*Coccus cacti*), melts at 40° (104° F.).

Cockchafer-oil (Fr., *Huile de Hanneton*), obtained from *Melolontha vulgaris*, is used for lighting, and for the manufacture of carriage-grease, in Hungary.

Conger-eel-oil is obtained from *Muræna Congre* in the N. Atlantic (see p. 1364).

Cooawanoo-oil is procured from the reptile *Caouana divacea* [*Chelonia Cephalo*] in the E. Indies.

Dog-grease is used medicinally, and in the manufacture of glazed gloves, on the Continent; melting-point, 26½° (79⅗° F.).

Duck-grease, from *Anser spp.*, contains 72 per cent. oleine and 28 stearine; melting-point, 25° (77° F.).

Emu-grease, from *Dromaius novæ hollandiæ*, is obtained by boiling the skin in small pieces after removal of the feathers, and is much esteemed by the colonists and natives of Australia as a remedy for sprains and rheumatism.

Frigate-bird-oil is got from the "frigate-bird" (*Tachypetis aquila*) in tropical regions.

Fulmar-oil is derived from the "fulmar petrel" (*Procellaria glacialis*), which bird is found in myriads on the islands of the N. Atlantic, e. g. the Hebrides, Orkneys, Shetlands, Færoes, and Iceland; the oil is abundant, and resembles that from cod-liver. (For Petrel-oil, see p. 1376).

Fur-seal-oil, from *Otaria spp.*, is occasionally imported into London by the Falkland Islands Co.; each animal's blubber furnishes about ½ gal. of excellent oil, adapted to the same purposes as ordinary seal-oil; it is mostly wasted. The value of the exports is included in Penguin-oil (see p. 1376).

Gata-oil, from an unknown fish, is used in the Cape Verdes, and esteemed superior to cod-liver-oil in medicine.

Ghee, or clarified butter, chiefly made from buffalo-milk, is universally employed in domestic cooking in India, and is an important article of local trade. Thus the value of the exports from Persia in 1879 were 15,000 rupees from Bushire, 32,000 from Lingah, and 5000 from Bahrein.

Giboia-grease (or oil) is from an undetermined Brazilian animal.

Goose-grease contains 68 per cent. oleine and 32 stearine.

Guacharo-oil is obtained from the so-called "oil-bird," *diablotin* (French Antilles), or "Trinidad goat-sucker" (*Steatornis caripensis*), found in Venezuela, Trinidad, Ecuador, the Peruvian Andes, and New Granada. It is a nocturnal bird, inhabiting deep, dark caverns, and feeding exclusively on oleaginous fruits. The young, soon after being hatched, become a mass of fat, when they are taken in immense numbers by the Venezuelan Indians, about midsummer, by the aid of torches and long poles; their fat is removed, and melted down over fires kindled at the cavern mouth, and the oil is run into earthen pots, and preserved for cooking and lighting purposes; it is pure and limpid, free from unpleasant taste or smell, and keeps sweet for a year.

Guariba-grease (or oil), from an undetermined Brazilian animal, is recommended against rheumatism.

Hippopotamus-grease, when boiled, is very similar to lard, but has always an oily consistence in S. and Central Africa; it has a slight flavour of train-oil, but keeps for many years without becoming rancid.

Hwangkuyn is an oil from an undetermined Chinese fish.

Iguana-grease, from *Iguana tuberculata*, is utilized in S. America.

Lamprey-oil, from *Petromyzon fluviatilis*, is used in Russia.

Ophiocephalus striatus, in the Malay Archipelago, affords a fish oil from its intestines.

Ostrich-grease, from *Struthio Camelus*, is used by the Arabs in food and medicine.

Ounce-grease, from *Felis Uncia*, is employed in Brazil.

Peacock-grease is esteemed in the E. Indies.

Penguin-oil is obtained from the "Patagonian penguin," or *manchot* (*Aptenopodites patagonica*), found in S. America; the bird is so abundant in Patagonia that one vessel has obtained more than 225,000 pints of its oil in 5 weeks; it is imported into London by the Falkland Islands Co., and is employed in leather-dressing. The value of the exports of penguin-oil (including seal) to the United Kingdom, were 1312*l.* in 1878, and 1200*l.* in 1879.

Petrel-oil is procured from two species of petrel, *Procellaria obscura* and *P. brevicauda*, the former in New Zealand, the latter in Tasmania, by pressing the bodies of the birds, who are allowed to escape alive, to accumulate a fresh supply; it burns very well in lamps, and is also employed against rheumatism. (For Fulmar-oil, see p. 1375).

Pheasant-grease, melts at 43° (109° F.).

Pigeon-grease (or oil), from *Columba migratina*, is used by the natives of N. America as a substitute for butter.

Piraracu-oil, from *Vastris gigas*, and perhaps other species, is employed in Brazil, Guiana, &c., against rheumatism.

Raposa-grease, from a species of fox, is used medicinally in Brazil.

Ray-oils are very extensively procured from the livers of *Raja clavata*, *R. pastinaca*, and other species indigenous to Indian seas, and possess qualities like those of cod-liver-oil (see p. 1364).

Salmon-oil, from a species of *Salmo* found in China, sometimes enters into the composition of "Indian ink."

Sandre-oil is obtained in Russia from the fat surrounding the intestines of *Leucoperca Sandre*, and is used like sturgeon-oil (see below).

Saw-fish-oils are procured from several species of *Pristis*: the liver of the sword- or comb-fish of Guiana (*P. pectinatus*) affords 15–20 gal. of oil, used for lighting and anointing; another species in India contributes very largely to the mixture of oils known as "Malabar oil" (see p. 1367).

Sea-wolf-oil is obtained from *Anarrhicus lupus* in the North Sea.

Silkworm-oil is extracted from the chrysalides of the silkworm, by pressure, by treatment with bisulphide of carbon, or by exhausting with alcohol and washing the extract with hot water; it is brownish-green, lighter than water, neutral, remains liquid at 0° (32° F.), is easily soluble in alcohol and ether, is readily saponifiable, and possesses an extremely disagreeable odour. The yield is 15 lb. of oil from 165 lb. of cocoons; the oil burns well in lamps.

Sturgeon-oil is prepared in Russia from the fat surrounding the intestines of the sturgeon (*Accipenser Sturio*), by washing and melting in the fresh state in steam-boilers; it is chiefly used for adding to the barrels of caviare, when the spawn itself is not sufficiently fat. It is also consumed as food. The common grades for industrial purposes are liberated by putrefaction, and amount to 100,000 *poods* (of 36 lb.) yearly.

Tapir-grease, or *Anta-oil*, from *Tapirus suillus*, is used medicinally in Brazil.

Tassoc-oil, obtained from a species of *Silurus*, is an important object of commerce in Cochin China and Siam, and is remarkable for the quantity of stearine it contains. Another species, *S. glanis*, is utilized in E. Europe.

Turkey-grease melts at 45° (113° F.).

Turtle-butter (or oil) is extracted from the eggs and fat of various species of turtle in Brazil and the S. Pacific Islands, and is used in food and medicine, and for lighting. The production in the

Orinoco, Amazon, and Negro rivers is estimated at over 10,000 jars annually. In the S. Pacific, a good-sized turtle will yield 10 gal. of oil.

Yusan is an oil from an undetermined Chinese fish.

A fat obtained from the *larvæ* of an insect living on the "Tucum palm" (*Astrocaryum vulgare*) is used medicinally in Brazil.

British India exported 429,830 gal. of animal oils in 1877, and 1374 gal. in 1879.

VEGETABLE OILS AND FATS [A. *Fatty or Fixed*].

Almond-oil (Fr. *Huile d'Amandes*).—The almond (see Fruit—Almonds, p. 1022) yields two oils: an essential or volatile oil, described in a separate section (see p. 1416); and a fixed or fatty oil, now to be discussed. This latter is afforded by both sweet and bitter varieties, to the extent of 55–60 per cent. For its extraction, the fruit is chosen recently gathered, but not too fresh. The sweet almonds are crushed unpeeled, the bitter are peeled, and deprived of their essential oil. They are shaken up in a bag, and crushed to paste; the latter is put into bags, and pressed. Perfumers, in order to obtain whiter cakes and a superior "paste," plunge them into boiling water, to separate the skins, but this method of proceeding is apt to provoke the rancidity of the oil, and thus diminish its value. Bitter almonds are generally preferred to sweet, as being cheaper, and leaving a useful cake for perfumers. The most esteemed oil is obtained from the almonds of Majorca. The manufacture is carried on principally in Spain, Italy, and S. France. The yield of oil on an industrial scale is said to be 1 lb. 6 oz. by cold expression, and an additional 12 oz. by hot expression, from $5\frac{1}{2}$ lb. of almonds. The oil has a clear yellow colour, and agreeable flavour; it is without odour, and very fluid; its sp. gr. is 0·917–0·920 at 15° (59° F.); it thickens and deposits stearine at − 10° (14° F.), assumes a butter-like consistence at − 20° (− 4° F.), and solidifies completely at − 25° (− 13° F.); it contains 24 per cent. of stearine, and 76 of oleine; it dissolves readily in ether, and in alcohol (25 parts cold, 6 hot). It is employed chiefly by perfumers, but also in medicine. It is frequently adulterated up to 50 per cent. with gingelly-oil, poppy-oil, mustard-oil, and peach-kernel-oil.

American Nutmeg-oil (Fr., *Suif de Virola*).—The "American nutmeg" called *Virola sebifera* [*Myristica sebifera*], known as *jejomadon* to the Creoles, and as *malagueto de montana* in Panama, is common in the forests of Guiana and N. Brazil, and extends as far as Panama. The seeds are there bruised, and macerated in boiling water, when a fatty substance separates from them, floats on the water, and solidifies by cooling. This solid fat is transported to Europe in the form of bricks, and has been received in considerable quantities. The yield from the seeds is stated at 26 per cent. The fat is completely soluble in alcohol, ether, and potash ley; its fusing-point is 44° (111° F.); it forms a hard soap, and is admirably adapted for making candles, which burn with a pleasant aromatic odour.

Argan-oil (Fr., *Huile d'Argan*).—The seed-kernels of the argan tree (*Argania Sideroxylon* [*Elæodendron Argan*, *Sideroxylon spinosum*]) afford a valuable fatty oil. The tree is found native only in the sub-littoral zone of S.-W. Morocco, where it is common between the rivers Tensift and Sous. A few scattered specimens are said to occur north of the Tensift, and the tree seems to be not infrequent in the hilly district between the Sous and the Oued Noun. Thus its area comprises a total length of about 200 miles, and a breadth extending from near the coast to a distance of 30–40 miles inland. At different times, the seed has been procured and distributed to various colonies, but its slow growth has led to disappointment. At Saharunpore, it did not survive, though probably well suited to N.-W. India. A tree in the Hobart Town Gardens has been fruiting for some years. In Morocco, the tree flowers in the middle of June, and the fruit remains on the tree during the greater part of the year. The young fruit sets in the end of July or beginning of August, and grows slowly till the rainy season commences, towards the end of September. It then enlarges rapidly, and attains its full size during that season, so that, by the middle or end of March, it is ripe enough to be gathered for economic uses. The prominent feature of the tree is the hardihood with which it withstands drought. The harvesting of the seed-kernels and extraction of the oil are performed in the following manner: In the end of March, camels, goats, sheep and cows are driven into the argan woods, when the fruits are shaken down from the trees. The green fleshy pericarp is greedily eaten by these animals, who afterwards reject the seed-kernels. The latter are collected by the peasants, and taken home. The hard bony shells are cracked between stones, and the inner white kernels are carefully extracted. These are roasted on plates of iron or pottery, and stirred constantly meanwhile, until they have a brown colour all over, without being charred on the outside. When the kernels have cooled, they are ground into a thick meal; this is placed in a vessel, moistened occasionally with warm water, and stirred and kneaded with the hand unceasingly, until the mass becomes so hard that it can no longer be kneaded. The harder the mass becomes, the more perfectly is the oil liberated. Finally, cold water is sprinkled over it, to expel the last traces of oil. During the operation, the oil escapes at the sides, and is poured into a clean receptacle at intervals. The main points needing attention are that the kneading shall be thorough, and that the hot water used shall not exceed what is actually necessary. The residual cake is an excellent cattle-food. The oil, when it has settled, has a clear light-brown colour, and a rancid odour and flavour. It is an important domestic oil among the Moors, being used as a substitute for olive-oil. The annual production is estimated at 1000 cwt. for the whole region. It is said that none whatever is exported.

Assai-oil.—A fatty oil is extracted by decoction from the fruit of *Euterpe oleracea* [*edulis*], the *assai* palm, found abundantly in Pará, growing in swampy places, especially on the banks of rivers within the tidal limits. The oil is of greenish colour, and slightly bitter flavour, and is used for illuminating.

Bean-oil.—The seeds of the Chinese oil-bean, the *sooja* or *miso* of the Japanese (*Glycine Soja* [*Soja hispida*]), afford 17–18 per cent. of a fatty oil. The plant is shrubby, attaining a height of 3–4 ft., and resembling the common dwarf kidney or French bean. The seeds are somewhat smaller than French beans, and vary in colour, from white to yellow and green. The plant is chiefly cultivated in the north of China, especially in the province of Shantung. The Chinese usually obtain 17 per cent. of oil from the seeds by simple pressure. The oil bears a general analogy to the ordinary edible oils of commerce, possessing an agreeable flavour and odour. It is useful for burning; exposed to a low temperature, it becomes pasty, and oxidizes rapidly on exposure to the air. As a drying-oil, it might replace linseed-oil for some purposes. As an illuminator, it is being rapidly replaced by American petroleum, but is still extensively used for food. The oil, the cake left after expression of the oil, and the beans themselves, are important articles of Chinese commerce. The exports from Chefoo in 1878 were 2468½ *piculs* (of 133⅓ lb.) of bean-oil, 994,188 of bean-cake, and 160,549⅓ of beans; in 1870, the exports of the oil from this port were 44,530 *piculs*; in 1877, only 327 *piculs*; and in 1879, 1491 *piculs*. The exports of bean-oil from Newchwang were 4947 *piculs* in 1877, 3287¼ in 1878, and 11,630 in 1879; of beans, in the same years, 1,439,062, 2,156,064, and 1,835,444 *piculs* respectively; and of bean-cake, 792,166, 1,924,968, and 1,800,523 *piculs*. Chinkiang exported 69,090 *piculs* of beans in 1877, and 43,784 in 1879. Hankow imported 21,077¾ *piculs* of native bean-oil, value 15,624*l*., in 1879. Kiukiang, in 1879, imported 17,675 *piculs*. Shanghai, in 1879, imported 282¼ *piculs* from native ports, and exported 33,940 *piculs* (besides 372 re-exports) to native ports. Wuhu imports quantities of the oil from Hohan, viâ Hankow, also from Hochow, Luchowfu, and some other places north of the river; the figures were, 659½ *piculs* in 1877, 13,574¼ in 1878, and 5284 in 1879. The cake is used for human and cattle food, and as manure. (See also Spices—Soy.) The plant is cultivated for its beans in many parts of India and the Archipelago; and has been successfully introduced into Austro-Hungary and N. Germany.

Beech-oil (Fr., *Huile de Faine*).—The fruit or "mast" of the common beech (see Timber) is valued for its oil in some parts of the Continent, notably France, and was so in England also in Queen Anne's reign. The forest of Compiègne is the chief locality for the production of the oil, which there forms an important industry, a vigorous tree being estimated to yield in good years not less than 22 gal. of oil. When the mast is ripe, at the beginning of autumn, it is shaken down upon cloths spread beneath, and sorted; the soundest fruits are placed to dry in the shade, crushed between rollers or in a mill, and sifted or fanned to remove the shells. Thus treated, the dried kernels are put into troughs, and stamped to a paste; this latter is enclosed in bags, and subjected to pressure; the escaping oil is poured into capacious vessels, and left to deposit the mucilaginous matters extracted by the pressure, after which, it is ready for commerce. This process is the best, not only as regards the oil produced, but also as affording a good cattle-food in the refuse cakes. Unfortunately, the shelling of the kernels is often omitted, when the shells retain some of the oil, and only release it on boiling in water, by which its character is impaired. Occasionally the nuts are hand-shelled singly, and treated with such care, that the cake left after expression of the oil contains sufficient amylaceous matter to be used as a kind of bread. The yield of oil is about 12–15 per cent. (20–25 per cent. by carbon bisulphide), or 1 gal. of oil from 1 bush. of mast. The newly-extracted oil has an acrid flavour, which disappears in time, or may be removed by washing with cold water. The oil has a clear-yellow colour, a peculiar odour, and a faint flavour; freshly-drawn, it is thick and cloudy; after sufficient rest, it is limpid, but slightly viscous. Its sp. gr. is 0·922 at 15° (59° F.); it becomes turbid at − 10° (14° F.), and congeals at −18° (0° F.) to a yellowish white mass; and keeps long without becoming rancid. It is sometimes used instead of butter for cooking in E. France, but is more commonly employed to adulterate olive-oil. It serves for illuminating; and forms with soda a dirty-grey, hard soap, but which always remains greasy.

Ben [Oil of] (Fr., *Huile de Ben, de Behen*).—Oil of ben is extracted from the so-called "ben-nuts," the seeds of one or more species of *Moringa*. The principal are *M. pterygosperma* [*M. oleifera, Guilandina Moringa, Hyperanthera Moringa*] and *M. aptera*. The former is a native of the E. Indies; the latter is said to be indigenous to Egypt and Arabia, and has long been naturalized in the

W. Indies. They are common objects of cultivation throughout India and Burma, in the N.-W. Himálaya up to 1500 ft., in Egypt, and in the W. Indies. The Indian species occurs wild in the lower Himálaya and Siwalik tract, from the Chenab to the Sardah, also in the Oudh forests. The seeds of both species are rich in fatty oil, which is extracted by simple pressure; it seems to be less availed of in India than in the other habitats of the trees. The Indian oil has a sp. gr. of 0·912–0·915 at 15½° (60° F.); it is fluid at 25° (77° F.), thick at 15° (59° F.), and becomes solid at lower temperatures; it is almost devoid of odour and flavour, has a pale-yellowish colour, saponifies slowly, and does not turn rancid. It consists essentially of oleine, margarine, and stearine. After separation of the solidifiable portion by cooling, it is highly esteemed by watch-makers as a lubricant, for which purpose it has been extensively imported. Locally, it is employed in medicine; also by perfumers, as it possesses great power of absorbing and retaining even the most fugitive odours. It is very commonly adulterated with virgin olive-oil. In the W. Indies, it is said to be used as a salad-oil.

Bicuhiba-wax (Fr., *Cire de Bicuiba*).—The fruit of the *bicuhiba* or *ucuhuba* of Brazil (*Myristica Bicuhiba*), affords a concrete oil, of yellowish-white colour, soluble in boiling alcohol, and melting at 35° (95° F.), which is locally employed in candle-making, and as a remedy for asthma, rheumatism, and tumours.

Bladder-nut-oil.—The kernel of the fruits ("bladder-nuts") of *Staphylea pinnata* are expressed in some parts of Central and E. Europe for the bland oil which they yield.

Boma-nut-oil.—The Boma-nut (see Nuts, p. 1351) which is not a species of *Vitex* as there supposed, but has been called *Pycnocoma macrophylla*, furnishes an abundanee of sweet bland oil, much used in cooking by the natives of central Africa.

Butter-nut- or Souari-oil.—The fruits of *Caryocar nuciferum* and *C. tomentosum*, lofty trees inhabiting the forests of tropical S. America, notably the banks of the Essequibo and Berbice rivers, afford edible oils.

Cacao-butter or Oil of Theobroma (Fr., *Beurre de Cacao*; Ger., *Cacaobutter*, *Cacaotalg*).—A valuable concrete fatty oil is derived from the seeds or beans of the cocoa- or chocolate-tree, principally *Theobroma Cacao* (see Cocoa, p. 684). This oil is procured almost exclusively from the chocolate-makers, who express it in the process of preparing the cocoa-nibs for the production of the article in various edible forms. The nibs are ground in heated mills, by which the oil is disengaged, and the mass becomes a soft paste; this is placed in canvas bags, and subjected to pressure under the influence of steam-heat. The oil then escapes in a perfectly liquid condition, and is collected in oblong tins. When necessary, it is decolorized by filtration through ivory-black, i.e. very fine animal charcoal. The yield of oil is from 30 to 45–50 per cent. of the weight of nibs. On cooling to ordinary temperatures, the oil becomes a light-yellowish, opaque, dry substance, unctuous to the touch, but brittle enough to break into fragments when struck, and showing a dull waxy fracture; it has a chocolate-like odour, and a pleasant bland flavour; its sp. gr. is 0·945–0·952; its fusing-point is 20°–30° (68°–86° F.); it is soluble in ether and spirit of turpentine; it dissolves also in 20 parts boiling alcohol, but only 1 per cent. remains in solution after cooling; it dissolves slowly in double its weight of benzol at 10° (50° F.), but partially separates by keeping; it may be kept for a long time (even several years) without turning rancid; it consists chiefly of stearine, and a little palmitine and oleine. It is extensively used in pharmaey, especially on the Continent. It is often adulterated with tallow, wax, &c., but its peculiar characters facilitate their detection.

Calaba- or Galba-oil.—The tree affording *calaba*-nuts (*Calophyllum Calaba*) flourishes most abundantly in Brazil and the W. Indies. Its seeds yield an excellent illuminating-oil.

Carmaru-oil.—The fruit-seeds of the eboe-tree (*Dipteryx eböensis*), and perhaps also those of the better known species, *D. odorata* (see Perfumes—Tonquin-beans), contain a large quantity of a clear, yellow, fixed oil. The trees flourish throughout Brazil, Guiana, and the Mosquito country (now the E. part of Nicaragua), but it is particularly in the last-named district that the oil is extracted and utilized by the natives. Its chief applications are for anointing the hair, and for curing ulceration of the throat.

Cashew-nut-oil, and Cardole.—The cashew-nut (see Nuts, p. 1352) affords two kinds of oil. The kernels, which have occasionally been imported into England from India as "cassia nuts," yield a light-yellow, bland, nutritious oil, of the finest quality, in every respect equal to almond-oil, and considered superior to olive-oil. It is very seldom expressed in India, as the entire kernels are so extensively eaten. A second oil, called *cardole*, or "cashew-apple-oil," is obtained from the pericarps or shells of the nuts; it is black and acrid, and is a powerful vesicating agent. It is employed in surgery as a caustic, and is frequently applied to timber which is exposed to the attacks of white ants. The yield of oil from the kernels amounts to 40½ per cent. commercially, and from the pericarp 29½.

Castanha-oil (Fr. *Huile de Juvias, de Châtaignes, de Castanheiro.*)—The castanha or Brazil-nut (see Nuts, p. 1351) is very rich in oil; each fruit contains some 20 nuts, and each lb. of nuts gives

10 oz. of oil. This is extracted by roasting the nuts, and pounding, pressing and straining the kernels. A superior product is obtained from the unroasted nuts. It is bland, pleasant, and of clear-yellow colour, and, in composition, differs but little from fixed almond-oil, which it resembles in its tendency to become rancid when kept. This last property renders it applicable only to illuminating, perfumery, and soap-making, for which it is well adapted. It is used for culinary purposes when fresh. It could be furnished in considerable quantities.

Castor-oil (Fr., *Huile de Castor, de Ricin, de Palma-Christi*; Ger., *Ricinussamenöl*).—The castor-oil-plant, or *Palma-Christi*, as it is often called, belongs to the genus *Ricinus*, of which some 16 forms are distinguished, but all usually considered mere varieties of *R. communis*. The variety known as *R. spectabilis* is said to give 22 per cent. more oil. The plant is indigenous to India, whence it has been distributed by cultivation throughout all the tropics, and in many temperate countries. It flourishes in India, China, Java; the Azores, and the W. African coast; the Mediterranean region (Algeria, Egypt, Greece, Spain, Crete, Sicily, and the Riviera); France, Germany, and England; Brazil, Spanish America, and the Portuguese colonies; the United States and the W. Indies; and in good summers, ripens its seed as far north as Christiania, in Norway. In the most favourable situations, it attains a height of 40 ft.; in the S. States of America, often 20–25 ft.; in the Mediterranean region, 10–15 ft.; in India, 8–10 ft.; in N. Europe, 4–5 ft.

The plant is probably most extensively grown in India, not only for the oil yielded by its seeds, but also on account of its leaves forming the food of some kinds of silkworm. Its cultivation is carried on in most parts of India. The whole of the N.-W. Provinces produce castor-oil, but inferior in quality to that obtained from the coast-grown seed of Coconada and that of Colcong. The plant might be raised much more extensively in Oudh. In Cuttack, it occupies much newly-cleared land, in the jungles of the Tributary States and Sumbulpore. Madras Presidency is reckoned to have 67,000 acres under this crop, chiefly in Coimbatore. Scarcely any cultivation is required, and the plant is frequently grown as a border for more valuable or delicate crops, especially as all insects are said to avoid it. It prefers a sandy loam, and will not thrive on clay. It attains full perfection as a hedge-plant, and flourishes well on newly-cleared jungle-land. Two kinds of the plant are distinguished by Indian native cultivators, a large-seeded and a small-seeded. Both are raised from seed, which is sown twice annually, in November and May. The natives sow and uproot the plant every year, though it grows and yields abundantly in the second and third years in open spaces. When growing it alone, they almost always sow too thickly, and thus prevent the proper development of the plant. The operation of gathering the seeds is tedious. The two kinds are kept distinct, the oil obtained from the small-seeded sort being esteemed much superior. Separate methods of extraction are also adopted.

The seeds of the small-seeded variety are treated as follows. Having been sifted clear of all dirt and foreign matters, while still fresh, they are slightly crushed between two rolls, then freed by hand from husks and coloured grains, enclosed in clean gunny-sacks, and lightly pressed in oblong moulds to form "bricks" of uniform shape and density. These bricks are placed alternately with sheet-iron plates in an ordinary press, and the escaping oil is caught in clean tinned pans. To each 1 gal. of oil, is added 1 pint of water, and the whole is boiled till the water has evaporated; the result of this is that the mucilage subsides, and encrusts the bottom of the pan, while the albumen solidifies, and forms a white layer between the oil and the water. The utmost care is necessary to remove the pan from the fire the moment the evaporation of the water is complete, as known by the cessation of bubbling; if allowed to remain longer, the temperature, hitherto that of boiling water, 100° (212° F.), suddenly rises to that of boiling oil, 315½° (600° F.), thereby deepening the colour and developing an empyreumatic odour and flavour. The oil is filtered through blanketing or similar fabric, and put into canisters for export. It is known as "cold-drawn" oil, and is usually of a light-straw to greenish colour. The cleaned seeds yield 47–50 per cent. of oil by this method, fit for the European market. Experiments with Calcutta seed resulted in a product of 324 lb. 1st class oil, 87½ lb. 2nds, and 76½ lb. 3rds, or a total of 488 lb. of oil from 1400 lb. of seed (980 lb. of kernels); 1400 lb. of Madras seed gave 318 lb. 1sts, 88 lb. 2nds, and 74 lb. 3rds, total 480 lb. The cost of the Madras oil, including the seed at R. 3·3 per bag of 164 lb., husking and selecting the kernels, crushing, moulding, pressing, boiling, filtering, overseers' pay, godown rent, 300 empty quart bottles, corks, cleaning, packing-charges, and sundries, was 76 *rupees* 1 *anna*, or an average of 4·06 *annas* per qt. of 1st, 2nd, and 3rd oil, or 4*d.* a lb. A second Indian method of exhausting this kind of seed is by hot-water extraction. The seeds are boiled in water for 2 hours, sun-dried for 3 days, shelled, pounded, and boiled in fresh water till the whole of the oil has risen to the surface. The yield is 1 qt. of oil from 3⅛ lb. of seed. It is straw-coloured, free from unpleasant odour and flavour, and is commonly used by native medical practitioners.

The oil of the large-seeded variety is occasionally extracted by the cold process, but most commonly by a combination of roasting and boiling. The seeds are first partially roasted over a charcoal fire, both to coagulate the albumen and liquefy the oil; they are then pounded, and boiled in water till the oil rises to the surface. The yield is about 33 per cent. of a very impure oil having a deep-red colour, and an empyreumatic odour, which is often very offensive during its combustion in lamps; it is thick and viscid, and soon grows rancid. It is produced only for home consumption, forming the common "lamp-oil" of the bazars, and being very extensively used for dressing articles of leather.

Most of the Indian oil is extracted in and exported from Calcutta, the crushed seed being sent up from Madras for the purpose—an inexplicable proceeding. The exports from Calcutta in 1870–1 were 654,917 gal., of which, 214,959 gal. were for the United Kingdom; in 1877–8, the total Indian export had grown to the very large figure of 1,411,216 gal. It is sent to the United Kingdom, Mauritius, the Straits Settlements, Ceylon, and Australia, chiefly, it would seem, for lubricating purposes, much of it being obtained from the large-seeded kind, and extracted by the roasting and boiling process.

The manufacture of castor-oil is actively carried on in the United States, especially at St. Louis, the seeds being largely produced in S. Illinois. In 1875, Kansas had 24,145 acres under this crop, producing 361,386 bush. of seed. Other states participate in the industry. The land is prepared as for other crops, and the seeds are planted much the same as maize, except that only one seed is put into each hill, and that every fourth row is missed to afford space for the harvesting. Ripening commences in August; the yield varies from 15 to 25 bush. an acre, 20 being considered fair. The oil is generally extracted in the following manner. The seeds, having been thoroughly cleansed from the dust and particles of the pod with which they are always contaminated, are placed in an iron tank, and heated to such a degree as will liquefy the oil without any risk of scorching. They are then pressed, the oil escaping being known as "1st quality." The pressed seed is heaped up and left for a day; on the following day, it is again heated and pressed, and gives a "2nd quality" oil. The yield from 1 bush. of seed is 12 lb. of 1st quality, and 4 lb. of 2nd quality oil; sometimes a 3rd expression is made, giving 1–3 lb. of a very much coloured oil. Occasionally too, the cake from the 2nd pressing is treated with bisulphide of carbon, which extracts a small additional quantity of thick, dark, common oil. All qualities need purifying and clarifying. This is usually effected by boiling first with a large quantity of water, and skimming off the impurities as they rise, while the mucilage and starch are dissolved, and the albumen is coagulated. The clear oil is removed and boiled with a very little water, which clarifies it, and drives off volatile acid matters. The chief point to be noticed is to expose the oil as little as possible to the air, or it quickly becomes rancid. The 1st quality oil is used medicinally, the 2nd for burning, lubricating, leather-dressing, &c. In America, the cake is frequently used as fuel.

Italian castor-oil has lately attracted some notice. It is principally expressed from the seed of plants grown in the province of Verona, especially the district of Legnago, in N. Italy; the produce is now 400,000 *kilo.* of seed yearly, but all Italian-pressed oil is not from Italian-grown seed, as Genoa imports considerable quantities of the seed from India. Two varieties are cultivated in Italy, the black-seeded Egyptian and the red-seeded American; the former yields the lesser percentage, but of a paler colour. The seeds are very carefully peeled, and after crushing, are placed in hydraulic presses, standing in a room which is heated to 21° (70° F.) in winter. The exudation of the oil is promoted by warming the press-plates to 32°–38° (90°–100° F.). The yield of oil is about 40 per cent. on the peeled seeds.

The castor-oil-plant grows as a weed in the Bahamas, but the little oil which is extracted by boiling is never met with in commerce. A supply of the best Indian seed has been sent to these islands, and is found to afford three times as much oil as the native plant, besides being quite as readily cultivated. Hopes are entertained that the colony will soon be an important producer of the oil. The plant has been introduced into Brazil from India, and attains an immense size; in 1879, an attempt was made to export castor-oil direct from Maccio to Europe, and probably large quantities will eventually be sent, as it is most extensively produced in the province of Alagoas, and locally used in lamps; the value of the shipments coastwise from Maceio rose from 16*l.* in 1877 to 117*l.* in 1879. In Angola (W. Africa), the dry sandy beds of the rivers in the hot season are often completely covered with a magnificent growth of the castor-oil plant. Among other countries, China may be mentioned as yielding considerable quantities of castor-oil; the exports from Newchwang were 581 *piculs* (of 133⅓ lb.) in 1877, and 1664 in 1878; Shanghai exported 555 *piculs* to other Chinese ports in 1878, and 3 *piculs* to Chinese ports, and 76 *piculs* to foreign countries, in 1879. In France, the fresh seeds are bruised and pressed in the cold, and the albumen and mucilage are separated by long standing and filtering; the product is 33 per cent. of the seeds, but is much weaker (less purging) than that obtained from the tropics. This remark applies also to the Italian oil. Rarely, the bruised seed is macerated in cold alcohol, 1 lb. of seed then giving 6 oz. of oil. Algeria and Egypt are large producers.

As to the claims of the plant upon cultivators of oil crops, Dareste estimated the yield to be 1800 *kilo.* (of 2·2 lb.) per *hectare* (of 2½ acres), while a similar area of oil-palms in the tropics gave only 900 *kilo.*, and of olives in S. Europe 600 *kilo.*; the seed was calculated to afford 52 per cent. of oil.

Castor-oil has a sp. gr. of 0·969 at 12° (53½° F.), 0·957 at 25° (77° F.), and 0·908 at 94°

(201¼° F.); it has usually a pale-yellow colour, viscid consistence, and slight mawkish odour and flavour, which are much intensified when it becomes rancid; at—15° (5° F.), it commences to congeal, but does not completely solidify above—18° (0° F.), when it dries up, forming a transparent varnish-like film in three layers; its boiling-point is 265° (509° F.), when it begins to distil, and affords various products; it mixes in all proportions with glacial acetic acid and absolute alcohol, and is even soluble in 4 parts alcohol of 0·838–0·850 at 15° (59° F.), and forms a clear mixture with equal weights of the same at 25° (77° F.); it is said also to render other oils mixed with it soluble in alcohol. It saponifies readily, yielding several fatty acids, the chief of which is ricinoleic ($C_{18}H_{34}O_3$), peculiar to this oil, and another appears to be palmitic. Its drastic principle and optical properties still await investigation. Some of its uses have already been alluded to. For medicinal use, as a purgative, the cold-drawn oil is the only kind fit for human subjects; but the oil obtained by roasting and boiling, or that extracted by alcohol, is preferred by veterinary surgeons, as containing much more of the drastic principle, and being therefore more powerful. The common kinds are largely used by leather-dressers, principally, perhaps, for morocco leather, but with equal success on all descriptions; moreover, it repels rats and other vermin, and does not interfere with subsequent polishing. As a lubricant, it is in extensive use in Europe and America; and as a lamp-oil, in India, Brazil, &c. Chiefly three sorts appear in the London market—that expressed here from imported (essentially Egyptian) seed, E. Indian expressed, and American expressed. The oil is imported in tins, barrels, hogsheads, and duppers. It is often adulterated with poppy-seed-oil and croton-oil. (See Drugs, p. 798).

Chaulmugra- and Lukrabo- [Lucrabau-] oils.—The valuable medicinal oils known as *chaulmugra* in India, as *lukrabo* in Siam, and as *ta-fung-tsze* in China, are obtained from the seeds of one or more species of *Gynocardia*; the Indian species is called *G. odorata* (*Chaulmugra*, *Hydnocarpus odorata*), while the other kinds are not yet specifically determined, though some botanists consider them identical. *G. odorata* grows in the forests of the Malayan peninsula and E. India (Tenasserim, Rangoon, Chittagong) as far north as Assam, and thence westwards along the base of the Himálayas, and on the Khasia Hills. It is a large tree, bearing fruits somewhat resembling an orange, in the pulp of which are imbedded the seeds whence the oil is extracted. The fragrant flowers appear in April–May, and the fruits ripen in December. The latter are then collected, dried, and sent to Calcutta; the outer integument is removed, and the kernels alone are treated for their oil, during a period extending to the end of February. The freshest seeds, gathered in December, afford the best yield of oil, which (by expression) amounts to about 10 per cent. Both cold and hot expression are adopted, the oil obtained by the former having superior keeping qualities. At ordinary European temperatures, the oil is a granular solid, resembling beef-dripping in colour and appearance, but of firmer consistence. In the Indian climate, it is more liquid, of a pale-sherry colour, and sp. gr. 0·900; a granular, white, fatty deposit is thrown down by keeping. The melting-point as ascertained in England is 42° (107½° F.), when the sp. gr. is 0·930. It has an acid reaction a slight persistent acrid flavour, and a faint scammony-like odour. A peculiar feature of the expressed oil is its (hitherto) indestructible green colour. The kernels treated with ether afford over 50 per cent. of fatty oil, which is almost colourless, or brownish when the seeds are not fresh. The expressed oil concretes at 17° (62½° F.); that extracted by ether or bisulphide of carbon requires a lower temperature. The chief constituents of the oil are about 63 per cent. of palmitic acid and 11½ per cent. of gynocardic acid in combination with glyceryl as fats; the latter acid is the seat of the colour and flavour, and probably also of the medicinal activity (see Drugs, p. 799) of the oil. The chaulmugra-oil met with in the Indian bazars is universally adulterated, and quite unreliable, as the detection of its impurities is practically impossible. The pure oil has been largely introduced into medical practice in this country through T. Christy and Co., Fenchurch St., and Corbyn, Stacey & Co., High Holborn. Of the closely allied Siamese drug, it may be mentioned that 48 *piculs* (of 133⅓ lb.) of lukrabo-seeds were exported from Bangkok to China in 1871. In 1879, Hankow imported 742 *piculs* of the seed, value 490*l.*; and Shanghai imported 552⅗ *piculs* from foreign countries, and 924⅓ from Hong Kong and Chinese ports, 410¼ being retained for local consumption.

Chequito.—This name is applied by the Kaffirs to a fatty substance yielded by the fruit of the "butter-tree" (*Combretum butyraceum*) of S.-E. Africa. It is largely used by them in admixture with their food, and is exported. It consists of about 25 per cent. oleine and 75 margarine, and possesses an aromatic flavour.

Cherry-oil.—The "stones" of the American red cherry (*Prunus serotina*) have for several years past appeared in the market in such abundance and at such a price as to induce manufacturers to extract their oil. For this purpose, the whole "stones," kernels and shells together, are ground to fine powder, which is carefully dried, and subjected to hydraulic pressure of about 2000 lb. a sq. in. The yield is about 5 per cent. of an oil having a slight (but not injurious) odour of bitter almonds, a sweet and agreeable flavour, and a dark-green colour which cannot be removed by either cold or hot water or alcohol; its sp. gr. is 0·906; it solidifies at −9½° (15° F.); its boiling-point is above that of mercury, which is 350° (662° F.), when it takes fire and burns with a yellow flame, leaving a pitch-like residue; at 138° (280° F.), it emits vapours, which are not disagreeable till 315° (600° F.) is reached; it is insoluble in alcohol, but freely soluble in ether, chloroform, oil of turpentine, olive-oil, and benzol.

Chironji-oil.—The fruit-kernels of *Buchanania latifolia*, a common forest-tree in Coromandel, Malabar, and Mysore, yield 50 per cent. of a pure, pale-straw-coloured, limpid, sweet, wholesome, edible oil, seldom found in the market, as the kernel is an esteemed dessert-fruit.

Cocculus indicus (see Drugs, p. 808).—The seeds contain about 50 per cent. of fatty oil, principally composed of stearine, which is extracted by the natives of India, and used for industrial purposes, but seems to be quite unknown in commerce.

Coco-nut- and Copra-oils (Fr., *Huile de Coco*, *Beurre de Coco*; Ger., *Cocosnussöl*, *Cocostalg*, *Cocosbutter*).—As indicated by its name, this oil is obtained from the fruit of the coco-nut-palm. The cultivation and distribution of this valuable tree have already been fully discussed elsewhere (see Nuts, p. 1353); the present remarks will be confined to the oil.

The albuminous pulp dried at ordinary temperatures (called "copra" or "copperah") contains 54·3 per cent. of oil, and dried at 100° (212° F.), 66 per cent. For preparing copra, only ripe nuts should be collected, and they should not be broken till 4–6 weeks after gathering; the copra then dries more quickly, does not become mouldy, and affords a greater yield of oil.

An Indian method of extracting this oil, when it is required to be colourless for perfumery manufacture, is as follows. The kernel is plunged into water, and boiled for a few minutes, then grated, and placed in a press; the emulsion thus obtained is boiled until the oil rises to the surface. This process is not cheap enough for ordinary commercial oils, and recourse is had to rude forms of oil-mill, worked by oxen, and treating about 130 lb. of copra daily, obtaining about 40 qt. of oil. Another plan is to divide the kernel into pieces, and dry them on shelves over charcoal fires; after 2–3 days, they are put into the press. By this method, 100 nuts carefully dried are estimated to yield by pressure 10–13 *edangalies* (of 92 cub. in.) of oil, or 40 nuts to a gallon; inferior nuts will not give more than 3–9 *edangalies*; those from trees on salt marshes afford the least oil.

In 1870–1, Bengal exported 7818 gal., and Bombay, 61,735 gal.; Madras shipped 1,088,887 gal. in 1869–70. The value of the oil exported from Malabar in 1873 was 356,187*l.* The exports of the oil from Ceylon were 278,216 cwt., value 330,689*l.*, in 1872, and 175,423 cwt., 204,661*l.* in 1878. The best comes from the Malabar ports, and locally fetches 20*s.* a ton more than that from Ceylon or the Coromandel Coast; yet in Western commerce, Ceylon oil is considered the best, and commands the highest price, Cochin and other kinds following.

The natives of Matabello (Ke Islands) are almost entirely occupied in making coco-nut-oil, which they sell to the Bugis and Goram traders, who carry it to Banda and Amboyna.

In the vicinity of Borongan, in the Philippines, quantities of coco-nut-oil are produced, and some 12,000 pitchers of it are exported yearly to Manilla; the nuts locally consumed would afford at least another 8000 pitchers. About 1000 nuts are required to yield 1½ pitchers of oil by the rude process here adopted, which is as follows. The kernel is rasped out of the woody shell of the nut on rough boards, and placed in old boats elevated on posts to undergo putrefaction; the oil escapes through the crevices of the boats into vessels placed beneath, and the pulp is finally pressed. The whole operation occupies several months, and yields a dark-brown viscid article, worth only 2½ dol. in Manilla, where a superior oil fetches 6 dol. Recently a factory has been erected at Borongan for the better preparation of the oil. The grating of the pulp is performed by iron discs with toothed edges, radiating from the ends of iron rods, and bluntly pointed towards the centre of the fruit. These discs are made to rotate by suitable gearing, while the workmen force the inner face of half coco-nuts, held firmly by both hands, and pressed by means of a pad on the chest, against the revolving rasps. The finely shredded nut lies for 12 hours in flat pans, to undergo partial decomposition, and is then gently pressed; the resulting liquor, consisting of ⅓ oil and ⅔ water is caught in tubs, and after standing for 6 hours, the supernatant oil is skimmed off. The latter is next heated in iron pans holding about 20–25 gal., until all the water has evaporated, occupying 2–3 hours. In order to cool the oil rapidly, and prevent its deepening in colour, 2 pailsful of cold oil, freed from water, are poured in, and the fire is quickly withdrawn. The compressed shreds are once more exposed to the air, and then subjected to powerful pressure. After these two operations have been twice repeated, the rasped substance is suspended in sacks between strong vertical boards, and alternately squeezed and shaken up for a considerable time. The refuse finally serves as pig-food. The oil which runs from the sacks is quite free from water, and very clear, and is used for cooling that extracted by the boiling process.

Mauritius exported 271,970 gal. of the oil, valued at 28,007*l.* in 1875, and 253,553 gal., value 37,263*l.*, in 1878. The Seychelles exported 162,475 *velts* (of 1·64 gal.) of oil in 1877, and 174,656½ *velts* in 1878.

Tahiti exported 690 tons of oil in 1868, and 420 tons in 1873. The Friendly Islands shipped 704 tons in 1866. The Fiji Islands exported 600 tons in 1864, and 200 tons in 1870.

Improved methods and machinery for extracting coco-nut-oil will be described in a separate section (see p. 1451). The oil is white, and almost as fluid and limpid as water in tropical climates, but solidifies at 16°–18° (61°–64½° F.), and consequently generally appears in Europe as a solid, opaque, unctuous substance, of the consistence of butter, and fusible at 24°–28° (75°–82° F.). When fresh, its odour and flavour are sweet and agreeable, but it quickly becomes rancid. It dissolves readily in alcohol, and saponifies with facility. Its principal fatty acid is laurostearic, together with oleic, palmitic, myristic, and some of less importance, all combined with glycerine. In Europe, the chief applications of the oil are for candle- and soap-making. It is an excellent illuminator, in both candles and lamps, as it emits no smoke; and it forms a hard and very white soap, more soluble in salt water than any other kind made on a commercial scale. During the last 15 years, its consumption for soap-making in England has been greatly reduced by the competition of palm-kernel-oil, extracted here. In the East, the oil is largely used in cooking and medicine while fresh, and for burning, painting, soap-making, and anointing the body, when rancid.

Colza- or Rape-oil (Fr., *Huile de Colza*; Ger., *Colzaöl, Rapsöl*).—Colza-oil and rape-oil are identical, and are derived from several species or varieties of *Brassica*, chiefly *B. campestris* and *B. Napus* [*Napa oleifera*], the seeds being known as rape-seed or cole-seed. The crop is extensively cultivated on the Continent and in India for the sake of the oleaginous seed. The mode of culture practised in Normandy is as follows. The seed is sown broadcast in July, preferably during wet weather, on well-manured land, forming the seed-bed of the future plants. When it is intended to transplant the young plants, the sowing is effected as with turnip- or cabbage-seed. In September–November, the young plants are removed from the seed-bed to a field richly manured with farm-yard dung, and which has just previously grown a crop of wheat. The plants are set out at distances of 18 in. in rows 2 ft. apart; in extra good soil, the crop will be heavier, and more equally ripened, by wider planting. One furrow is generally left between each two rows. The plants quickly recover, and remain thus till February, when the ground is pulverized with a horse-hoe after the frosts. At this season, manuring is beneficial, the application usually taking the form of guano, rape-dust, or the cake left from expressing rape-oil, this last being an excellent stimulant. After this spring dressing, a double mould-board plough is passed between the drills, to throw the earth well up to the stems of the plants. The chief enemies of the crop are hail and the heavy rains of July. The harvest takes place towards the middle of July, the crop being ready as soon as the straw and seed-pods become yellow. The cutting is done by sickles, and the plants as cut are laid across the ridges, so that air may circulate well amongst them. After 6–10 days, threshing commences. A space cleared in the field is covered with sail-cloth, and to this the sheaves are brought by means of a light hand-barrow lined with canvas. Great care is necessary in handling the stems, as the seed falls out very readily. The threshing is done with flails, the slightest stroke sufficing. The grain is stored dry, and needs constant turning to prevent its heating and spoiling. The colour and strength are also better preserved by the admixture of a certain quantity of husk with the seed; but nothing will obviate the necessity for repeated turning and thorough ventilation.

A second French mode of growing resembles Scotch turnip-culture. The seed is sown in drills, with guano, bone-dust, or other manure, in spring and in damp weather. Transplanting is not adopted, but the plants are thinned out, as if raising swedes for seed. The crop is nearly as heavy as that obtained by the other method, and the cost is greatly diminished by the saving effected in labour.

In India, rape-seed is very commonly sown mixed with mustard-seed, and almost always as an auxiliary with grain crops. It prefers loams, and does not flourish on clay soils. The sowing takes place in October, and the harvest in the following February, the plants being cut somewhat prematurely, or the pods would burst, and much of the seed be lost. The latter is ripened by exposure to the sun for 3–4 days on the threshing-floor, and is then easily dislodged.

The yield of seed per acre, and of oil from the seed, vary exceedingly, principally according to the soil, the season, and the care bestowed. Rotation of crops is as necessary for this as for every other culture. A crop that stands well and thick on the land does not always yield the most oil. In France, the seed is estimated to average 20 bush. an acre and often exceeds that figure; and the product of oil is calculated at 50 lb. (unrefined) from 22 gal. of seed. There are no available statistics showing the seed-crop per acre in India; but the Indian seed known as "Guzerat rape," largely crushed at Dantzig, is found to yield 3½ per cent. more oil than European seed, and leaves a cake richer in fatty matters and albuminoids; it is shipped from Bombay, and brings the highest price of any.

In France, colza-culture extends throughout the regions of the north-west and the plains of the north, but is little known in the south, and in the mountains of the centre. The chief departments engaged in raising this crop are Pas de Calais, Calvados, Seine-Inférieure, Nord, Somme, Saone-et-Loire, and Eure. The industry is declining before the extensive imports of mineral oils from America. In 1873, there were 415,491 acres under the crop, which yielded 6,541,718 bush. of seed; and in 1877, 344,187 acres afforded 5,992,591 bush. of seed. Considerable quantities of rape-seed are produced in Germany and Belgium, and much is imported in addition. The expression of the oil forms a large industry at Dantzig and Stettin. The former crushed 12,500 tons of rape-seed in 1879, exporting 88,000 cwt. of oil; of this, 2600 cwt. refined and 35,000 cwt. crude were exported to England. The total exports in that year were 92,833 cwt., value 127,650*l.*, as against 77,922 cwt., 124,675*l.*, in 1878. Memel shipped 2532 cwt, value 1266*l.*, in 1879. A great deal of rape-seed is grown in Hungary, but the area sown varies remarkably. During the years 1854–77, the annual production has fluctuated between 6300 and 123,900 tons of seed, averaging 38,882 tons; the crop of 1877 amounted to 100,000 tons. In the countries bordering the Danube, colza grows both wild and under cultivation. The shipments of seed from Roumanian (Danube) ports increased from 52,882 quarters in 1874 to 86,754 in 1879; in 1877, they were only 16,065 quarters (wild); in 1878, 117,297. The exports from Galatz in 1879 were 4087 quarters. Denmark exhibits a downward tendency in the cultivation of this crop, the number of acres occupied by it being 35,330 in 1866, and 1272 in 1876; the production in 1878 had fallen to 23,000 bush. Quantities of rape-seed are exported from Russia; the shipments in 1879 were 69,153 quarters from Nicolaieff, 71,572 from Taganrog and Rostov, 15,712 from Mariopol, 5149 from Yeisk, and 255 from Genitchesk. Wild rape is dying out in the Nicolaieff district, and being replaced by cultivated. The produce is shipped chiefly to N. France. The rape-crop is very general throughout India, and is growing in importance, the shipments of seed having increased from 359,854 cwt. in 1873–4, to 3,193,488 cwt. in 1877–8. The Chinese district of Ichang produces large quantities of colza-oil.

Colza- or rape-oil has a sp. gr. of 0·912–0·920, and congeals at—6° (21°F.); its colour is brownish-yellow, and it acquires a nauseous odour and flavour by keeping. It consists of 54 per cent. oleine and 46 per cent. stearine; as extracted, it contains much mucilage, which is removed by treatment with 2 per cent. of sulphuric acid; this operation diminishes the colour and density of the oil. As the purified oil ages, it becomes whiter and more viscous, and increases in density, at the same time losing its combustibility, and burning with a most unpleasant smoke; it is very slightly soluble in alcohol, and is itself a solvent of sulphur and phosphorus. Formerly, the chief application of the oil was for illuminating purposes, and it is so still in India; but in Europe, it is used as a lubricant, and is employed extensively by indiarubber manufacturers.

Coquito-oil.—This is said to be obtained from the fruits of a palm, *Elæis melanococca*, gathered in immense quantities in the states of Oaxaca, Colima, Guerrero, and other portions of Mexico, though the name *coquito* is applied in Chili to another palm, *Jubæa spectabilis*. The yield of oil is stated at 50 per cent.; it is solid at the ordinary temperature of the central portion of the country; and is manufactured into soap of very fine quality.

Cotton-seed-oil (Fr., *Huile de Coton*; Ger., *Baumwollensamenöl*).—The seeds which are separated from the "lint" or "wool" of the various kinds of cotton in the process of "ginning" (see Fibrous Substances—*Gossypium*, p. 948) are valued for their oil. The utilization of this oil is assuming the importance of a distinct industry in the United States, where there are now upwards of 40 oil-mills, 9 being situated in Mississippi, 9 in Louisiana, 8 in Tennessee, 6 in Texas, 4 in Arkansas, 2 in Missouri, 2 in Alabama, and 1 in Georgia. The quantity of seed treated for its oil now amounts to over 400,000 tons annually, and the increasing production of the oil may be gathered from the following figures, showing (*a*) the number of gallons exported, and (*b*) the home consumption:—year 1876–7, *a* 1,316,000, *b* 2,000,000; 1877–8, *a* 1,457,000, *b* 1,800,000; 1878–9, *a* 5,750,000, *b* 2,425,000. The American process of extraction is as follows. The seed coming from the ginning operation (see p. 957) still has some fibre adhering to it, and has a tendency to accumulate in masses. These are thrown into a machine containing a screw-knife revolving in a trough, which divides the materials into particles fit for the screening operation. This is conducted first in a sieve with meshes that allow the sand and dirt to pass, while retaining the seed; and then in one through which the seed can escape, but not husks and coarse foreign matters. The cleaned seed is next passed through a special gin for removing all remaining fibre (useful for paper-making and other purposes); and finally through a hulling-machine or decorticator, consisting of fixed and revolving knives set so close as to sever the seeds. The huller made by D. Kahnweiler, 120, Center Street, New York, was favourably noticed at the Centennial Exhibition. Thus treated, the seeds are taken through one or more separators, which pass the kernels but retain the shells. The kernels are pressed into cakes between iron rolls, and are then placed in steam-jacketed iron tanks, 4 ft. wide and 15 in. deep, where, by constant stirring, and the action of dry heat obtained from injecting steam at 35 lb. a sq. in. into the jacket, the oil is liberated from the cells in the course of about 5 minutes. The heated mass is then filled into sacks and subjected to repeated hydraulic pressure, till most of the oil is extracted. This process of extraction is replaced in England by an improved method, described under a separate heading in the present article, see p. 1451. By the American plan, the yield from 1000 lb. of seed averages 490 lb. of husks, 10 lb. of cotton, 365 lb. of cake, and 135 lb. of oil.

In India, cotton-seed is used more as a cattle-food direct, than as an oil-yielder. By the native mills, it affords 25 per cent. of a good oil, which, if purified, might become of considerable commercial importance. The seed cannot safely be shipped without undergoing preliminary cleansing, otherwise it heats and deteriorates in bulk on the long voyage. Egypt exports large quantities of the seed to Marseilles and English ports; the total exports for the season 1879–80 were estimated at 2,200,000 *ardebs* (260,000 tons), value 1,750,000*l.*, of which, 98⅝ per cent. was for the United Kingdom; the official figures are 1,282,770*l.* worth to Great Britain, 66,200*l.* to France, and 100*l.* to Turkey. The Turkish port of Adana shipped 3,389,375 lb. of cotton-seed, value 6740*l.*, in 1878; and Bagdad exported 134 cwt., value 189*l.*, to Europe and India in the same year. Quantities of cotton-seed oil are produced in Ichang (China). The native imports of this oil at Hankow in 1879 were 1333½ *piculs*, value 2493*l.* The export of native-grown cotton-seed-oil from Shanghai to Chinese ports in 1879 was 1309½ *piculs*.

The yield of oil varies with the season and the locality in which the seed is produced. In the United States, it is reckoned that for each 1 lb. of ginned cotton there are 3 lb. of seed, or a total approaching 4000 million lb., half of which only is required for sowing. One authority estimates that 100 lb. of seed give 2 gal. of oil, 48 lb. of oil-cake, and 6 lb. refuse fit for soap-making; another says that 1 ton of American seed gives 20 gal. of oil; a third, that the oil product is 37 per cent. of the weight of the kernels; a fourth, that 2 gal. of oil and 96 lb. of cake are afforded by 1 cwt. of seed; a fifth, that 1 ton of cotton material yields at the rate of some 35 gal. of oil. The crude oil is often dark and turbid; when refined, it assumes a dark sherry-colour, has a pleasant, sweetish flavour; sp. gr., 0·925—0·9306; congealing-point, 1° (34° F.); and is largely used in adulterating other oils, as linseed-oil, sperm-oil, and lard-oil, for painting, burning in lamps, and lubricating. It is extensively mixed with olive-oil, and often replaces it altogether; as a preventive measure, the Italian Government has levied a heavy duty on its importation. Large quantities of it are consumed by soap-makers, in combination with other oils and fats. For lubricating purposes, some manufacturers prepare a "winter oil" from it, which does not thicken in cold weather, by precipitating and removing the stearine; but its gumminess must limit its application. Its value in New York is about 18–20*d.* a gal. The cake remaining after the expression of the oil is invaluable as a cattle-food and as a fertilizer, and is an important article of commerce. In 1880, Galveston (U.S.) exported 309,841 lb., of cotton-seed, value 459*l.*; and New Orleans, 255 sacks of cotton-seed, and 8137 barrels of the oil, besides 3480 barrels of "soap-stock."

Coumu-oil.—Three or more species of *Œnocarpus* which are common on the Amazon, notably the *patawa* (*Œ. Batawa*), the *bacaba* (*Œ. Bacaba*), and *Œ. disticha*, bear oleaginous nuts, whence the Indians extract clear, fluid, greenish-yellow oils, which, when purified, are inodorous, of sweet flavour, excellent for cooking and lighting purposes, and used in Pará for adulterating olive-oil. The second-named is said to make good soap.

Crab-, Carap-, or Andiroba-oil (FR., *Huile de Carapa*; GER., *Carapafett*).—The nuts of *Carapa guianensis* [*Xylocarpus Carapa, Persoonia guareoides*] afford a fatty oil. The tree grows numerously in the forests of Guiana, where it is called *carapa* and *andiroba*; it is found more or less commonly throughout tropical America and the W. Indies. It is remarkably abundant in Brazil, and any quantity of the oil can be obtained at Pará and Manaos. The nuts are so plentiful in the district of Cachipour, in French Guiana, as to cover the ground for more than a foot in depth over an area of several miles. There is a dual harvest—in June–July, and again in October. The oil is extracted from them in the following manner:—The seeds are boiled without being shelled, and exposed to the air for 8–10 days, to allow the oil to develop itself; they are then removed from the shells, and ground into a paste, which is placed in vessels exposed to the sun, taking care to set them on an incline, so that the exuding oil may run off. This first-run oil, ordinarily quite fluid, is put aside for domestic applications. The residue, on being pressed, yields another product, having the consistence of grease; this is less esteemed, and is used only for lighting and similar purposes. The excessive bitterness of the oil repels all insects, and it is therefore used for anointing, and for preserving wood. For the former application, it is extracted by peeling the seeds and exposing them to the sun on long strips of bark, inclined so that the oil may escape into receptacles; this is then mixed with annatto, and takes the name of *touloumaca*. For application to timber, the oil is mixed with pigments or tar. The yield of oil from the seeds amounts to 70 per cent. of their weight. The oil acquires a solid consistence in Europe. It contains a large proportion of stearine, associated with oleine and margarine. It makes an excellent soap, and is said to be a valuable lubricant, protecting iron and steel from rust in a remarkable degree. It received a prize medal at the Exhibition of 1851. Similar products are Mote-grease, and an oil obtained from *Carapa moluccensis* (see pp. 1395–6).

Croton-oil (FR., *Huile de Croton, de Graines de Tilly, de Graines des Moluques, de petits Pignons d'Inde*).—The valuable medicinal agent known as croton-oil is obtained from the seeds of *Croton Tiglium* [*Tiglium officinale*], and what are probably equally useful oils are afforded by several other species, noticed below. *C. Tiglium* is a small tree (15–20 ft. high), indigenous to the Malabar Coast and Tavoy, and found cultivated in gardens in Bengal, S. India, Ceylon, Burma, the Indian Archipelago, the Moluccas, and even in Mauritius. The fruits contain 3 seeds, measuring ¾ in. long and ⅗ in. broad, whose kernels afford 50–60 per cent. of fatty oil. This is extracted by grinding the kernels, and pressing the meal in bags between iron plates; the oil is allowed to stand for 15 days before being filtered. The solid residue from the expression is saturated with twice its weight of alcohol, and heated on a sand-bath at 49°–60° (120°–140° F.); the mixture is pressed again, the alcohol is distilled off, and the oil is filtered after standing for a fortnight. The product obtained by this process from 2 lb. of seed is 6 fl. oz. of oil by the first expression, and 5 fl. oz. by the second. Occasionally the seeds are roasted before being pressed. The oil is orange-yellow or sherry-coloured, of the consistence of nut-oil, with a slight odour resembling that of jalap-resin, and an acrid flavour. It is powerfully cathartic. Its sp. gr. is 0·942. It becomes turbid at a moderate degree of cold, and, exposed to the air, slowly changes to a thick viscous mass. It dissolves in 23 parts of alcohol of sp. gr. 0·848, but its solubility in this medium seems to vary according to the age of the oil and the freshness of the seeds yielding it, and increases as it becomes more oxidized. The oil consists largely of stearic, palmitic, and other fatty acids combined with glyceryl as fats, but contains other bodies which are the origin of the peculiar properties that render the oil serviceable in medicine (see Drugs, p. 809). The oil prepared in India is largely adulterated with castor-oil and the oil of the physic-nut. The seed is therefore imported, in cases, bales, or robbins, chiefly from Cochin and Bombay, and the oil is expressed in this country by one firm only, it is believed. Precautions are necessary in handling the seed and extracting the oil, on account of the powerful ill effects manifested upon the workmen. Medicinal oils having precisely similar applications among native practitioners, but which have not yet been scientifically investigated, are yielded by the seeds of *C. oblongifolium* in Bengal, *C. Pavanum* in Assam and Burma, especially Camrup and Ava, and *C. polyandrum* [*Baliospermum montanum, polyandrum, indicum*; *Jatropha montana*] in S.-W. India, Bengal, Nepal, Sikkim, and Burma.

Dika-fat.—The seeds of *Irvingia Barteri*, the *dika* of W. Africa, afford 60 per cent. of a solid fat resembling cacao-butter, fusing at 30°–33° (86°–91½° F.), containing myristine and laurine, and capable of making very fine soaps. Much of the dika-fat imported into this country is almost as hard as stearine, with a reddish colour from suspended impurities, and a fatty acid melting at above 49° (120° F.); its soap is very hard.

Dilo-, Domba-, Pinnay-, Poon-seed-, or Tamanu-oil.—This oil of many names is the produce of *Calophyllum inophyllum* [*bintagor*], a large and very handsome forest-tree, of wide distribution in the E. tropics. It is found in the western peninsula of India, from Concan and Orissa southwards; in Ceylon; in the eastern peninsula, from Pegu southwards; in the Andaman Islands; in Java and the Malay Archipelago; and in most of the island groups of the S. Pacific, as the Fiji, Society, Marquesas, Cook's, and New Caledonia Islands. The tree prefers a moist sandy soil, thrives best within the range of sea-breezes, and is even not averse to land impregnated with salt water. Commencing almost on the sea-beaches, it follows the streams up the valleys, spreading where the ground is suitable; but inland it is of rare occurrence, and probably will not grow beyond a certain distance from the sea. It propagates itself with great readiness, the seeds germinating where they fall in the shade of the parent tree; they may be transplanted when 9–10 in. high without risk, needing an occasional watering, and protection from cattle, till 5–6 ft. high. Commonly the seeds are sown in the place which the trees are intended to occupy, without any transplanting. The trees are fruitful at the 5th year, and yield 2–3 harvests of oil-seeds annually, according to the locality. In Bengal, Orissa, Madras, Travancore, and S. India generally, there are usually 2 crops yearly, in August-September and February–March, though the tree is in flower and fruit during the greater part of the year. When three gatherings are made, they take place in June–July, November–December, and February–March. In Tanjore, 437 acres are occupied by this culture, the produce being an average of 24⅝ *cullums* of seed per acre, yielding 2670 *maunds* of oil. A nursery of young plants has been started in British Burma, and promises to be a complete success as an industrial enterprise. In the Andamans, the tree attains an enormous size. In Java, it is largely cultivated for its shade and fragrant flowers, and is called *njamplong* and *bientangoor*. Formerly, it was exceedingly abundant in Tahiti, and is still to be found there in great numbers in some districts, though the natives have cut down very many for the sake of the timber, which is highly esteemed for some purposes (see Timber—*Calophyllum*).

The fresh seeds when shelled afford a large quantity of oil, amounting even to 60 per cent. by weight. In India, this is extracted in the following manner. The mature seeds are gathered, and beaten with a small wooden hammer or similar instrument, to separate the shell from the kernel; the latter is then cut into slices, sun-dried, and triturated in the common country mill. The result is a yield of about 33 per cent. of a dirty, dark-green, disagreeably odorous oil, the thickness and depth of colour augmenting with the age of the seed. No method of refining is attempted. The cake is used as fuel, and sometimes for illuminating, but is not consumed as cattle-food, nor applied as a manure. It is said that, in the Calcutta market, this oil cannot compete with castor-oil for industrial purposes in its present crude condition, though in Burma it fetches about 4 times the Calcutta price of castor-oil. Doubtless it might be very much improved by extracting it by means of simple hydraulic pressure, instead of subjecting it to the friction of the mill. In the Society Islands, the kernels are exposed to the sun for about two months, reduced to powder, and pressed in linen sacks. When the oil ceases to run, the cakes are broken up, exposed to a gentle heat to coagulate the albumen, and again put under the press. Thus a second flow of oil is induced. The first exudation would be much facilitated by warming the powder, but the product then becomes much more quickly rancid. The usual results of the operation are stated thus:— 100 lb. of entire nuts give 39 lb. of kernels; 100 lb. of kernels give 41 lb. of oil by the first expression, and an additional 40 lb. by the second, or a total of 81 per cent. In Fiji, the mature fruits are allowed to fall to the ground, and lie until the fleshy covering has rotted. The remaining kernels in their shells are baked on hot stones; the shells are then broken, and the kernels are ground to powder. The macerated mass is then placed in an exceedingly rough kind of filter-press, made of the fibre of one or more species of *Hibiscus* (see Fibrous Substances, pp. 961–2), and thus a portion of the oil is extracted. The pressure is quite inefficient, and much of the oil is thereby wasted. It will be noticed that preliminary heating of some sort is common to all the processes, probably indicating that the oil does not exist ready formed in the kernels, but is developed by heat.

The oil varies in colour from greenish-yellow to deep-green, possesses a peculiar disagreeable flavour, and an odour which is described as fragrant by some but unpleasant by others. These qualities are all ascribed to the resin which it holds in solution. The oil may be separated from this resin by treatment with alcohol, the resin being dissolved by this agent, while the oil remains insoluble. The latter is also insoluble in ether and chloroform. Treating with 2 per cent. of sulphuric acid, and subsequently washing with hot water, is perhaps a simpler and cheaper method of purifying the oil. The sp. gr. of the oil is 0·9347. Its congealing-point and boiling-point are not known; it is liquid at ordinary temperatures, begins to thicken when cooled below 10° (50° F.), but is said not to be solid at −4° (25° F.). Locally, the oil has a great reputation as a remedial agent in rheumatism and similar affections; it is also employed for ointments, and largely as an illuminator, but not for culinary purposes. As regards its future utility, experiments show that, when freed from the resin, it makes an excellent, coloured, aromatic soap; it mixes readily with pigments, and, applied as paint, whether previously boiled or not, dries completely within 12 hours. Formerly there was a considerable export of the oil from Madras, the shipments in 1847–8 having been 3871 gal. of the oil and 508 cwt. of the seed, to Ceylon and the Straits.

The tree further affords a resin (see Resinous Substances—Tamanu).

The seeds of the Indian species *C. Walkeri* [*decipiens*] of S. India and Ceylon, and *C. Wightianum* [*spurium, decipiens*] of the mountains on the W. coast of the W. Peninsula, yield oils differing but little from that obtained from *C. inophyllum*, and are probably the sources of the oil erroneously referred to *C. Calaba*, which is not an E. Indian tree. Other species afford Calaba- and Keenatel-oils (see pp. 1379, 1392), the former in the W. Indies, the latter in Ceylon.

Dogwood-oil.—The berries of the dogwood (*Cornus sanguinea*), in Italy, Siberia, and Cashmere, are utilised for their oil. It is extracted by crushing the entire berries, boiling them, and skimming off the oil as it rises: the albumen is then removed by boiling the crude oil in water strongly acidulated with sulphuric acid. Properly prepared, it is edible, and said to be so applied in Italy; more usually it is applied as a lamp-oil; it also makes good soap. In Germany, an illuminating-oil is obtained from another so-called "dogwood-" or skewerwood-tree (*Euonymus europæus*).

Gamboge-butter.—The seeds of the *Garcinia pictoria* (see Pigments—Gamboge), a good-sized tree, common in the forests of Coorg and W. India generally up to 3500 ft., afford a yellow-coloured semi-solid fat, which is used by the better natives as a lamp-oil, and by the poorer as a substitute for *ghee*. It is extracted by pounding the seed in a mortar, and boiling the paste until the oil rises to the surface.

Gingelly-, Sesame-, Til-, or Benné-oil (Fr., *Huile de Sésame*; Ger., *Sesamöl*).—Gingelly-oil, whose name is variously spelt, is obtained from the seeds of *Sesamum indicum* [*orientale*], an annual plant 2–4 ft. high, indigenous to India, but long since propagated by cultivation in almost all tropical and sub-tropical countries, and now found nowhere in the wild state. There appears to be only one true species, but Indian cultivators distinguish two varieties—a white-seeded, called *suffed-til*; and a black-seeded, called *kala-til*. The two kinds are by them never sown together, but each is grown as a mixed crop with other plants. The white-seeded, commonly called "second sort," is sown in June, and ripens in August; the black-seeded, or "first sort," which is much the more common, is sown in March, and ripens in May. The mode of cultivation usually adopted is sufficiently simple. Ploughing is commenced towards the end of February, and is completed before the middle of March. If no rain has fallen some time previously, the field is irrigated; it is then ploughed three times, the seed being sown broadcast immediately before the 3rd ploughing, by which it is covered. Sometimes manuring and weeding receive attention, and occasionally a second irrigation is given. The soil preferred is red loam, but sand is also suitable. The crop is generally considered exhausting. It is commonly reckoned that an acre requires $\frac{1}{16}$ bush. of seed, and yields $1\frac{1}{2}$–2 bush., occupying the land for about 3–4 months. When ripe, it is cut down, and stacked for 7 days; it is then sun-dried for 3 days, being collected into a heap at night, and kept in heap on alternate days between the sun-drying. This causes the bursting of the pods and the liberation of the seed. The latter is subjected to frequent washings in cold water, and subsequent exposure to the sun, with the object of bleaching it, and the oil is extracted by pressure. In India, the common yield is 2 qt. of oil from 9 lb. of seed; it may be said to range between 45 and 50 per cent. by the commercial processes in vogue, though it is present to the extent of 56 per cent. and upwards.

In Europe, the plant does not succeed well so far north as S. France; it is grown on a very small scale in N. Italy (near Bologna and Lucca), Sicily, Malta and Gozo, and to some extent in portions of Greece and Turkey; Gallipoli exported 945 quarters, value 4080*l.*, in 1871; and the two Greek provinces of Calamata and Messenia produced 68,000 lb., 535*l.*, in 1880. In most parts of Asia, it is a familiar crop. The Turkish dominions produce very large quantities of the seed, as may be judged from the fact that, in 1878, the port of Adana shipped 9,736,787 *kilo.*, value 92,795*l.*; Aleppo, 1227 tons, value 22,086*l.*, to France, 108 tons, 1944*l.*, to Turkey, 59 tons, 1062*l.*, to Italy, and 4 tons, 72*l.*, to Egypt, total, 1398 tons, 25,164*l.*; Bagdad, 1380 cwt., 843*l.*, to Europe; and in 1879, Jaffa exported 13,750 tons, value 24,444*l.*, to Europe. The Jaffa produce goes almost entirely to Marseilles, where it is highly esteemed as affording the finest culinary oil. The Persian exports in 1879 were 10,500 *rupees'* worth of seed from Bushire, and 6500 *rupees'* worth of oil from Lingah. There are few districts in India that do not cultivate the plant; but the culture might be immeasurably extended, and the seed (or oil) be remuneratively exported to Europe. The Madras presidency is said to have 870,000 acres under this crop, chiefly in the Godavery district. The white seeds produced in Sind are said to yield the finest Indian oil. The exports of seed from India were 1,039,687 cwt. in 1879. Ceylon grows large quantities of gingelly-seed. Eastwards and northwards, the culture extends throughout the Corea, Siam, China, Formosa, and Japan. Bangkok exported 50,000 cwt. in 1868, and 77,000 cwt., 183,009*l.*, in 1870; the exports in 1875 from Siam were 13,193 *piculs* (of $133\frac{1}{3}$ lb.), value 21,003*l.* Formosa exported 46,000 *piculs* of seed in 1869, but only 3700 cwt. in 1871. Kiungchow exported 12,295 *piculs*, value 12,832*l.*, in 1877, $13,011\frac{1}{4}$ *piculs*, 13,979*l.*, in 1878, and $21,864\frac{1}{3}$ *piculs*, 23,127*l.*, in 1879. Chefoo exported 329,745 lb., value 1368*l.*, of gingelly- and mustard-seeds in 1878. The total exports and re-exports from Hankow in 1878 were $352\frac{1}{2}$ *piculs* of seed, and $320\frac{1}{2}$ *piculs* of oil; the exports of oil alone in 1879 were 201 *piculs*, value 333*l.* Much oil is produced in the district of Ichang. Shanghae, in 1879, imported $7094\frac{1}{2}$ *piculs* of native gingelly-seed, $1375\frac{1}{4}$ being for local consumption; the exports were $382\frac{1}{4}$ *piculs* to foreign countries, 150 to Hong Kong, and $1645\frac{1}{2}$ to Chinese ports. Taiwan exported $1963\frac{1}{2}$ *piculs* of seed in foreign bottoms in 1879. Among African countries, Egypt stands first, affording the chief supplies for the European markets, especially Marseilles, where the expression of the oil is extensively carried on. From Egypt, the culture has spread to Morocco; from Tangier, 92 cwt. of the seed, value 115*l.*, were shipped to Great Britain in 1878. In E. Africa, the plant grows everywhere on the coast, and extends far into the interior, Mozambique and Zanzibar furnishing considerable quantities of the seed. The mode of extraction practised here is to pound the dry seed in a mortar, adding a little hot water when the oil begins to appear, and then squeezing the mass with huge pestles; the supernatant oil is ladled out as it exudes. On the W. coast of Africa, gingelly-culture is becoming popular. Senegal exported 600 cwt. of the seed in 1870. Lagos (where it is called "beni-seed") shipped 729 tons in the same year; but since that date, there is a remarkable falling off—46 tons in 1875, 284 in 1877, and 43 in 1878. All over Angola it should become an important product, as the plant will grow near the coast, in soil too arid for the ground-nut. On the American continent, the plant ranges from the United States, through Central America, into British Guiana, and other portions of S. America, besides being grown in the W. Indies. In the United States, it flourishes in poor, dry, sandy soils, scarcely fit for any other crop, and receives no manure. The seed is sown in drills, 3–4 ft. apart; the plants are thinned to 12 in. or more in the drill, and kept clear of weeds. Sowing takes place as soon as the frosts are over; in the Gulf States, it lasts from 1st April till June. In the autumn, the leaves fall off before the pods expand, and are left to manure the land. The stems are then cut, bound in sheaves, and stacked in the field to dry for a few days, taking no harm from rain. When the pods are quite dry, they are simply shaken over a large sheet spread on the ground. The yield of seed is estimated at 20 bush. to the acre, but much is probably wasted. In Georgia, the return of oil is found to be $9\frac{1}{2}$ gal. from 3 bush. of seed.

In France, where this oil is very largely prepared, it is usual to subject the Levant seed, which is considered the best, to three processes of expression. After the first simple expression, affording superfine (*surfine*) oil, the cakes are softened with cold water, and again pressed (*pression à froid* or *froissage*), and finally they are treated with steam and hot water for a third pressing (*pression a chaud* or *rabat*). The average product from 100 lb. of seed is 30 lb. of oil by the 1st pressure, 10 lb. by the 2nd, and 10 lb. by the 3rd. Calcutta seed gives only 47 lb.: 36 lb. by the *pression à froid*, and 11 lb. by the *pression à chaud*. Bombay seed affords also 37 lb.: 25 lb. superfine, 11 lb. by the *pression à froid*, and 11 lb. by the *pression à chaud*. This last is contrary to the experience of Dantzig seed-crushers, as mentioned previously. The commercial oil has a sp. gr. of 0·923 at 15° (59° F.), and some extracted by ether, 0·919 at 23° (73½° F.). This latter solidified at 5° (41° F.), becoming turbid at several degrees above this point; yet the congealing-point of the ordinary oil is placed at 0° (32° F.) by Prof. A. B. Prescott, and at −5° (23° F.) by Dr. Pohl. It commences visible ebullition at 100° (212° F.). At ordinary temperatures, it is more fluid than ground-nut-oil, and is less liable to change under the influence of the air; indeed, when well prepared, it is said to keep for years without manifesting any rancidity. The oil is essentially composed of oleine, which is sometimes present to the extent of 76 per cent., but it is not invariable in commercial samples. Among the other fatty acids, are stearic, palmitic, and myristic. The oil is frequently adulterated with ground-nut-oil. It is said that 10 per cent. of gingelly-oil in admixture with other oils may be detected by shaking 1 grm. of the oil with 1 grm. of a mixture of sulphuric and nitric acids previously cooled, when a fine green colour is produced which no other oil exhibits. The local uses of gingelly-oil are for cooking, medicine, anointing the body and hair, absorbing the fugitive odours of plants, and illumination. In Europe, the superfine quality largely replaces olive-oil for domestic purposes, and the other grades are employed by soap-makers.

Gold-of-Pleasure-oil (Fr., *Huile de Cameline*).—The plant known in England as "gold of pleasure" (*Camelina sativa* [*Myagrum sativum*]) is cultivated to a considerable extent on the Continent, for the sake of its oleaginous seeds. It thrives on light, shallow, dry soils, and the crop scarcely fails on land of the poorest description. It is very hardy, enduring both drought and wet; and, grown as a rotation crop, is said to allow the ground to recover itself, doing well after corn-crops. In S. Europe, it matures so rapidly that two crops are taken off in a season; in the colder portions of the Continent, as N. France, Germany, Holland, and Belgium, though not giving a double harvest, it may be sown in June–July, when other crops have failed, or, if sown early, can be removed in time for root-crops and grasses. The spring sowing usually takes place in March–April; the autumn, in August. The quantity of seed required is about 14 lb. an acre; it is sown either broadcast, or in shallow drills 10–12 in. apart. It is ready for the sickle about 3 months after appearing above ground; the seed is ripe when the pods change from a green to a golden colour, and care must be taken to cut the crop before the seed is too ripe, or much will be lost. The stems when reaped are bound in sheaves, stacked, and threshed like other grain. Over 30 bush. of seed, yielding 540 lb. of oil, have been obtained from an acre. The oil is extracted by pressure, much in the same manner as other seed-oils. It has a clear golden-yellow colour, and peculiar, mild odour and flavour; its sp. gr. is 0·925 at 15° (59° F.); it congeals at −19° (−2° F.), forms a soft soap, and dries rapidly in the air. When fresh, it burns well, without smoke. It is much used in the localities of production as a lamp-oil; also for dressing woollen goods, making soft-soap, and in painting. The chaff from the seeds is eaten by horses, but the oil-cake is too acrid for cattle-food when used alone. The stems yield a fibre (see p. 934).

Grape-stone-oil (Fr., *Huile de Pepins de Raisins*).—The "stones" or seeds of the common grape (*Vitis vinifera*), elsewhere described (see Beverages, p. 432; Fruit, p. 1027), have been utilized for their oil in Europe for more than a century. In S. France, it is computed that an average of 1 lb. of seeds is furnished by the grapes converted into 1 gal. of wine, so that the production is considerable as a whole. The seeds of black grapes contain much more oil than those of white ones; and those obtained from vines in full vigour are more oleaginous than those gathered at other periods. Generally speaking, the seeds of black grapes give 15–18 per cent. of oil; of white ones, 10–14 per cent. In France, the vines of Roussillon, Aude, and Hérault afford the most oil. It is probable that American, especially Californian, vines may yield more oil than French vines. The preparation of the oil from grape-seeds is largely carried on in S. France, and in those parts of Italy where vine-culture is common, and olive-culture is rare, notably Lombardy.

The seeds chosen for the purpose are separated as promptly as possible from the refuse resulting from the distillation of brandy (see p. 201) or the manufacture of verdigris (see p. 30); they are rendered perfectly clean, and most completely dried in the sun and air, and are then ground to a fine flour in ordinary mills, the fineness of the grinding having a direct influence on the yield of oil. Some manufacturers first subject the flour to a cold expression, and extract about 5 per cent. of oil, afterwards repeating the pressure with heat, and obtaining an additional 10–15 per cent. A more detailed operation sometimes adopted is as follows. The flour is moistened with a little water as fast as it emerges from the mill, and is then thrown into open boilers; a hole is made in the middle of the flour by the hand, reaching to the bottom of the vessel, and into this some water is poured; a slow fire is then kindled under the boiler, and the contents are unceasingly stirred, to thoroughly incorporate the water with the flour; the fire is withdrawn as soon as the heat is greater than can be borne by the hand inserted in the mass, and the latter is placed in bags and immediately pressed.

The oil has a clear yellow colour when fresh, becoming brownish-yellow with age; it is inodorous, and of faint flavour. Its sp. gr. when new is 0·918; in a short time, it increases to 0·920 at 15° (59° F.). It solidifies at −13°– −16° (9°–3½° F.); becomes viscid and rancid when exposed to the air; and saponifies readily, but gives a soap lacking hardness and density. It is said to contain chiefly erucic acid, with some stearic and palmitic acids, combined as glycerides. The fresh oil is used in Italy for culinary purposes, being considered superior to nut-oil, and but little inferior to olive-oil. It is valuable for illuminating, emitting a bright light quite free from smoke. It has been recommended as a lubricator, on account of its low congealing-point, but its drying properties preclude its use in this direction.

Ground-nut- or Arachis-oil (Fr., *Huile d' Arachide, de Pistache de Terre*; Ger., *Erdnussöl*).—The ground-nut (see p. 1357) is very widely cultivated for the sake of its oily seeds. In Java, the oil is extracted by drying the seeds in the sun, and then subjecting them to pressure. In European mills, the nuts are first cleaned, then decorticated, and winnowed, by which the kernels are left perfectly clean. These are crushed like any other oil-seed, and put into bags, which are introduced into cold presses; the expressed oil is refined by passing through filter-bags. The residual cake is ground very fine, and pressed under 3 tons to the inch, in the presence of steam-heat; this affords a second quantity of oil, inferior in quality to the cold-pressed. The usual product is 1 gal. of oil from 1 bush. of nuts by the cold process, besides the extra yield by the hot-pressing. In France, where the oil is most largely prepared, 3 expressions are adopted, as with some sorts of gingelly: the first gives about 18 per cent. of superfine oil, fit for alimentary purposes; the second, after moistening with cold water, affords 6 per cent. of a fine oil, suitable for lighting and for woollen-dressing; the third, after treating with hot water, yields 6 per cent. of *rabat*, or oil applicable only to soap-making. In India, the total mean yield is 37 per cent. at Pondicherry, and 43 in Madras. The cold-pressed oil is almost colourless, of agreeable faint odour, and bland olive-like flavour. The best has a sp. gr. of about 0·918, or 0·9163 at 15° (59° F.); it becomes turbid at 3° (37½° F.), concretes at −3°– −4° (26½°–25° F.), and hardens at −7° (19½° F.). By exposure, it changes very slowly, but thickens with time, and assumes a rancid odour and flavour. As an illuminating-oil, it has feeble power, and its chief industrial uses are for soap-making and lubricating, particularly the former. Locally, it is employed for cooking and burning, and as a general substitute for olive-oil. Indeed, very large quantities are readily passed off as olive-oil in European markets. As a rule, the seeds are exported in a raw state to such centres as London, Marseilles, Bordeaux, Nantes, Dunkirk, Hamburg, and Berlin, where they are crushed, and the oil passes into general commerce without maintaining its identity. Thus statistics concerning it are meagre. Pondicherry exported 99,330 *veltes* (of 1·64 gal.) of the oil in 1860; but the most extensive foreign trade in the oil takes place with China. Thus Shanghai, in 1879, imported 1601½ *piculs* (of 133⅓ lb.) from Chinese ports, and exported 8167⅗ *piculs* to Chinese ports, and 840½ to foreign countries; in 1878, the exports to foreign countries were 786 *piculs*. The lowest estimate of the annual export from Pakhoi is 90,000 *piculs*. Hankow, in 1879, imported 651 *piculs*, value 1497*l*., of native oil. The nuts from the Galam district (W. Africa) are most esteemed for their yield of oil and the thinness of their shells.

Hazel-nut-oil (Fr., *Huile de Noisettes*).—The hazel-nut (see p. 1358) affords about 60 per cent. of oil, which, in some parts of continental Europe, is extracted by pressure, in the same manner as almond-oil. It is limpid, clear-yellow in colour, and of sweet and agreeable flavour; it congeals at −19° (−2° F.) [some say at −10° (14° F.)]; has a sp. gr. of 0·924 at 15° (59° F.); and soon becomes rancid. Its chief application is for perfumery. Other wild species in India and elsewhere probably yield similar oils.

Hempseed-oil (Fr., *Huile de Chanvre, de Chènevis*; Ger., *Hanföl*).—The seeds of the hemp-plant, so well known as a fibre-producer (see Fibrous Substances, p. 934), are valued for their oil. It is from Russia and Lorraine that the seed for expressing mostly comes. When the fibrous stems are tied in bundles, the seed is rudely threshed out, and spread in thin layers under cover to dry. The extraction of the oil is performed in the same manner as with other seed-oils, described in a separate section of this article (see p. 1451). The proportion of oil contained in the seed is about 34 per cent. on an average; the yield varies from 25 to 30 per cent. The oil is at first greenish- or brownish-yellow, deepening with exposure to the air; the flavour is disagreeable, and the odour is mild. It has a sp. gr. of 0·9252 at 15° (59° F.); it thickens at −15° (5° F.), and solidifies at −25°– −27½° (−13°– −18° F.); it dissolves in 30 parts of cold alcohol and any proportion of boiling; it saponifies with difficulty, forming a soft soap, but less soft than that from linseed-oil. It is locally consumed largely for lighting, but its most important application is for making soft-soaps. The exports of hempseed from Riga were 21,011 quarters in 1875, and 78,690 in 1878; and in 1879, 725,809 *poods* (of 36 lb.) of the seed, and 573 of the oil. In 1872 (the date of the latest return), Russia had 812,630 acres under hemp, which yielded 14,410,000 bush. of seed. In France, 238,100 acres under hemp in 1874 produced 1,263,424 bush. of seed.

Hickory-nut-oil.—From the seeds of several species of *Carya* (see Nuts, p. 1358), excellent oil for illuminating and lubricating purposes has been extracted in Ohio. It continues fluid at very low temperatures, and is used for delicate machinery, and even for watches, when refined. The pig-nut (*C. glabra*) is preferred, on account of its thin shell and greater yield of oil, which is bitter. The oils from the "shell-bark" and the large sweet hickory-nut are very palatable, and might come into table use.

Horse-chestnut-oil (Fr., *Huile de Marron d'Inde, de Fécule*).—The whole fruit of the horse-chestnut (see Nuts pp. 1352–3) contains two fixed oils, one in the case, which is greenish-coloured, and a second in the kernel, of an orange-yellow tint. The proportion of oil in the kernel is very small. Chemists have detected by analysis a quantity varying from 3 to 5½ per cent., reckoned upon the green kernels; but the highest yield obtained in practice has been 1½ per cent., even when treating 2 cwt. at a time. Nevertheless some hundreds of cwt. of the oil have been made in France, chiefly by Emile Genevoix, a Parisian druggist. He employs the unpeeled kernels, and proceeds by destroying the starch present by boiling them with water acidulated with sulphuric acid, and collecting the oil which floats upon the surface. He remarks that the production of the oil is certain only when acting upon large quantities, that the water plays an important part in the operation, and that every precaution is necessary to prevent the oil being saponified during the process. The fresh oil seen in bulk is greenish-brown, with an empyreumatic odour, and a peculiar flavour; these qualities are intensified by age. It is remarkably slow to become rancid, and may be kept almost indefinitely. On the Continent, it has a great reputation as a cure for gout, rheumatism, and neuralgia.

Illipi-butter.—The almond-like fruit-kernels of *Bassia longifolia* afford a semi-solid fat. The tree flourishes in Malabar and on the Coromandel coast. The seeds contain about 30 per cent. of oil, 12½ lb. of them yielding about 2 gal. of oil by the ordinary rude native way of expressing. The oil will not keep for more than 2–3 weeks in the Indian hot season; it then becomes rancid, and emits a disagreeable odour. When well secured from contact with the air, it will keep for some months in cool weather. Its colour is usually bright-yellow, varying somewhat according to the care used in preparing it. It is eaten as a substitute for *ghee*, is burnt in lamps, and is employed in the manufacture of country soap, and for external medical application. The cakes left after the expression are used for washing the head, and form an article of trade. Fats from other species of *Bassia* are described under Mahwa-oil (p. 1394), Phulwara-oil (p. 1408), and Shea-butter (p. 1410).

Jupati-oil.—The fruit of the jupati-palm, *Raphia* [*Sagus*] *tædigera*, which is equally or more important as a fibre-plant (see Fibrous Substances, p. 994), affords a yellowish, bitter oil, by decoction and expression, used locally for soap-making.

Kanari- or Java-almond-oil.—The *kanari* or Java almond (*Canarium commune*) is indigenous in the Moluccas, where it affords shade to the nutmeg plantations, and is cultivated also in Java, throughout the Indian Archipelago, in Malabar, and on the Indian peninsula. It bears a nut resembling the almond in shape and flavour, but much exceeding it in size. The nut affords a very large proportion of oil by simple expression. This oil is prepared by the inhabitants of the Moluccas on an extensive scale, and is in general use among them for cooking when fresh, and for burning in lamps, superseding coco-nut-oil. In India, also, the oil is employed for all culinary purposes, and is considered purer and more palatable than coco-nut-oil. The nut is very generally eaten without being deprived of its oil. The trees of this genus also afford gums or resins (see Resinous Substances).

Katiow-oil.—This is extracted by the natives of Borneo from the seeds of a tree, chiefly produced on the Sadong, Linga, and Kallekka rivers, and exported to Sarawak and other places. It is yellow-coloured, and has an odour precisely resembling almond-oil; it is valued locally for cooking and for lamps, burning with a bright flame and pleasant aroma. It is very cheap and abundant, and might be valuable to soap-makers and perfumers.

Keenatel-oil.—The seeds of *Calophyllum tomentosum* yield a great quantity of oil in Ceylon, where it is used in lamps.

Kikuel-oil.—This name is sometimes applied in India to the fatty oil of some species of *Salvadora*. It is a solid fat, of a dull, sulphury-yellow colour.

Kukui- or Kekune-oil (Fr., *Huile de Noix de Bancoul.*)—An oil bearing a multitude of names is obtained from the candle-nut (see p. 1352). It is the most important product of the tree, and constitutes about ⅔ of the entire weight of the kernel of the nut. A great obstacle to its wider development is the difficulty encountered in extracting the kernels from the shells, both on account of the extreme hardness of the latter, and the obstinacy with which the two adhere. Boiling is out of the question, as the kernels are cooked long before the shells are affected; but there is every reason to suppose that a slight roasting would have the desired effect, inasmuch as this plan seems to be adopted successfully by the Samoans. The weight of the shells necessitates this treatment being performed on the spot, and, as the kernels quickly become rancid and dark-coloured after liberation, they must also be operated upon without removal. The local cheapness of labour is an additional argument in favour of preparing the oil at the places where the nut grows. The extraction of the oil is very simple. In Jamaica, Polynesia, and the E. Indies, 50 per cent. is obtained by boiling the kernels in water; by reducing the kernels to meal, heating in a water-bath, and placing the mass in bags under hydraulic pressure, the yield is about 60–66 per cent. The shells are themselves excellent fuel. The oil is completely clarified by mere filtration. As ordinarily prepared, it is amber-coloured, tasteless and odourless; slightly viscid at the temperature of the air in England, congealing at 0° (32° F.); its sp. gr. is 0·923; it is insoluble in alcohol, and saponifies readily, giving a very soft soda-soap. It is locally used in small quantities, while fresh, in cooking and medicine; but it is much more extensively employed as a lamp-oil, giving a brilliant light, without any objectionable odour. It dries less rapidly than linseed-oil, and is used for mixing paints and making oil-varnishes. It is said to corrode tin-plate and even platinum. Its commercial value is placed at the same figure as colza- and gingelly-oils. The cake is useless as cattle-food, on account of its purging qualities, but would make valuable manure. In 1843, 8600 gal. of the oil were shipped from Honolulu (Sandwich Islands), valued at 1*s.* 8*d.* a gal.; and in 1862, the exports from the group were 10,000 gal. yearly, destined for the ports on the W. coast of S. America.

Kurung- or Poondi-oil.—The seeds of *Pongamia glabra*, a tree widely diffused in S. India, Pegu, Malacca, the Indian Archipelago, S. China, Australia, and Fiji, are expressed for the sake of their oil in several of these countries. The oil is thick, reddish-brown in colour, and has a tendency to deposit stearine in cold weather. It is used alone or combined for burning in lamps, and is much esteemed medicinally.

Lallemantia iberica.—This is a well-known plant of Syria and Persia, where it is extensively cultivated; it attains a height of 1½–2½ ft., and single plants have afforded as many as 2500 seeds, which yield a very pure culinary oil. The plant has been acclimatized at Cherson, S. Russia, for industrial purposes.

Laurel-oil.—A so-called "laurel-oil" or "bay-oil" is obtained from the fruits of the bay-laurel (*Laurus nobilis*), chiefly in Holland, Spain, Italy, and Switzerland. The fruits are peeled, ground to paste, boiled, and expressed; the oil concretes on the surface of the expressed mass when cold; it is collected, and melted in a water-bath to remove the moisture. When the fruits have been kept for some time, they are better ground and hot-pressed. The oil is used in veterinary medicine, and is found to repel flies from meat and living animals. The plant also affords a volatile oil (see p. 1422).

Linseed-oil (Fr., *Huile de Lin*; Ger., *Leinöl*).—The flax-plant, so well known as yielding a textile fibre (see Fibrous Substances—*Linum usitatissimum*, p. 964), affords a valuable oil-seed. The separation of the seed from the stems of the plant has been described on p. 967. The supplies of linseed for crushing are furnished chiefly by Russia and India. It is found that, as a general rule, the colder the climate in which the seed is grown, the greater are the drying properties of the oil, but the worse is its colour. In India, preference is given to white seed, as yielding 2 per cent. more oil, affording it more freely, and giving a softer and sweeter cake, than the red seed; the latter, moreover, always comes to market largely mixed with rape-seed, which is very difficult of separation, and greatly depreciates the market value. Oil from unripe seed is watery. The seed should always be kept for 3–4 months in a dry place, as the oil furnished after this lapse of time is much more abundant than when the expression takes place immediately after the harvest. The seed is crushed and pressed in the manner described in a separate section (see p. 1451). The best and finest oil is that which is "cold-drawn;" it is paler, less odorous, and less flavoured, but the yield is only 21–22 per cent. of the seed. By the aid of a temperature not exceeding 93⅓° (200° F.), and powerful and long-continued pressure, as much as 28 per cent. of very good oil can be obtained. The cake forms a valuable cattle-food. The Italian variety is said to have a much more highly oleaginous seed than the Russian.

Some 70,000 metric quintals (of 2 cwt.) of this oil are produced annually in France, chiefly in the departments of Pas-de-Calais, Somme, Nord, Maine et Loire, Vendée, Haute-Marne, Haute-Garonne, and Lot-et-Garonne; 175,772 acres under flax in 1877 produced about 1 million bush. Belgium still continues to import linseed from Russia and India. Holland had 44,114 acres under flax in 1878, and produced 446,520 bush. of linseed. The German Empire exported 586,600 centners (of 110¼ lb.) of linseed- and palm-oils in 1879; the port of Memel shipped 236,460 cwt. of linseed, value 115,000*l.*, in 1879. Sweden, in 1878, had 33,655 acres under flax and hemp, and produced 197,091 cwt. of seed. Russia has a larger trade in linseed than any other country, the exports in 1878 having been 2,684,032 *chetverts* (of 5¾ bush.); Archangel shipped 67,885 quarters in 1877, and 25,761 in 1878; of the 36,801 *chetverts* in the latter year, 19,897 went to Great Britain, and 16,904 to Holland. Riga exported 225,810 quarters of crushing-linseed in 1877, and 90,330 in 1878; in 1879, Revel shipped 43,169 *chetverts* to Great Britain; Nicolaieff, 91,818 quarters, Taganrog and Rostov, 644,204 quarters, Mariopol, 29,770; Yeisk, 83,896, Genitchesk, 214. In 1872 (the date of the latest Return), Russia had 2,247,700 acres under flax, which yielded 17,292,000 bush. of linseed. The Roumanian Danube ports shipped 4429 quarters of linseed in 1879. Kastamuni, in Asia Minor, exported 160,000 *okes* (of 2·83 lb.) of linseed, value 1500*l.*, in 1879. The total Indian exports of linseed were 7,198,918 cwt. in 1878, but only 3,503,795 cwt. in 1879. Algiers, in 1879, produced 734,795 *kilo.* of Riga linseed, and 1,384,969 *kilo.* of Italian. New York shipped 14,187 gal. of linseed-oil in 1879, and Philadelphia, 503 gal.

Linseed-oil has a faint colour, and mild odour and flavour, when pure, but the commercial article is dark-yellow, with sharp repulsive flavour and odour. Its sp. gr. is 0·930; at −18° (0° F.), a little solid fat separates out; at −20° (−4° F.), it solidifies. By exposure to the air, after heating with oxide of lead, it rapidly dries up to a transparent varnish. The fresh oil saponifies readily, giving a yellow and very soft soap with soda; by saponification, it yields 95 per cent. of fatty acids, chiefly linoleic, with a little oleic, palmitic, and myristic acids. It dissolves in 1·6 parts of ether, and in 32 parts of alcohol at 0·820 sp. gr. The oil is very extensively used in the manufacture of paint, printing-ink, floorcloth, artificial indiarubber, oil-varnishes, and soft-soap. For artists' use, it is purified by shaking up with whiting, and warming. Linseed-oil is never met with in commerce really pure, nor even the seed itself. Previous to the Crimean War, it was a recognized custom at the Black Sea ports to add 1 measure of hemp or other seed to every 39 of linseed. Since then, the proportion has advanced to 1 in 19, in addition to which, the Indian seed is grown mostly as a mixed crop with mustard and colza; pure linseed-oil can only be obtained by picking out the seeds individually. The methods of refining this oil are described on p. 1460.

Mabo.—The seeds of a plant which is thought to be a *Parinarium* have been imported into England and Germany for the sake of their oil. They have intensely hard "stones," measuring about 2½ in. by 1¼ in., and are highly oleaginous, but it is a question whether the oil can be profitably extracted. They are brought from Liberia, and are closely allied to the *mola* plum of Zambesi land (*P. Mobola*), which is supposed to be identical with the *noxa* or *nocha* (?*niko*) of Lower Guinea.

Macassar-oil.—This oil was originally obtained from the unctuous fruit of *Stadmannia* [*Cupania*] *sideroxylon*, growing in the islands of Sunda and Timor, and usually known as *kesambi*-wood. See also Safflower-oil, p. 1410, and Ilang-ilang-oil, p. 1422.

Madia-oil.—The seeds of *Madia sativa* afford some 30–40 per cent. of fatty oil. The plant is a native of Chili, where it has long been cultivated for the sake of its oil. It has been successfully introduced into Asia Minor and Algeria; its culture has also been attempted in S. France and in Wurtemburg, but without the success that was anticipated, mainly owing to the irregularity with which the seed ripens in these climates. It requires a sandy soil, and is very easily grown. In Europe, sowing takes place in October. The seeds must be threshed out soon after the stems are cut, or the latter ferment and cause injury. The seed resembles sunflower, but is much smaller. The yield of oil from an acre of the plant is rather more than from colza (rape): 1 *hectare* (2½ acres) gives 726 *kilo.* (of 2·2 lb.) of seed; and 100 *kilo.* of seed yield 32 of oil. It is extracted by expression, both cold and hot. It is deep-yellow, thick, and mild; of sp. gr. 0·935 crude, and 0·9268 at 15° (59° F.) purified; solidifies at −10° to −17° (14°–2° F.), according to the method of extraction; dries slowly; and dissolves in 30 parts of cold alcohol or 6 of boiling. The finer qualities may replace olive-oil; the coarser are used for illuminating.

Mahwa-oil.—The *mahwa* or *mhowa* (*Bassia latifolia*) is chiefly known as yielding flowers which are an important article of diet, and from which an intoxicating beverage is distilled, but it also claims notice as affording an oil. The tree is cultivated in most parts of India, and is abundant in Central India, notably in the Concans, the Circars, Bengal, Guzerat, and Rajputana. It is extremely hardy, thriving well on poor stony ground, and readily propagating itself by its seed. Its culture is therefore capable of the widest extension. The flowers are succeeded by fruits, whose kernels or seeds give some 33 per cent. of oil. The latter is obtained by bruising, rubbing, and pressing the seeds. It is greenish-yellow in colour, and of an oily consistence, when newly expressed, but immediately assumes a concrete state, remaining thus until a temperature of 43½° (110° F.) is reached. Its sp. gr. is 0·972; it is soluble in ether, scarcely in boiling alcohol. In a cool climate, the oil keeps good for a long time; but in the plains of India, it acquires a bitter flavour and rancid odour after a few months' exposure to the air, separating into a heavy brown mass below, and a little clear fluid above. It saponifies easily, and the resulting soap is good as to quality and colour, and satisfactory as to quantity. The fatty acids are easily separable, by the simple process of "training" or "seeding," described on p. 1362. The proportion of stearic acid is about 40 per cent.; it is inodorous while translucent, and is admirably adapted for candle-making. The oleine separated is superior to that from tallow and palm-oil. For industrial purposes in this country, the oil has about the same value as coco-nut-oil; it has been imported into England and France from Calcutta for soap-making. Locally, it is extensively used by Bunniahs and Muhajuns for adulterating *ghee*; it is also employed in cooking and for burning. The residual cake forms food for man and cattle; and the timber of the tree is valued (see Timber). Oils from other species of *Bassia* are Illipi-butter (p. 1392), Phulwara-oil (p. 1408), and Shea-butter (p. 1410).

Mamey-oil.—About 40 per cent. of a fixed oil bearing this name is extracted by means of expression at a high temperature from the fruit-kernels of *Lucuma Bonplandii*, in Mexico. It is employed in the manufacture of soap and cosmetics, and for illuminating purposes.

Mangosteen-oil, Brindonia-tallow, or Kokum-butter (Fr., *Beurre de Cocum, Huile de Madool*).—The fruit-seeds of *Garcinia indica* afford a fatty oil of unusual purity. The tree is indigenous to the coast region of W. India, known as the Concan, lying between Goa and Daman. The oil is extracted by the natives of India in the following manner:—The seeds are sun-dried for several days, bruised, and boiled in water; the oil escapes and collects on the surface, and, on cooling, concretes into a solid cake. The yield is about 10 per cent. The crude product needs purification by melting in a steam bath, and filtering. Thus treated, it becomes perfectly transparent and light-straw coloured, consolidating at 27½° (81½° F.) into a crystalline mass, commencing to melt again at 42½° (108½° F.), and fusing entirely at 45° (113° F.). It is composed chiefly of stearic acid, with minor quantities of myristic and oleic acids, all in combination as glycerides. It saponifies readily, and produces a fine hard soap. It is soluble in ether, and slightly so in rectified spirit. When kept long, it acquires an unpleasant rancid odour, and a brownish colour. It occurs in the Indian bazars in the form of oblong lumps, measuring 4 in. by 2 in., and weighing about ¼ lb.; it is whitish, firm, dry, and friable, yet greasy to the touch. In India, it is largely used by the natives for adulterating *ghee*, and more recently by Europeans for pharmaceutical preparations. Its present abundance does not admit of its general application to soap-making or candle-making, but it is a superior article for such purposes.

Margosa- or Neem-oil.—The fruits of *Melia Azadirachta*, and probably several allied species, afford a useful oil. The trees or shrubs are found native throughout India, and are now widely diffused in tropical and sub-tropical regions. They are hardy, and grow in almost any soil. The fruits are produced abundantly, and drop when ripe. They are gathered, and treated either by expression or boiling. Some accounts state the oil to be derived from the pulp of the fruit; others say it is obtained from the seed, the kernels yielding 25 per cent. The oil is acrid-bitter, deep-yellow, and with a strong disagreeable flavour. During the winter months in India, it becomes solid, but partially regains fluidity in summer. It is largely used by native physicians, both internally and externally; it is frequently burnt in lamps, but emits an offensive smoke; and is applicable to soap-making.

Melon- and Pumpkin-oils.—The seeds of all the members of the melon, pumpkin, cucumber, and gourd family contain appreciable proportions of oil, but the only kinds which are utilized to any considerable extent are those of the sweet melon (*Cucumis Melo*) and the water-melon (*C. Citrullus*). Considerable quantities of melon-seed, under the local French name of *petit béraf*, are collected in various parts of W. Africa, notably Senegal and Abeokuta. The production in Senegal in 1860 was 62,226 *kilo.* of the seed, which was shipped to France. China grows very large quantities of melon-seed, and has an extensive commerce in it. Thus, in 1879, Chefoo exported 4207 *piculs* (of 133⅓ lb.); Hankow, 6642 *piculs*, value 6165*l.*; Kiungchow, 1722¾ *piculs*, value 1125*l.*; Newchwang, 16,191 *piculs*. The yield of oil is about 30 per cent. The oil is clear, bland, and limpid, and closely resembles olive-oil; it is consumed as food, burnt in lamps, and made into soap. It dries slowly, and solidifies at −15° (6° F.); its sp. gr. is about 0·923.

The *egusi* oil of Abeokuta, the *abobora* of Brazil, the *ogadioka* of the Gaboon, S.-E., and S.-W. Africa, the *chocho*, and several other oils of local application, belong to this numerous and wide-spread order, the *Cucurbitaceæ*.

Moodooga-oil.—An oil is obtained from the seeds of *Butea frondosa* (see Resinous Substances—Butea kino) in India, Java, &c.; it is afforded in small quantity, is bright, clear, and fluid, and used medicinally.

Mote-grease, Tallicoona-, Kundoo-, or Coondi-oil (Fr., *Huile de Touloucoona, Tallicoona*).—The nuts or seeds of *Carapa guineensis* [*Touloucoona*], which plant has recently been declared identical with *C. guianensis* (see Crab-oil, p. 1386), afford about 33 per cent. of a valuable fatty oil.

The tree is found growing abundantly in the Timneh country and near Sierra Leone, and occurs throughout Senegal and the Guinea Coast. The seeds (18–30 in one fruit) vary in size from a chestnut to a hen's egg. The oil is extracted from them by the natives of W. Africa in the following manner:—The seeds are sun-dried, and hung up in wicker racks or hurdles exposed to the smoke of the hut-fires. After sufficient exposure, they are roasted, and triturated in large wooden mortars till reduced to a pulp. The mass is then boiled, and the supernatant oil is skimmed off. It usually forms a concrete mass on cooling, resembling frozen olive-oil, but the best samples remain liquid at ordinary temperatures. It has a pale-yellow colour, and a strong bitter flavour; the latter is due to an alkaloid principle, which is easily destroyed by boiling in water acidulated with sulphuric acid, allowing to settle, and then washing with fresh water to remove all traces of the acid. The oil is entirely soluble in ether; alcohol separates it into (1) a concrete substance, which dissolves in the alcohol, and retains the odour and flavour, and (2) an oil fluid at ordinary temperatures, and nearly colourless and tasteless. By the Africans, the oil is used most largely for lighting purposes, but is also employed as a purgative and anthelmintic. Industrially, it is capable of the same applications as crab-oil (p. 1386), and is imported into Marseilles from Senegal for soap-making. The seed is also shipped to France.

M'Poga.—The kernels of the nuts of the *m'poga* (probably a species of *Parinarium*), a tall tree abundant in the Gaboon, afford some 80 per cent. of unusually fluid oil, but difficult of extraction, on account of the hardness of the nut.

Mustard-oil (Fr., *Huile de Moutarde*).—Three species of mustard are grown more especially for the well-known condiment which is prepared from the seeds; these are *Brassica* [*Sinapis*] *nigra*, *B. alba*, and *B. juncea*; for a description of their localities and modes of culture, the reader is referred to Spices—Mustard. The seeds of these species all yield fatty oils by expression. *B. nigra* affords about 23 per cent. (over 33 with ether) of a mild-flavoured, inodorous, non-drying oil, solidifying at −18° (0° F.), and consisting essentially of the glycerides of stearic, oleic, and erucic or brassic acids, the last-named being homologous with oleic acid. The fixed oil of *B. alba* amounts to 22 per cent. of the seed, and resembles generally that of *B. nigra*. The seeds of *B. juncea*, in Russia and India, afford by pressure 20 per cent. of oil, which is used like the best olive-oil, and for burning in lamps. These oils vary in sp. gr. from 0·9142 to 0·917, and are soluble in 4 parts of ether.

Other species of mustard, whose seeds are not prepared as a condiment, but which are utilized for their oleiferous properties, are as follows:—*B. arvenis*, the charlock, yields an excellent burning-oil, and it is to be regretted that this common and troublesome weed, so abundant in Europe, has not been turned to better account. A mustard-plant thrives so well in California as to smother the corn in the fields. The seed is gathered by the Chinese and brought into San Francisco, where the oil is expressed, and used as salad-oil. *B. cernua* is cultivated for its oil in Japan. *B. chinensis* is grown with the same object in immense quantities in China, notably in the Yangtze-kiang and Han-kiang river-valleys, in the provinces of Chekiang and Kiangsu, and to some extent also in the district of Ichang, province of Hoopih. It is in seed and ready for harvesting in the beginning of May. The seed is treated by a rude press, yielding a dark-yellow, pleasantly-odorous, thick oil, used for cooking, in lamps, and for anointing the hair.

An allied oil-plant is the colza or rape (see p. 1384).

Myrobalan- and Jungle-almond-oils.—Small quantities of fatty oil are expressed from the seeds of two Indian species of *Terminalia*, *T. Bellerica*, and *T. Chebula*, plants which are much more important on account of their astringent properties (see Tannin—Myrobalans). The oil of the first species readily separates into two portions, a pale-green fluid, and a white, floccular semi-solid. It is used locally for anointing and strengthening the hair. The oil of the second species is procurable only in very small proportion; it is a clear, transparent, almost colourless fluid, of medicinal use.

A third species of *Terminalia*, the jungle-almond of India (*T. Catappa*), is much more widely distributed, and of greater importance as an oil-yielder. It is fouud abundantly in both E. and W. Indies, and grows freely in Mauritius and Bourbon. The fruits (nuts) are gathered, and exposed to the sun for a few days, to facilitate their breaking, which is one of the main items in the cost of extracting the oil. The kernels are next freed from shell, crushed, and cold-pressed. The oil is similar to almond-oil in flavour, odour, and sp. gr., but is deeper coloured, and deposits stearine by keeping. It is, however, very slow to become rancid; and if carefully prepared and refined, it might well replace true almond-oil and hazel-nut-oil for most purposes.

Niger, Kersanee, or Ram-til Oil.—The "Niger seed" of African commerce, and the *ram-til* or *kersanee* of Indian cultivators, is the product of *Guizotia oleifera*. The plant grows wild on the Gold Coast of Africa, and is cultivated in Abyssinia, and in many parts of India, especially Mysore and the Deccan; here the seed is sown in July–August, after the first heavy rains, the fields being simply ploughed, and neither weeded nor manured. The crop is cut 3 months after the sowing, and, after being sun-dried for a few days, the seed is threshed out, the produce being about 2 bush. an acre. By the common country mills, only 25 per cent. of oil is got from the seed, but better appliances bring the average up to 35. The oil is limpid, clear, pale, and sweet-flavoured, and is used as an edible oil by the poorer classes of India, and commonly as a lamp-oil. Though much inferior to gingelly-oil, it is frequently used as a substitute for it, and to adulterate both this and castor-oil. The oil contains but little stearic or palmitic acid, hence soap made from it, though very white, is soft. The cake is an esteemed food for milch cows.

Nounga and Djave.—These two fatty substances are said to be produced by a species of *Bassia*, which has been called *B. gabonensis*, found on the Gaboon. The former has the consistence of butter; the latter is available only for soap-making. Their united yield is 56 per cent.

Nutmeg-butter or Mace-oil (Fr., *Beurre de Muscade*; Ger., *Muskatbutter*, *Muskatnussöl*).—The fixed or fatty oil obtained from the nutmeg (see Spices—Mace and Nutmeg), must not be confounded with the essential oil, which is described in another section (see p. 1424). The fixed oil or butter is extracted from refuse nuts, by powdering, heating in a water-bath, and pressing while still hot. The yield is about 28 per cent. The fat is a solid unctuous substance, with an orange-brown colour of varying intensity, and presenting a mottled appearance; it has a pleasant odour, and fatty, aromatic flavour; its sp. gr. is 1·010–1·018; it melts at 45° (113° F.); and dissolves perfectly in 2 parts of warm ether, or 4 of warm alcohol at 0·800 sp. gr. It contains a large proportion of myristine, among other glycerides, and about 6 per cent. of the essential oil before mentioned. We import the article chiefly from Singapore, in oblong blocks measuring about 10 in. by 2½ in. sq., wrapped in palm-leaves.

Ochoco.—The *ochoco* tree of Guinea (*Dryobalanops sp.*) yields 61 per cent. of an oil fusible at 70° (158° F.).

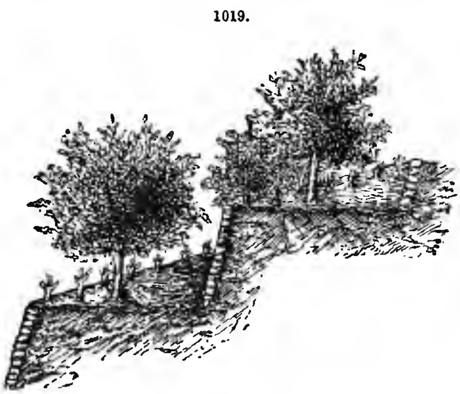
Odal- or Adul-oil.—From the seeds of *Sarcostigma Kleinii*, a native of S. India, a thick, semi-fluid oil is expressed; it is burnt in lamps, and has a high medicinal reputation.

Okro-oil.—The seeds of more than one species of *Hibiscus* (principally *H. esculentus*), plants which have more importance as fibre-yielders (see Fibrous Substances, pp. 961–2), afford clear, limpid oils, which are said to rival olive-oil for alimentary purposes, but are nowhere extracted on a commercial scale.

Olive-oil (Fr., *Huile d'Olives*; Ger., *Olivenöl, Baumöl, Provencer Oel*) **and Pyrene-oil.**—Of the common olive (*Olea europœa*), some 20–30 varieties are distinguished by different botanists as the result of prolonged cultivation. The most useful and esteemed of these are the following:—(1) *caillet* or *cayou*, preferred in the neighbourhoods of Grasse and Cannes, growing best in strong soils, needing air and sun to fructify its flowers, and not yielding all its oil until quite black; (2) *blanquette*, chiefly grown about Antibes, thriving best on dry ground, having little colour when ripe, and affording a sweeter, whiter and more delicate [but ill-keeping] oil than (1); (3) *roubeirou*, growing tall and with few branches, bearing a small fruit that gives little oil, but superior to all others; (4) *plant d'Entrecasteaux*, of rapid growth, adapted for almost all soils, but especially strong, requiring little manure, an abundant cropper and ripening early, but demanding a situation sheltered from cold, and frequent pruning; (5) *curnet*, succeeding under all exposures, and furnishing an abundance of excellent oil; (6) *caillet-roux*, flourishing in low bottoms, and a plentiful yielder of good oil; (7) *redounaou*, hardy, and less esteemed for its oil than for preserving; (8) *arabon*, very productive of good oil; (9–12) *verdale*, *colliasse*, *clermontais*, and *gros cornialle*, very fruitful, while attaining only small dimensions, facilitating the harvesting of the fruit, and permitting planting at 16 ft. apart; the *verdale* is specially recommended as bearing in the 3rd year. The great seat of the cultivation of this species is in the countries bordering the Mediterranean, whence it has been introduced into America, Australia, and other localities possessing a suitable climate. Other species of *Olea* are found inhabiting the Himálayan portion of India, Afghanistan, the Malay Peninsula, Burma, Cochin China, the Cape of Good Hope, New Zealand, and Florida. Nevertheless, *O. europœa* seems to be the only species which is an object of systematic cultivation, and it is exclusively to it that attention is directed in the following remarks.

Soil, Climate, and Situation.—The olive thrives and is most prolific in dry, calcareous, schistous, sandy, and rocky ground, and may thus be grown on land which is worthless for many other crops. It is commonly said that good vine-soil is good olive-soil. The soil must be loose and permeable, and the deeper the better. Clays and bottom lands, even when well drained, are generally unsuitable. Efficient drainage is an essential in all cases; at the same time, a certain amount of moisture is requisite, and when this is not sufficiently provided by deep cultivation, mulching and watering must be resorted to in dry weather. No variety of the olive can support burning heat nor freezing cold: thus a northern aspect is chosen in tropical countries, and a southern in temperate climates, and preference is given to gentle slopes, over both plains and hill-tops. When the face of the hill is too abrupt, it is often cut in terraces, as in Fig. 1019. In the Old World, olive-culture is successful wherever the mean annual temperature is 14°–19° (58°–66° F.), that of the coldest month not falling below 5½° (42° F.), nor that of the hottest below 22° (71° F.). The altitude varies with the latitude, aspect, and proximity to the sea.

1019.



Propagation. By Cuttings.—The olive may be freely propagated by means of cuttings. In making a nursery with cuttings, if the soil is not naturally sandy, some sand may be advantageously put into the holes as the cuttings are stuck in. In this case, the cuttings need not be more than 8–12 in. long; they should be neatly trimmed with a sharp knife, to avoid bruising the bark, and only one good bud should be left above ground. The cuttings may be from either branches or roots; the latter are best planted entirely under ground, but they possess no special advantage, and are not recommended, except when removing or thinning out the trees, or when at a loss for material from which to raise a large nursery stock of a particular variety.

By Layers.—Of course, a tree reproducing itself so readily from cuttings, will grow from layers: but in adopting this method of increase, it must be remembered that the form and general welfare of the parent tree are prejudicially affected, until the layers are detached, and the sap again enters into free and natural circulation. This method is condemned by the best Continental horticulturists.

By Suckers.—Suckers, which often rise from the roots of old trees, if strong, may be carefully and neatly detached. They make good trees, as far as concerns their having a well-formed stem to commence with; but they are considered by the foremost authorities to yield less and live a shorter time, possessing the germs of all the maladies of the parent tree.

By Seed.—Seedlings can very readily be raised in a light and well-drained soil. Before sowing the olives, it is necessary to remove the oily pulp surrounding the kernel, so that moisture may reach the latter. This is effected by a process of decomposition, which may be brought about by steeping the fruits for 12 hours in hot water or in yeast, or by 24 hours' immersion in an alkaline ley, producing a soap from the oil, readily soluble in the moist earth. The seeds used should be the finest fruit, and chosen from the healthiest trees, and, being some months in germinating, they should be sown as soon as ripe. The sowing should be pretty thick, in a sheltered place, in furrows 6 in. apart and 2–3 in. deep. The ground needs previous trenching 3 ft. deep, and good manuring. During the spring and summer, careful occasional watering is necessary, as well as the removal of weeds as fast as they appear. When the little plants begin to shoot, small green branches are stuck in the ground between the furrows, to shelter the shooting plants, which continue to progress during the rest of the autumn, and even during nearly the whole winter, unless it be cold. If frosts are expected, the plants are covered with dry leaves, straw, or litter. If the plants succeed, they come up thickly in this seed-bed; the weakest are plucked out during the second spring, or, if pulled up early, may be replanted elsewhere. There is a two-fold object in raising seedlings, primarily to obtain stocks for grafting on, and secondarily as a means of securing new varieties suited to the climate—an important consideration in commencing the culture in a strange region.

By Grafting.—Grafting is much practised on the olive, and is among the most certain methods of procuring strong trees of approved varieties. The grafts known among horticulturists as "shield," "cleft," and "crown" are all used, and variously recommended. It is probably immaterial which is adopted, provided the scion and stock suit each other in point of age and size. Underground grafting is considered decidedly preferable in Australia, not more than 2 eyes of the scion being left above the surface. The union is better ensured by binding the point of junction with a strip of calico steeped in a mixture of mutton, tallow and bees'-wax; the earth should afterwards be heaped into a mound above the graft. The operation is performed in spring, when the sap is rising; and the scions are of 2-year-old wood. Seedling-stocks may be successfully grafted at 2–6 years old; but in using 2-year-old scions, it is as well that the stock should not be much more than the same age, so that there may not be more than sufficient sap to effect the junction, thus avoiding the necessity for keeping down suckers and surplus shoots.

By Truncheons.—"Truncheons" are very stout cuttings, 1–10 ft. long, and 1½–6 in. in diameter, according to the method in which they are to be planted. There are two ways of doing this. By one, the pieces have a length of 4–10 ft., and are placed in holes 20–50 in. deep, according as the soil is deep and well drained. The process is as follows. Holes are opened to the depth suited to the character of the ground, either in early spring, or better during the previous summer, the soil being left in the rough to get mellow. The truncheons are planted upright in the holes on a good layer of chopped leaves, rotten dung, or other thoroughly ripe but not too hot fertilizer, and the holes are fitted in firmly with the soil which was taken out. The surface around each is left slightly hollow to facilitate watering, which must be done whenever the weather is dry. The objects of manuring the bottom of the hole are to stimulate the truncheon to send out roots from the lower end, and thus secure a well- and deep-rooted tree, and to help retain moisture where it is most needed. In transplanting rooted trees, the same precaution should be adopted. When the length of stem above ground is great, the soil is sometimes heaped around it, to mitigate the drying influence of the air before the plant has rooted; a hole is then made on one side, and kept open by a wisp of straw, for the purpose of watering. The advantages of planting by truncheons in this manner is that a year is saved, and that the tree commences with a good straight stem.

The second way of propagating by truncheons is in lengths of 1–3 ft., which are perhaps preferable to the others. They are cut neatly, without any bruises or ragged edges, in which moisture might lodge and do mischief. They are planted horizontally, 4–5 in. below the surface, the soil being fine, and kept moderately moist. This system may be adopted also for planting in permanent situations, but is better suited for nursery planting, as the soil requires careful preparation, and two plants may start from the same truncheon. In 2 years, the trees will be 4–6 ft. high, with stems 1–2 in. thick, according to the kind; these are fit for planting out, and will make strong scions for grafting seedling-plants. These latter will have been growing meanwhile. This short-truncheon system is especially recommended in hot dry climates, such as Queensland.

By Uovoli.—Upon the bark, especially of the upper roots, of the olive, are formed numbers of small "knaurs" or embryo buds, termed *uovoli* by the Italians. These are easily detached by a sharp penknife, care being taken not to injure the tree. The latter must not be less than 10 years old when subjected to this treatment, as it must be mature, deep-rooted, and strong. When removed, the knots are planted like bulbs.

Cultivation.—The importance of thorough drainage has been already pointed out; and the intending cultivator, bearing this well in mind, will understand that the digging of holes is not to imply that the intervals are to be left without being broken up. Where a depth of 4 ft. is used, it would be impossible, without artificial drainage, to prevent the wet from hanging about the roots of the trees, unless the soil were naturally deep and very porous. It must be remembered that one object in the cultivation of the olive is that the slopes of hills whose soil is unsuited for general cultivation may be utilized. In these situations, any considerable depth of soil will not be found, and 24 in. may be the maximum depth attainable. If this be the case, holes will have no advantage in point of economy over continuous trenching, say to the width of 8–10 ft., with the additional facilities for drainage afforded by the latter mode. While such trenches will give sufficient room for the health of the trees, these will still benefit by the breaking up, at some subsequent period, of the intervening spaces, either by the hoe or plough.

Cultivation between the trees should be practised with caution. There is no mistake so great as to suppose that economy is gained by taking out crops from between the trees, unless it is quite certain that the latter are not being robbed of light, air, or nutriment. When the trees are quite young, and cover little space, a shallow-rooted crop may safely be taken off, provided that even then the seed is not allowed to fall within 5 ft. each way of the trees. If this be done for a year or two, it is as much as can be ventured; after this, any crop raised, in place of being taken off, should be ploughed in, to restore what the previous crops have taken out of the soil. It is quite possible, however, that the soil, in situations such as those advocated for the olive, may not be sufficiently good to make it worth while to attempt a green crop. In that case, rather than waste the space which is not wanted by the trees in their young state, pumpkins or sweet potatoes might advantageously be grown in holes specially manured, and fed to pigs. While, however, careful cultivation within certain limits between the trees may be permitted, not only must any crop be kept well away from the trees, but the soil about them must be periodically stirred as deeply as is compatible with safety to their roots.

Manures.—Manuring with suitable fertilizers, at intervals, forms an important element in the successful cultivation of the olive, especially in soils naturally poor. While the tree enjoys the mechanical looseness of sandy, gravelly, and stony soils, and freedom from stagnant moisture, it is not among the very small number of fruit-bearing trees which are most fruitful in sterile soil. Nutriment is necessary to its productiveness, and, if not already in the soil, must be introduced artificially. Stable-manure also acts mechanically in retaining moisture, thus helping the tree to withstand drought, and effecting a saving of labour in watering, which, if the manure has been well dug in, may be done less frequently. The stronger kinds of manures are recommended for the olive, such as pigeon- and sheep-dung; but the best of all for sandy soils is night-soil. Raw, unripened, hot manures of any kind are as bad for this tree as for most others. Nothing equals a good old compost heap; and where the materials are procurable, it will well repay the labour and first cost to make one. This is best effected by excavating a hole of sufficient dimensions, into which should be thrown sheep- and fowl-dung, stable-manure, soot, ashes, refuse fat, scraps of leather, hoofs, urine, leaves, weeds, and other substances which will ferment and rot. The heap should be occasionally turned until thoroughly incorporated; and when mature, which will probably not be for 12 months, may with great advantage be applied to the trees, being well turned in under the surface. In S. France, old rags of all kinds, including woollen, are largely used for manuring the olive. The tree likes limestone ridges, therefore an addition of lime to the compost heap, or its separate application, would soon make its effects visible in healthy appearance and more vigorous growth.

Where the soil is absolutely poor, the trees should be manured every year; but, otherwise, every second year will be sufficient. Of course, if the orchard has been established in rich alluvial bottoms, or fat loam, and the trees have a tendency to over-luxuriance, manuring is not only not wanted, but would be wasteful, and inimical to productiveness. In applying manure, if it be in fit condition, it is most profitable to dig it in just before the rainy season; by doing this, the tree at once receives the full benefit of the dressing.

Mulching.—Mulching, especially while the trees are young, will be found a useful adjunct to the cultivation of the olive, as it is with other trees, in hot dry climates. Its effect is principally mechanical, in retaining moisture, and in keeping cool the surface of the soil about the roots of the tree. Long manure—grass, straw, or any such substance—will answer the purpose; but it is as well to select something which will gradually decay, and, when dug in, will act as a fertilizer. Care should, however, be taken that the material selected be free from seeds, or it will involve additional labour with the hoe.

Pruning.—Judicious pruning is of great importance, as the olive has the character of only bearing in alternate years. The fruit is produced on the young shoots of the preceding year; and, in pruning, the object to attain is to secure a regular distribution of wood of the previous year from the axils of the leaves. In poor soil, where the trees would have a struggle to produce both fruit, and young shoots for next year's harvest, pruning is especially necessary; and it is probable that, in the genial climate of Australia, skilfully managed plantations ought to bear, with fair certainty, a regular annual crop. Some authorities consider that pruning once in 3 years is sufficient. By the old method of leaving the tree to attain its full growth, any considerable crop was not yielded for many years; and hence the character of the olive for tardy productiveness. Under the present system, however, of cultivating comparatively dwarf trees, abundant crops are afforded in 3–4 years. A clear, straight stem, of 5–6 ft., should be kept. Not only is the growth thus made handsomer, but the tree is more vigorous and strong to resist wind, and the fruit is sufficiently remote from reflected heat, and consequent premature ripening.

Distance.—The distance apart for planting the trees must be determined partly by variety, and partly by soil and aspect. Under the old system, which was content with a biennial crop, and left the trees to grow much as they pleased, a distance of 30–40 ft. was necessary. But of late years, the propagation of new and highly productive varieties, and the adoption of a system of pruning the trees to such limits as will render the gathering of the fruit by hand comparatively easy, has enabled cultivators to bring their trees closer together, and thus to economize space, and consolidate their operations. Orchards are now planted at distances of 16–30 ft., according to variety, the distance being further regulated by the quality of the soil.

While guarding against the false economy of overcrowding, the annexed table will show the number of trees which can be grown per acre at 16, 20, 30, and 40 ft. apart respectively, deducting a dray-road 12 ft. wide.

Distance apart.	Acre, 220 ft. × 198.	Acre, 264 ft. × 165.	Acre, 330 ft. × 132.
16 ft.	110 trees required	112 trees required	108 trees required
20 "	72 " "	66 " "	56 " "
30 "	30 " "	28 " "	27 " "
40 "	16 " "	15 " "	14 " "

Excluding all consideration of the fractional spaces adjacent to the dray-road, and simply calculating how many times the area required for each tree is contained in the available areas of acres of each of the preceding forms, gives:—

Form of Acre.	Available area in sq. ft.	Trees 16 ft. apart.	Trees 20 ft. apart.	Trees 30 ft. apart.	Trees 40 ft. apart.
ft. ft.		Trees required.	Trees required.	Trees required.	Trees required.
220 × 198	34,104	133	85	38	21
264 × 165	33,840	132	85	37	21
330 × 132	33,048	129	83	37	21

At whatever distance apart it is determined to plant the trees, the most effective method for securing a free circulation of air is what is known as "quincunx fashion," which has been explained under the cultivation of coffee (see Coffee, p. 693).

With careful attention, the olive will begin to repay the expense of culture in 4–5 years after planting, without taking into account what may meantime be got off the ground by inter-cultivation.

Diseases and Enemies.—Many insects attack and live upon the olive. Perhaps the worst is the olive-fly (*Dacus oleæ*), which appears when the fruit is ripening, and is most numerous in years of abundance. It inhabits the pulp of the fruit, sometimes more than one in each, and is more troublesome according as the harvest is later. It is destroyed by ants, but no real remedy for it has been devised. Another pest is *Tinea oleella*, which attacks the leaves, buds, and fruits by turn, and also causes excrescences on the branches. *Psylla oleæ* is abundant at the flowering season, and attacks the leaves and the peduncles of the flowers; it sucks the sap from near the flowers, causing them to be abortive, and attaches a cotton-like substance which increases the bleeding. No means are adopted to repel this parasite, and the growers in Italy look for the N.-W. wind to drive it away. *Coccus oleæ* does more damage by causing a serious loss of sap, than by what it actually consumes. No real remedy has been invented for it. *Hylesinus oleiperda* lives under the bark of the young branches, and even occurs on dead wood. Its ravages are curtailed by cutting and burning infected branches. *Phloiotribus oleæ* causes a manna-like exudation. Among vegetable parasites, are a mushroom, *Dæmatium monophyllum*, which causes branches and leaves to become black; the remedies used are lime-water, coal-tar, and petroleum. Another fungus, *Agaricus olearius*, infests the stems of old trees.

Harvesting.—The fruit of the olive is a "drupe," a botanical term applied to fruits which are externally succulent or fleshy, with a hard-shelled seed. The shape varies according to kind: it is generally oval, sometimes round, sometimes obovate, occasionally acuminate. It varies still more in colour, according to kind, and to stage of maturity,—green, whitish, violet, yellow, red, or even black. The fruit is produced in vast profusion, so that an old olive-tree becomes very valuable to its owner.

The proper time for gathering is the eve of maturity, presuming that the cultivator aims at the production of the finest quality of oil. If delayed too long, and the fruit becomes over-ripe—especially if it be allowed to fall,—there is a loss in quality, but a small gain in quantity. But while advocating the gathering of the fruit at the stage at which it will produce the best and highest-priced oil, it is necessary to point out, as one of the advantages of the crop, that should the owner be unable to gather his olives then, they are yet available even in a state which in other fruits would be regarded as rottenness—for the production of a still marketable though not so valuable commodity.

Another inducement to harvesting the olive as soon as it is fit for gathering is to be found in the fact that, by delaying too long, the productiveness of the tree for the next year is prejudicially affected. Early gathering, on the other hand, relieves the tree, and gives it time to strengthen for another crop. The olive, if left to itself, will only bear once in two years. This has been attributed in great measure to the injury received by the tree in the practice of beating down the fruit; but there is no doubt that, in skilfully-managed plantations, the trees bear annual crops, and that the early gathering of the fruit contributes largely to this end. If the fruit is left on the tree too long, it is taking sap which ought to go to the formation of new shoots for fruiting in the following year.

The best mode of gathering is by hand. The system elsewhere alluded to, of cultivating low-growing trees, much facilitates the harvest. The gathering can be done by children, and, with the aid of light "steps," the fruit can be reached from the top of the tree. The system of beating the fruit from the tree with light wooden rods, although very old, and still resorted to in some places, should never be practised by the intelligent and painstaking agriculturist. However skilfully done, it cannot fail more or less to injure the young branches, as the blows must fall at random; and what will suffice to bring down the fruit will also strew the ground with leaves and tender shoots. The practice has the additional disadvantage of involving the picking-over of the fruit, in order to separate leaves, sticks, and other rubbish, before pressing. Shaking the tree is also resorted to as a means of obtaining the fruit; but, though not so injurious as beating, is not recommended. The practice obtains in Syria.

A good method of ascertaining if the fruit is fit for gathering is to apply a slight pressure with the finger and thumb; if oil exudes, the olives are considered fit for the press. The largest fruit is the Spanish; and the olives of Andalusia are said to surpass, both in size and quality, those of other Spanish provinces. The harvest extends over 6–8 weeks; as the fruit matures, and is gathered, it should be laid on shelves, so as slightly to dry. Contact will do no harm, so long as it does not bring about actual heating; excessive fermentation results in inferior quality of oil.

Yield and Value.—Decandolle states the quantity of oil produced by the olive at 50 per cent. of the gross weight; Sieuve says that 100 lb. of olives yield 32 lb. of oil viz.:—21 from the pericarp, 4 from the kernel, and 7 from the shell; others state it at 25 per cent., and from inferior varieties as low as 10 per cent. It is extremely difficult to give an average yield per tree. Productiveness is governed by variety, climate, soil, culture, and age. The quantity of the crop is also liable to be affected by extremes of wet or drought, lateness of season, hailstorms, gales of wind, and seasons unusually rife with destructive insects; but after allowing for all possible drawbacks, the tree is considered to be one of the most profitable crops known to agriculture. The lowest average stated for a series of years is 1 gal. a tree; while on other estates, the average is given at 1¼–2 gal. Taking the lowest average of 1 gal. a tree, and 60 trees to the acre, the produce at 8*s.* a gal. would be worth 24*l.* an acre in the early years of bearing; while the value of the cultivated tree increases as a matter of certainty with each additional year of age, until maturity. These figures exclude all consideration of the feeding or manurial value of the residue from the expressing process.

Extraction.—In the extraction of the oil, there are two distinct processes—(1) crushing, and (2) pressing.

In the first process, the fruit is by some completely crushed; by others, the pericarp only is first crushed, and when the oil from that part of the fruit has been separately expressed, the more complete crushing is applied for obtaining the remainder of the oil. This difference of system arises from the fact that opinions differ as to the quality of the oil from the several parts of the fruit. There is no doubt that much of the delicacy of flavour which characterises the oils of highest repute is due to the pressing and storing, rather than to the crushing; while it is also influenced to no slight extent by the variety of the olive, and the degree of maturity and the condition of the fruit when crushed.

The time for gathering the fruit is the eve of maturity. It is overripe for the finer quality of oil, if allowed to fall. This condition being complied with, much still depends upon the length of time allowed to elapse between the gathering and crushing, and the treatment to which the fruit is subjected in the interval. There is no doubt that fermentation in the fruit should be carefully watched, as anything like excess impairs the quality of the oil produced. On the other hand, no amount of fermentation affects the quantity of oil; and where this is the main object of the maker, the olives are often allowed to ferment in heaps for months, till it is convenient to crush them, when they have to be dug out of the bins to put through the mill. But a slight degree of fermentation, if unaccompanied by any material heating, does not appear to affect injuriously the quality of the oil, while it facilitates the separation of the oil from the mucilage. The extent, however, to which fermentation is allowed to proceed should be jealously regulated, as there is no doubt that, beyond a certain point, the oil suffers in quality, and becomes unfit for the more delicate uses of food and cookery. The safest plan is to gather the olives at the right time, and crush them as soon as there are enough together. Meanwhile, they should be stored in moderate layers on shelves, the most complete arrangement being one which will admit of free currents of air above and below the layers.

The fruit is first reduced to a pulp, either with or without crushing the stones, according to the views of the miller as to the effect which this has upon the quality of the first droppings from the press, which are always regarded as the best. The crushing process should be conducted by a slow and regular movement, without jerking, in order that all the oil-cells shall be broken, and the press not be called upon to do any of the work which is supposed to have been previously done by the mill. The pulp or paste is then shovelled into bags, which are placed one on the other to a convenient depth in the press. In this process, as in that of the crushing, the power should be applied steadily, slowly, and regularly, to afford time for the oil, as it exudes, to escape from the press through the proper channels. The pressing should be conducted in a warm temperature, and with as little exposure to the air as possible.

"Virgin" oil is that obtained by the first pressing, before the application of water or heat to the pulp. This is run into water, where it is allowed time to deposit its mucilage, and, after being skimmed off, is kept separate. In the district of Montpellier, however, the term is applied to the oil which spontaneously separates from the paste of crushed olives. This oil is not met with in commerce, the quantity being obviously too small; it appears to be used by watchmakers, and for other purposes requiring extreme purity. So soon as all exudation of oil from the first pressing ceases, the screw is reversed, and the bags are removed and emptied. The pressed pulp being put carefully aside, and the bags refilled, pressure is again applied, and the process is repeated until the whole crushing has gone through the mill.

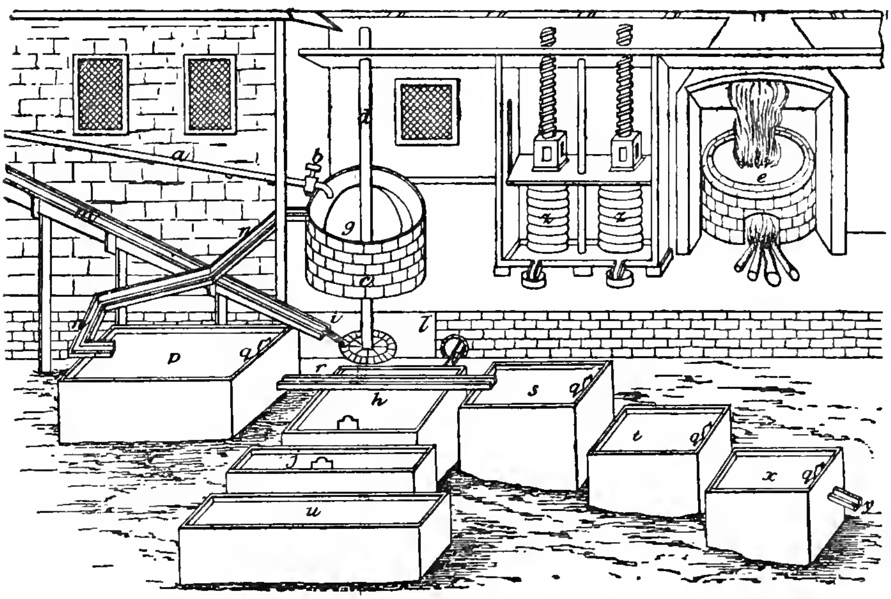
The marc, which has thus been once pressed, is then thoroughly separated, and stirred up with boiling water, and the process of pressing is renewed, this time the pressure being increased, though still gradual and steady. This second oil is nearly as good as the first, but apt to become rancid in time. The bulk of the oil, after this second process, is skimmed off the water in the receivers; but entire separation takes a long time, and, when it is complete, the process is reversed by the water being drawn off from below. Once more is the marc subjected to treatment with boiling water; and it is at this stage that, when the stones were not crushed in the first milling, that process is now gone through, and the last of the oil is obtained. This pressing is, however, regarded as of inferior quality, and is kept carefully separate from the results of numbers one and two, being commonly termed "pyrene-oil."

The water which has been used in the several processes, and which still contains an admixture of oil, is conducted into large reservoirs, generally constructed underground. Here it is left for a considerable period, during which, the mucilage, water, and oil thoroughly separate—the first falling to the bottom, while the last rises to the top, whence it is ultimately skimmed off, and applied to local uses of an inferior character, such as burning in lamps. This oil, taking its name from the French designation of the reservoirs used in its extraction, is termed "oil of the infernal regions."

The process of the second extraction by the aid of heat is in large mills sometimes effected by an arrangement for the thorough separation of the pulp, and freeing of the oil, as illustrated in Fig. 1020.

The plant required in the manufacture of olive-oil on a moderate scale consists of a mill for crushing, a press for separating the oil from the solid portions of the fruit, receivers into which the oil is run from the press, and the necessary vessels for storage and for the market. Besides these, there must be a building of some kind in which the various operations are carried on. In the large majority of cases, the machinery employed is of the rudest kind, and its merits rest entirely upon its simplicity. The mill is universally an edge-runner, made of some perfectly non-absorbent material, such as granite or red marble. The motive power may be cattle or water. The press is usually of the old screw or beam types, such as any carpenter could construct. In Spain, the oil is stored in immense stoneware jars, called *tinajas*. Fig. 1020 shows the complete arrangement of a mill and refinery, for extracting all the available oil, suited to the needs of a planter. The most improved apparatus for conducting operations on a very extensive scale is described in separate sections of the present article (see pp. 1451, 1459).

1020.



The wooden or leaden pipe *a* with a tap at *b*, is for admitting water into *c*, which is a stone or wooden tank of sound and solid construction, with a millstone on the floor perforated in the middle. The hard-wood beam *d*, generally of oak, is held vertical by a cross-beam, and penetrates the wall of *c*, into the opening *i*; a horizontal water-wheel *l* is here attached to it, and it rotates on its axis at *k*. The millstone *g* is generally 5–6 in. thick, and 4–5 ft. deep; the heavier it is, the better the crushing is performed. The wheel *l* is driven by the current of water supplied by the channel *m*. The feed of this water is important, as it determines the speed at which the apparatus is driven; the motion must not be too rapid, or there would be a danger of re-absorption of part of the oil. The channel *n* is for the escape of the crushed fragments and liberated oil from the tank *c*; it is made in a zigzag, to relieve the rush of the water and materials into the reservoir *p*. To prevent the inflow from stirring up the sediment on the bottom of the reservoir, it is made to impinge on a slab of wood fixed close to the end of the spout *n*. The 1st reservoir *p* is made of either stone or brick; it is the largest of the series, and commonly measures 10 ft. by 8 ft. The outlet from *p* is made by a valve *q*, connected with a spout *r*, the exit being from the centre of the depth of the tank, and not from the surface. The spout *r* empties into the 2nd tank *s*, impinging on a slab as in the 1st. The tank *s* communicates directly with *t*, and *t* with *x*, the exits being at the centre, as shown at *y*. The water that flows from the upper part of the tank *c* is charged with remnants of the fruits, a little oil, and some particles detached from the kernel of the fruit, known as "black crust"; the other parts of the kernel remain at the bottom of the tank, but as they retain little bits of fruit, provision is made for their withdrawal by a hole in the wall of *c*, connected with a pipe *f*, which thus carries the water and the rest of the fruit, called "white crust," into a tank *h*, communicating with two others *j u* by valves similar to *q*. The mode of operation is as follows. The husks of the olives, after having been crushed in the ordinary mill, are spread on the floor of the refining-mill, to be taken from there into *c*. When there is a sufficient quantity in *c*, the mill is set in motion for ¼ hour, so that the crust (husk) is crushed another time. After this, *b* is opened to let in some water, and the wheel is made to turn again. The forcé of the water rushing rapidly, and that of the mill, serve to more completely dissolve the husks; more water is added to turn the wheel, and at last all the water is let loose. The black crust rises to the surface, and the water flowing through *n* drags it into the tanks *p*, *s*, *t*, *x*. When it appears that the water drags no more particles of black crust, the valve at the bottom is opened, and then the water carries off the white crust into the tanks *h*, *j*, *u*. When the waters of these black and white crusts have arrived into their respective tanks, or when the vat is emptied of whatever kind of crust, the vat is replenished with husks.

While this operation is going on again, a man near the tanks, armed with a long-handled scraper or rake, passes it lightly over the surface of the water in the tank, and thrusts it into the corners, so that the oil and particles of the fruit come to the top, upon which he takes a short-handled perforated ladle, or what is still better, a hair sieve, and gathers all that is on the surface to throw it into a bucket. He goes on with this work till the water of the different tanks, without being agitated, shows nothing more on its surface; hereupon he carries his bucket over to the boiler *e*, into which he empties the contents. This boiler is half full of water, which is allowed to boil until the smoke is quite white and thick, which is a sign that the water has evaporated sufficiently, and that the paste is thick enough.

The workman takes the substance out with a large ladle, and fills the baskets *z*; these are put one above the other, and pressed by screw presses, the oil escaping into receptacles. The whole of the paste or doughy water is not taken away during the operation. It is necessary to leave a certain quantity at the bottom of the boiler, in order that the boiler should not be burned, and that there should be time to fetch some water from the tubs.

As soon as the press acts on the baskets, boiling water is sprinkled on the outside of them. This helps to detach from the outside those particles of oil which otherwise would not drop down. They flow with the other oil into the same tubs. The whole is then put into jars; and as water is heavier than the oil, the former goes to the bottom, and the latter floats. The whole is allowed to rest for a few days, during which all the sediment separates from the oil and goes to the bottom of the water. The jars are opened by a tap at the bottom, when the sediment is the first to come out, and it is carried to the boiler to be re-boiled; afterwards comes the water. Then, when the oil begins to show, the tap is shut. This oil is put into casks; but sometimes again into other jars, which operation naturally purifies it still more.

Reverting to the tanks containing the different kinds of crusts. After having gathered as much as possible of the oleaginous part, and the different particles of fruit, a workman armed with another scraper agitates the bottom of the basins, towards where the sediment with the other particles has been precipitated; then all the oleaginous and light particles that float on the top are taken away. This operation is repeated often, and when it appears that there is nothing more to be taken away from the tanks *p s t x*, the valve is opened in the basin *x*, to allow the water and sediment to flow away. Even this sediment could be boiled over again, and would give a little oil, for if there were basins for half a mile, the last would give some particles.

The husks, after having been taken away from the press, are made use of to keep up the fire under the boiler. They form also an excellent kind of grease. As to the white crust, or remainder of the kernels that remain in the tanks *h j u*, they have to undergo the same operations as the black crust. Finally, the valve is opened; but, as this tank is furnished with an iron grate, it is only the water that can escape, and the white crust remains dry. This crust is sometimes sold for heating the furnaces, and the profit derived from it is sufficient to pay the wages (in Spain and Italy) of the men employed in the refinery. Husks and various oily crusts and residues are now exhausted of their oil by the carbon bisulphide process (described on p. 1454) in many places on the Mediterranean coasts. Such oil is usually dark-green and stronger in stearine than the other oil; it is used for soap-making. The only purification of the oil generally adopted in S. Europe is by allowing it to stand for a long time, and deposit its sediment. More elaborate processes of purification are described under a separate heading of this article (see p. 1458).

Statistics of Production and Commerce.—The olive is grown in 12 departments of France, all situated in the S.; they are chiefly Var, Vaucluse, Bouches du Rhône, Gaud, and Alpes Maritimes. The area occupied by it was stated at 317,800 acres in 1877; the production of fruit in that year was 7,318,352 bush., and of oil, 392,618 cwt. Nantes exported 4636 *kilo.* in 1879 to England, Mexico, Venezuela, and Brazil. Lisbon exported 267,073 *decal.* (of 2⅕ gal.), value 83,555*l.*, in 1876. The Portuguese oil is very carelessly prepared, but of fuller and richer flavour than those of France and Italy. Spain is calculated to have 1 million *hectares* (of 2½ acres) planted in olives. The chief oil-producing districts of the province of Cordoba are Aguilar, Baena, Bujalance, Cabra, Castro del

Rio, Fuente Obijuna, Hinojosa, Lucena, Montilla, Montoro, Posadas, Pozoblanco, Priego, Rambla, and Rute, which have a total of 468,335 acres covered with olives, and produce an annual average of over 2⅗ million gal. of oil. The oil from Bujalance and Montoro finds a ready market in La Mancha and Madrid; whilst Aguilar, Cabra, and Lucena send their surplus to Malaga. The oil from the other districts goes mostly to Seville for exportation; but the Spanish oils are unable to compete with Italian and French in the foreign market, owing to their strong odour and flavour. The exports of olives and olive-oil from Cadiz in 1878 were:—Olives: 14,596 *kilo.* to Germany, 13,060 to Brazil, 458,202 to Spanish colonies, 1946 to Denmark, 7280 to United States, 6729 to France, 4112 to Holland, 50,263 to England, 1750 to Italy, 52,712 to Mexico, 4112 to Portugal, 112,956 to Argentine Republic, total, 727,718 *kilo.*; olive-oil: 269 *kilo.* to Germany, 930,578 to Spanish colonies, 4020 to United States, 20,618 to France, 13,382 to England, 1150 to Morocco, 73,975 to Mexico, 20,566 to Argentine Republic, 440 to British Colonies, total, 1,064,998 *kilo.* Santander, in 1879, shipped 50,000 lb. of olive-oil to France. Seville, in 1877, exported olives and oil as follows:—Olives: 140,000 *kilo.*, value 2800*l.*, to England; 145,000 *kilo.*, 2900*l.*, to France; 30,000 *kilo.*, 600*l.* to United States; 1,792,000 *kilo.*, 35,840*l.*, to Spanish colonies and coastwise; total, 2,107,000 *kilo.*, 42,140*l.*; oil: 1,230,000 *kilo.*, 49,200*l.*, to Great Britain; 309,000 *kilo.*, 12,360*l.*, to France; 15,358,000 *kilo.*, 614,320*l.*, to Spanish colonies and coastwise; total, 16,897,000 *kilo.*, 675,880*l.*; the olive-refuse shipped from this port in 1877 was 400,000 *kilo.*, 800*l.*, to Great Britain; 1,766,000 *kilo.*, 3532*l.*, to France; total, 2,166,000 *kilo.*, 4332*l.*; the olive-refuse exported to France in 1878 amounted to 7400 tons. Malaga exported 3,108,000 gal. of olive-oil in 1878, and 1,400,000 gal. in 1879; it goes mostly to the Baltic. The total Spanish exports of olive-oil were 52,356,000 *kilo.* in 1873, 4,992,000 in 1876, and 24,612,000 in 1878.

The area occupied by olive-yards in Italy in 1874 was 2,223,768 acres; the production of fruit in the same year was 9,310,375 bush. The total Italian exports of olive-oil were 51,413,000 *kilo.* in 1878, and 88,655,000 in 1879. The shipments of olive-oil from the chief Neapolitan ports in 1878 were:—10,820 tuns from Gallipoli, 915 from Taranto, 5860 from Gioja, 1885 from Brindisi, 925 from Monopoli, total, 20,405; the destinations were: 5553 for United Kingdom, 5752 for Russia, 972 for France, 310 for Germany, 305 for Holland and Belgium, 203 for Austria, 6950 for Italy, 360 various; total, 20,405. In 1879, the shipments were:—4298 from Gallipoli, 6138 from Taranto, 9727 from Gioja, 7654 from Brindisi, 3070 from Monopoli, 1744 from Rossano, total 32,631; the destinations: 10,313 to Great Britain, 10,573 to Russia, 7786 to Italian ports, 1619 to France, 2340 to other countries, total, 32,631. Naples, in 1879, exported 1,485,721 *kilo.*, value 101,064*l.* Civita Vecchia, in 1877, exported 9187 *kilo.* of oil, value 497*l.* The island of Sardinia, in 1877, produced 53,326 *hectol.* (of 22 gal.), 47,446 being from Sassari province. The Balearic Islands exported 26,838 *hectol.* of olives, and 3,152,493 *litres* (of 1¾ pint) of oil, value 123,236*l.*, according to the latest returns; Ivica and Palma send most, Minorca none. The olive is cultivated along the littoral of S. Dalmatia, the best oil being produced in the district of Ragusa. The export of oil was 208,466 centners (of 110 lb.) in 1875, and much greater in 1876 and 1877. Trieste shipped 354 tons of oil to Great Britain in 1879. The total Greek export was 12,244,615 *okes* (of 2·83 lb.) in 1875. The exports of olive-oil from Samos in 1879 were valued at 4700*l.* to England, 6180*l.* to Austria and Germany, 8900*l.* to Turkey and Egypt; total, 19,780*l.* Patras, in 1878, was expected to prepare about 10,000 tuns of olive-oil for exportation. The provinces of Calamata and Messenia produced 2000 tons of olive-oil, value 68,000*l.*, in 1880. The Santa Maura harvest of 1878–9 was unusually abundant, amounting to 55,000 barrels, or about 3437 tons. The Zante crop of 1879 was estimated at 20,000 barrels as against 70,000 in 1878. The shipments of oil from Syra in 1879 were valued at 260*l.* to Austria. The value of the olive-oil shipped from Corfu to Great Britain was 9484*l.* in 1877, besides nearly 200*l.* worth of soap made from pyrene-oil. In 1878–9, the crop was 220,009 barrels (of 16 gal.), or 13,968 tuns, and the values of the exports were 34,000*l.* to England, 106,200*l.* to Austria, 123,000*l.* to Italy, 22,000*l.* to Russia, &c., the total exceeding 304,000*l.*; there were besides 560 tons of soap made from common oil, and 150 tons from pyrene-oil, representing a total value of 19,800*l.* Cyprus produced 103,114 gal. of olive-oil a short time since, but this figure might be enormously increased. Crete depends chiefly upon its olive-yards; the exports of oil in 1879 were:—2400 tuns, value 84,350*l.* from Candia; 2050 tuns, 71,700*l.* from Canea; and 400 tuns, 14,400*l.* from Rethymo. Its destination was almost exclusively the Barbary coast, only 330 tuns coming to the United Kingdom. The exports of olive-oil soap in 1879 were: 50,000 cwt., 66,540*l.*, from Candia; 11,700 cwt., 15,750*l.* from Canea; and 21,000 cwt., 27,000*l.* from Rethymo. Thessaly exported 20,000*l.* worth of olive-oil in 1880. Olive-oil is produced throughout Syria, but chiefly on the plains of Safet, Nazareth, and Nablous. The plantations are being extended widely. The exports from Jaffa in 1879 were 2,000,000 *okes* (of 2·83 lb.), value 74,074*l.*, to Europe, chiefly France; also 55,000*l.* worth of olive-oil soap. The Persian province of Ghilan exported 2884*l.* worth of oil and soap to Russia in 1878, and 3077*l.* worth in 1879. The olive-groves of Roodbar annually produce an average of 100,000 cwt. of oil, of an inferior quality from careless treatment. The climate of Algeria is specially suited to the olive, and at least 3 million trees are now growing there under cultivation. In 1877, the production of fruit was 55,239,000 *kilo.*, yielding 1,543,400 *hectol.* (of 22 gal.) of oil. In 1878, the figures increased, and there is yet room for development, especially in Kabylia. The exports of oil were 3,245,708 *kilo.* in 1877, 710,330 in 1878, and 3,003,703 in 1879. Olive-gardens constitute the main wealth of the Moroccan provinces of Haha and Sus, but during the last few years, the crops have constantly failed, and barely supplied local needs. The Tunisian districts of Susa, Monastir, Media, Sfax, and Biserta maintain 4–5 million olive-trees. The exports in 1873 were 3472 tuns, value 125,893*l.*, chiefly to France. Olives have been grown successfully in several of the S. states of America, but not profitably. More satisfactory results have been obtained in California, where one grower has some 6000 trees in bearing, and recently sent 1000 gal. of the oil to San Francisco. The Department of Agriculture is fostering the industry by importing cuttings of the best European varieties. Olive-oil is extensively prepared in several states of Mexico, especially Guanajuato and the Federal District. Victoria had 20 acres under olives in 1878–9, besides many trees in gardens; the industry has doubtless a great future before it in portions of every Australian colony, and in much of the N. island of New Zealand. At the Cape, at least one indigenous species of olive (*Olea capensis*) is found growing wild almost everywhere, and only needs grafting and cultivation to become a valuable resource to the colonial planter.

Characters and Uses.—Superior olive-oil is a somewhat viscid liquid, pale- or greenish-yellow, of faint, agreeable odour, and bland oleaginous flavour; sp. gr. 0·916 at $17\frac{1}{2}°$ ($63\frac{1}{2}°$ F.); commences to lose transparency by separation of a crystalline fatty substance at 0°–10° (32°–50° F.); when congealed and pressed, affords $\frac{1}{3}$ of solid fat, melting at 20°–28° (68°–$82\frac{1}{2}°$ F.), the fluid portion (oleine) remaining liquid at − 4°– − 10° (25°–14° F.). It is one of less alterable, non-drying oils. The best kinds of oil are consumed enormously in food and medicine, constituting the "salad-oil" of the shops; the commoner kinds are employed in lubricating, illuminating, woollen-dressing, and the manufacture of soaps. It is most extensively adulterated with refined cotton-seed, ground-nut, and other oils.

Ouabe and Bread-nut-oil.—The former name is applied in Guiana to an oil extracted from a species of *Omphalea* (see Nuts—Bread-nut, p. 1352), and said to be an admirable lubricator. In Jamaica, a fine limpid oil is also obtained from one species, but its congealing-point is not ascertained.

Owala or Opochala.—The seeds of *Pentaclethra macrophylla*, known as *owala* in the Gaboon, and *opochala* in Fernando Po, afford much oil. The kernels alone yield 56 per cent. by ether extraction, and the whole seeds 50 per cent. It has a clear-yellow colour, but becomes brown on purification. It loses its limpidity at 11° (52° F.), and becomes viscous at 0° (32° F.), but does not dry in thin layers, even after several days' exposure. Its flavour and odour are not disagreeable. It is adapted to soap-making and lubrication, and is edible. The seeds are imported into Rotterdam.

Palm-oil (Fr., *Huile* [*Beurre*] *de Palme*; Ger., *Palmöl*).—The so-called "palm-oil" is a product of the fruit of several species of palm, but particularly of *Elæis guineensis* (see Nuts—Palm, p. 1359).

For the production of commercial oil for exportation, the spadices are cut from the trees, and put in a heap in the outer air, where they are allowed to remain for 7–10 days; this causes the joints of the nuts to be weakened by the process of decomposition, and they are then easily detached by simply beating them. The nuts or fruits are gathered together, and the husks that adhere to their base are removed, either by hand or by the rubbing them together, and are separated by throwing them in the air, and allowing a strong breeze to blow them away. A hole about 4 ft. deep is dug in the earth, and lined with plantain-leaves, into which the nuts with their hard unyielding pulp are put, and covered over, first with plantain-leaves, and then with palm-leaves and earth. The nuts are allowed to remain for various periods—from three weeks to three months—until more or less decomposition has taken place, so that the pulp when removed is soft, and appears as if it had been thoroughly boiled. They are now put into a trough, made by digging a hole 4 ft. deep, and paving it below and around with rough stones. In some cases, a portion of the nuts is boiled in iron or earthenware pots, and then mixed with the unboiled portion before putting into the trough. They are now pounded with wooden pestles by men standing around the trough, until the pulp is quite detached from the surface of the hard nut; the whole is removed from the trough and piled in a heap, and the stones are taken out, leaving the oily fibrous pulp, which is put into a pot with a small quantity of water under a good fire, and well stirred until the oil begins to melt out. The pulp is then put into a rough net, open at both ends, to which are attached two or three short sticks, by turning which in opposite directions the oil is squeezed out through the nets; it runs into a receiver or tub, leaving the fibre behind. The longer the oil-nuts remain underground, the thicker the oil will be when made, the quality will also be inferior, and the smell bad. On the other hand, the shorter the time, within certain limits, during which the nuts are underground, the better will be the oil made from them. It is evident from this rough mode of preparation that the oil is liable to contain more or less vegetable fibre, which is apt to act as a ferment, and render the oil rancid in course of time, besides holding in suspension a varying quantity of water. These impurities in the commercial oil are further increased by the fact that, when the oil is brought down to the coast, should no vessel be there prepared to receive it, it is frequently buried in the sand till an opportunity arrives for exporting it.

The following is the method of manufacturing the oil for internal consumption. The spadices are kept in a hot place for 3–4 days, and the nuts are then taken out. A small quantity (3–4 lb.) is made at a time. They are boiled in iron pots, then put into a wooden mortar, and pounded with wooden pestles. The pulpy mass is next mixed with tepid water with the hand. The chaff is first removed, and afterwards the stones. The oil remains mixed with the water, which is passed through a sieve (to remove the remaining chaff) into a pot placed on the fire, heated up to boiling-point, and allowed to continue in that state whilst the oil floats up as a bright-red substance. The water at this stage is being continually stirred, and the oil is removed as it floats up until the whole is collected. The oil is now put into a pot and heated, to drive out any water that may remain.

It has been estimated that the yield of oil from this palm is at the rate of 7 cwt. an acre, or more than $\frac{1}{3}$ greater than the oil product from the olive in S. Europe. On some parts of the W. coast of Africa where the regular collection of the fruits is not practised, the trees grow so thickly, and afford such regular and rapid crops, that the ground becomes covered with a thick deposit of the fatty matter afforded by the fallen nuts.

The oil obtained from the pericarp, the palm-oil proper, has the consistence of butter, a yellow colour, an odour resembling violets, and a mild flavour; it easily becomes rancid, bleaches in the sunlight, saponifies readily with alkali, dissolves in all proportions of ether, and in alcohol at 0·848 sp. gr. Its industrial applications are for the manufacture of candles and soap (see Candles; Soap); and the manufacture of tin-plate, in S. Wales and elsewhere. For this latter purpose, its non-drying qualities render it valuable as a preservative of the surfaces of the heated iron sheet from oxidation, until the moment of dipping into the bath of melted tin, the sheets being rapidly transferred to that from the hot oil bath, which consists almost entirely of palm-oil. The softest, purest, and most neutral oil is preferred for this purpose, and the kind known as "Lagos" is much used therefor. The exports of palm-oil from Lagos were 3,304,967 gal., value 239,133*l.*, in 1877, and 1,570,638 gal., 139,094*l.*, in 1878.

Until 10–12 years ago, palm-oil from certain parts of the African coast was usually mixed with the oil obtained in a very crude way from the kernel of the fruit (see Palm-nut-oil); as the kernels were somewhat burnt in the process of extraction, they communicated a peculiar smell to their oil, and that again to the palm-oil, which was known in the market as "coffee-oil," and, being difficult to bleach, and weaker in body, was considerably lower in price than good palm-oil. It is more usual now, however, for the kernels to be sent to England to be treated.

Scarcely any oil that finds its way into commerce has a greater range of quality than palm-oil. The various kinds are well known by the names of the parts of the coast whence they are shipped. The oil used to be brought home by small vessels trading from London, Liverpool, and Bristol, which went out with empty casks, and lay some months along the coast, especially near the mouths of rivers, until they were filled up with oil. The great regularity with which steamers now call at many African ports, and the cheapness of freight, has materially altered the mode of conducting the trade. Casks are now left at the various depots, and instead of, as formerly, a 300-ton ship coming home laden with one or two classes of oil, steamers arrive regularly in Liverpool with cargoes chiefly of palm-oil, made up at various ports of call, ranging perhaps from 8° N. and 13° W. (near Sierra Leone) to 10° S. and 12° E.

Along so great a range of coast, it is not a matter of surprise that there should be such variations in the quality of the oil, especially when, to differences in climate affecting the trees and their fruit are added differences in mode of preparation, &c. It is found, however, that the oil from any given port is tolerably uniform in quality. Thus, as explained before, Lagos oil, which chiefly comes to London, is the most neutral (i.e. non-rancid) and the cleanest, the water and other impurities not exceeding 1–2 per cent.; it is also nearly the softest. On the other hand, "Brass" oil is almost equally pure, but is the hardest of all the varieties, and contains the largest percentage of palmitic acid; hence it usually commands the highest price for candle-making in the Liverpool market. "Cameroons" and "Windward" oils (which chiefly come to Bristol) occupy an intermediate position as regards hardness; in the latter, impurities may amount to 5–6 per cent. "Saltpond" and "Monrovian" may be mentioned as instances of the most impure oils, 25 or even 30 per cent. being not an unusual amount of impurity. On this account, it has been proposed to sell palm-oil by analysis, guaranteed to contain —— per cent. of clean oil, just as soda-ash is sold at, say, 55 per cent. soda. The presence of these impurities tends to partially decompose the oil, and render it harder, since the fatty acids are more solid than the neutral fat whence they are derived. Any determinations, therefore, of the melting- or solidifying-points of palm-oil are utterly misleading. Commercial palm-oil itself is a mixture of palmitine and oleine (the glycerides), and of palmitic and oleic acids, in very varying proportions, with the addition of uncertain quantities of water, vegetable fibre, and sand.

Palm-nut-, Palm-kernel-, or Palm-nut-kernel-oil.—This oil, which is known in commerce under each of the synonyms given, is extracted from the nuts or kernels of the fruit described under Palm-oil. Some 10–12 years ago, the nuts were partly charred, and the oil that ran from them, discoloured by the burnt cellulose, was exported either separately or mixed with palm-oil. This brownish oil could only be very slightly bleached, and was therefore not of great value for soap-making. Since the improved methods of oil extraction (see p. 1451) have been worked out, the nuts have been exported to England, and the nearly colourless oil there extracted, while the ground nuts have been used for cattle-food. The following is a description of the old process, which is still in vogue in some districts.

The nuts which have been subjected to the processes described for making oil are deprived of their external pulp, and the kernels only remain; or old nuts are picked up from under the trees, and put in the sun for days, and even months, until they are perfectly dry. They are then broken between two stones, and the kernels are obtained whole, in perfect condition, and fit for exportation, and so form the commercial palm-kernels. If they have not been perfectly dried, the kernels break into pieces. The oil obtained from these kernels by the following process is called "white-kernel-oil." They are placed in wooden mortars, and pounded very finely; then removed to a grinding-stone, and ground into a homogeneous mass, which is put into cold water, and stirred with the hand. The oil rises in white lumps on the surface of the water, and is collected and boiled. It is of a very light straw-colour, and, when exposed to the sun and dew, becomes, after a time, perfectly white. "Brown" or "black" oil is thus obtained. The kernels are put into a pan, and fried; the oil oozes out, and is strained; the fried nuts are placed in wooden mortars, pounded, and afterwards finely ground on a grinding-stone. The mass is thrown into a small quantity of boiling water, and stirred constantly; the oil rises, and is continually skimmed off. The pulpy mass is removed from the fire, spread out in a large bowl, and allowed to cool, after which it is again ground, and put by until the cool of the day, when it is mixed with a little water to soften it. It is now beaten with the hand for some time until the oil comes out in white pellets. As soon as this is observed, a large quantity of water is put into it, and a fatty substance floats on the top; this is skimmed off and boiled, and the pure oil is obtained.

By whichever of these processes it is obtained, the oil, when freed from impurities, is of a pale primrose-yellow colour, with a characteristic odour not unlike that of coco-nut-oil, which it strongly resembles in its chemical and physical characteristics. Indeed, for soap-making, it has largely supplanted coco-nut-oil in the cheaper soaps in which that has hitherto been employed on a large scale. (See Coco-nut-oil; Soap.) It is slightly softer than good coco-nut-oil, its fusing-point being tolerably constant at $25\frac{1}{2}°$ (78° F.). If, however, the *whole* of the oil be removed from the kernels (by a suitable solvent), the resulting meal is not so fattening for cattle, but the oil is slightly harder, containing a larger proportion of the higher terms of the series, lauric (or lauro-stearic) acid, cocinic acid, &c. The oil itself, being tolerably pure, is a neutral glyceride, and does not readily get rancid. Its fatty acids, however, are partly fixed and partly volatile, like those of coco-nut-oil.

Phulwara-oil.—The *phulwara* or "Indian butter-tree" (*Bassia butyracea*) is a native of Nepal and the Almorah Hills, ranging between 1500 and 4500 ft. in elevation. The seeds or kernels, having the appearance of blanched almonds, are bruised to the consistence of a fine pulp, which is placed in cloth bags, and left under a moderate weight until the oil has escaped. The latter immediately assumes the consistence of hogs' lard, and remains in this semi-solid condition in the ordinary temperature of the plains of India, say 35° (95° F.), but melts completely at 49° (120° F.). It has a delicate white colour, keeps for many months in India without exhibiting any unpleasant flavour or odour, and is soluble in warm alcohol. Locally, it is extensively used as a medicinal application, as a perfumed ointment, and as an adulterant of *ghee* (clarified animal butter). It makes an excellent soap, burns in lamps with a bright flame free from smoke and smell, and is suitable for candle-manufacture. The refuse cake after extraction of the oil is eaten by the Indian poor. For oils yielded by other species of *Bassia*, see Illipi-butter (p. 1392), Mahwa-oil (p. 1394), and Shea-butter (p. 1410).

Pine-oils.—It is said that Prof. Guillemare has succeeded, by a very simple chemical process, in obtaining a lamp-oil, of unusual brightness and cheapness, from the resin of *Pinus maritima* (see Resinous Substances), which grows in great numbers on the S.-W. coast of France, and in Dalmatia. Pine oil is produced in Sweden by distilling refuse wood; 3 out of 15 factories there made over 3000 gal. in 1870. A similar product is obtained from *P. Abies*, in the Black Forest. Their sp. grs. vary from 0·926 to 0·931, and all have very low congealing-points, say below −25° (−14° F.). The quantity of oil extractable by carbon bisulphide from the seeds of various kinds of pine, fir, spruce, &c., varies from 11–12 per cent. in the hemlock-spruce, to 29 in the Swiss stone-pine and Weymouth pine.

Piney-tallow (Fr., *Suif de Piney*).—The seeds of *Vateria indica*, an Indian tree (see also

Resinous Substances—Piney-varnish), are cleaned, roasted, ground, and boiled in twice their bulk of water till the oil floats; the latter is removed, and the contents are stirred, and left till the following day, when more oil will have separated. It is a solid fat, melting at 35°–36° (95°–97° F.), of sp. gr. 0·926 at 15° (59° F.), white, greasy, and of agreeable odour; it makes excellent candles.

Piquia-oil.—The fruits of *Caryocar brasiliense*, a native of Guiana and Brazil, yield a sweet concrete oil, of brown colour, retaining much of the flavour of the fruit.

Pistachio-nut-oil (Fr., *Huile de Lentisque*).—An oil is extracted from the pistachio-nut (see p. 1359) on a small scale in Italy. The oil is greenish-coloured, sweet-flavoured, and aromatic; it is used in food, but soon becomes rancid, and is then applied to lighting purposes.

Plum-oils.—The kernels of the common plum (*Prunus domestica*) are pressed, in Wurtemberg, and made to yield a limpid illuminating-oil; its sp. gr. is 0·9127 at 15° (59° F.), and its congealing-point is −9° (16° F.); it soon becomes rancid. The apricot (*P. armeniaca*) gives an oil used in India for cooking, in lamps, and on the hair. The Briançon plum (*P. brigantiaca*) is similarly utilized in France, &c., by expressing the peeled kernels; the oil is well known under the name of *huile de marmotte*, and is largely used instead of, or as an adulterant of, almond- and olive-oils.

Poondy-oil.—The seeds of *Myristica malabarica*, a native of the forests of Malabar and Travancore, when bruised and boiled, yield a quantity of yellowish concrete oil, which, when melted down with a little bland oil, is applied efficaciously to ulcers.

Poppy-oils (Fr., *Huile d'Œillette, de Pavot*; Ger., *Mohnöl*).—Oil is yielded by the seeds of three kinds of poppy—the opium-poppy (*Papaver somniferum*), the spiny-poppy (*Argemone mexicana*), and the yellow-horn poppy (*Glaucium luteum*).

The cultivation of the first-named has been described at length under the head of Narcotics—Opium. In Asia Minor and Persia, after the collection of the opium from the poppy-heads (see p. 1309), the latter are gathered, and the seed is shaken out and preserved. It is black, brown, yellow, or white; some districts produce more white seed than others. The seed is pressed in wooden lever presses, to extract the oil, which is used by the peasants for culinary and illuminating purposes. Some of the seed is also sold to Smyrna merchants, who ship it to Marseilles, where it is employed in soap-making, and as a substitute for linseed-oil. The average yield of oil is 35–42 per cent., the white seed being considered the richest. Samsoon, in 1878, exported 454,820 *kilo.* of poppy-seed, value 5458*l.*, to France. The values of the exports of poppy-seed from Bushire in 1879 were 25,000 rupees (of 2*s.*) to England, and 17,000 to India. The same economy takes place in India, where the plant is also grown for the sake of its seed alone in some districts. In this latter case, the sowing takes place in March–April, about 2 lb. of seed being sown broadcast to one acre. The seed-vessels ripen in August; the heads are then cut off, sun-dried, sorted, and trodden out in bags, or threshed. The seed is immediately crushed and pressed, the yield of oil being in proportion to the freshness of the seed, and amounting to 14 oz. from 4 lb. under favourable conditions. The oil readily bleaches by exposure to the sun in shallow vessels, and is then transparent and almost tasteless. The natives use it very largely for cooking purposes, and as a lamp-oil. The cake is consumed as food by the poorer classes. The unpressed seed is largely exported from India, almost exclusively from Bengal; the shipments were 449,394 cwt. in 1878, and 249,072 in 1879. About $\frac{2}{3}$ of the total come to England, and $\frac{1}{3}$ goes to France. The latter country grows a large quantity of poppy-seed at home, over 100,000 acres in the N.-W. having been returned as under this crop some few years since. The French oil is of two kinds, a white cold-drawn oil, and a coarser oil obtained by a second expression and from inferior seed, the total yield being 40 per cent. The finer oil is fit for alimentary purposes, and is largely used to adulterate olive-oil; it is also employed as a lamp-oil, and very extensively by artists for grinding light pigments, as, though possessing less strength and tenacity than linseed-oil, it keeps its colour better. The coarser kind is chiefly made into hard soaps in S. France, being used with other oils to the extent of about a quarter. The pure oil has a golden-yellow tint, and agreeable flavour; its sp. gr. is 0·924 at 15° (59° F.); it solidifies at −18° (0° F.), and remains long in this state at −2° (28½° F.); is slow to become rancid, and saponifies readily; dissolves in 25 parts cold and 6 parts boiling alcohol; and dries in the air more rapidly than linseed-oil.

Argemone mexicana, a native of Mexico, has become distributed all over the globe, and is found abundantly in waste places and in rubbish heaps, notably in the E. Indies and America. In Bengal, and more or less throughout India, the seeds are collected and expressed for their oil, which is yielded almost as plentifully as from mustard-seed. The drawn oil is twice allowed to stand for a few days to deposit a whitish matter, after which it remains clear and bright. It has a light-yellow colour, slightly nauseous odour, and raw flavour; it remains liquid at 5° (41° F.), dissolves in 5–6 volumes of alcohol at 0·818 sp. gr., and saponifies readily. It burns well, and has been recommended as a lubricator, besides being credited with medicinal virtues.

Glaucium luteum is a common plant on the sandy shores of the Mediterranean, the W. coast of Europe as far as Scandinavia, and some parts of N. America. It is very hardy, and cultivated with little trouble. It prefers stony and chalky soils, where few other plants will thrive, and has therefore been recommended for culture on such otherwise waste land. Under cultivation, it affords about 10 bush. of seed per acre. The seed contains 42½ per cent. of oil, and yields about 32 per cent. by pressure. The oil obtained by cold expression is devoid of odour and flavour, and has a sp. gr. of 0·913. It is applicable to culinary and illuminating purposes, as well as for soap-making and paint. The cake is a good phosphatic manure. It seems to have been very little utilized, probably on account of the comparatively small yield of seed.

The common red poppy (*Papaver Rhœas*) has been described under Dyestuffs (p. 864); in France, it is cultivated in Artois and Picardy, and the seeds are pressed on the spot for their oil, which is known as "white oil."

Pulza-, Seed-, or Purqueira-oil (Fr., *Huile de Médicinier, de Pignon d'Inde*).—The seeds of *Curcas purgans* (see Nuts—Physic-nut, p. 1359) yield a large quantity of oil, some 350,000 bush. of the seed being sent annually from the Cape Verdes to Portugal for expression. This operation is performed in the dry, on seeds slightly roasted and crushed; 1000 lb. of the seeds give 640 lb. of kernels, which yield 260 lb. of oil. The industry is carried on most extensively at Lisbon.

Safflower- or Curdee-oil.—The seeds of the safflower (see Dyestuffs, p. 865) afford about 20 per cent. of fatty oil. The plant is cultivated chiefly for the sake of its dye, but the abstraction of the petals for this purpose (see pp. 865–6) does not affect the yield of seed. There are two ways of extracting the oil from the seed:—(*a*) The seeds are freed from husks, crushed, and pressed, the product being about 25 per cent. of oil, of light colour, and good burning qualities. (*b*) An earthen jar is set in the ground, and covered with an earthen plate having a hole of about ¼ in. diameter in the centre; upon the plate, is inverted a second jar filled with the seed, the joints are carefully luted with clay, and earth is piled up to the shoulder of the inverted jar; dried cow-dung is then heaped around the upper jar, and kept burning for about ½ hour. On completion of the operation, the upper vessel will be ½ full of charred seed, and the lower ⅓ full of black sticky oil. The latter, extracted in this way, is valueless for burning, but esteemed by the natives above all others for preserving leathern vessels exposed to water, and the yield is ¼ more than by the press. The expressed oil is light-yellow and clear, and used locally for culinary and other purposes; it is also said to enter largely into the composition of the so-called "Macassar hair-oil." Its industrial qualities have been neglected in Europe.

Shea-, Galam-, or Bambouk-butter.—The *cé*, *shea*, or butter-tree of W. Africa (*Butyrospermum* [*Bassia*] *Parkii*) forms miles of forest on the S. bank of the Niger, and the same or an allied species, locally termed *lulu*, is common on the river Djour, in the Bahr el Ghazal province, where its "butter" is used by the natives in cooking. The seeds, as large as pigeons' eggs, are exposed for several days to dry in the sun, and reduced to flour in a mortar; the flour is placed in a vessel, sprinkled with warm water, and kneaded to the consistence of dough. When the kneading has proceeded so far that greasy particles are detached by the addition of hot water, this last operation is repeated until the fat is completely separated, and rises to the surface. The fat is then collected, and boiled over a strong fire, with constant skimming, to remove any remaining pulp. When sufficiently boiled, it is poured into a damp mould, and, when set, is wrapped in leaves, and will keep thus for two years. The yield is 30–40 per cent. The "butter" is white, with sometimes a reddish tinge, and may be rendered white by repeated filtration in a warm closet; it resembles tallow in appearance, but is more unctuous, and greases the fingers; it has a faint characteristic odour, and a sweetish flavour. Its melting-point is variously stated, from 23°–24° (73½°–75¼° F.) to 43° (109½° F.). According to one authority, the fatty acid is margaric, and its melting-point is 61° (142° F.); according to others, there are two fatty acids, stearic and oleic, the melting-point of the mixture being 69° (156° F.). Yet another authority states the proportions as 7 of stearine to 3 of oleine, and states that when acidified and distilled, it gives a yellow, crystalline fatty acid melting at 56° (133° F.), and when pressed, at 66° (151° F.), but that it cannot be used for candle-making, as it is soft, despite its high melting-point. It dissolves entirely in the cold in turpentine-spirit, incompletely in ether, and is almost insoluble in alcohol. It saponifies readily with alkalies. There is also present in it, in the proportion of ½–¾ per cent., a substance resembling guttapercha, and which has been called "guttashea" (see Resinous Substances). It is insoluble in alcohol, alcohol and ether mixed, acids, and alkalies; but slightly soluble in pure ether, and in ordinary animal and vegetable fats. It can be removed from the fat by dissolving in a mixture of 3 parts of ether and 1 of alcohol, when it separates in a filmy state, more readily if the fat be first saponified. It exists ready-formed in the oil, some in suspension, removable by filtration, some in solution in the fat. The fat itself, shea-butter, is imported to the extent of 300–500 tons annually, from Sierra Leone, for use in the manufacture of hard soaps, chiefly in combination with other oils. It is largely consumed in some of the Continental candle-factories. The natives employ it for food, for anointing, and for lighting. Other *Bassia*-oils are described under Illipi-butter (p. 1392), Mahwa-oil (p. 1394), and Phulwara-oil (p. 1408).

Simbolee-oil.—A clear, transparent oil is expressed from the seeds of the "curry-leaf" tree (*Bergera* [*Murraya*] *Königii*), in Bengal and S. India.

Siringa-oil.—The seeds of *Hevea brasiliensis* [*Siphonia elastica*] (see Resinous Substances—Indiarubber) afford an oil which is useful for making hard soaps, and printing-ink.

Soap-nut-oil.—A semi-solid oil is obtained from the seeds of *Sapindus emarginatus* [*trifoliatus*] (see Nuts—Soap-nuts, p. 1360) in India, and is used medicinally. Another oil is procured from *S. Saponaria* in the W. Indies and N. Central America.

Sunflower-oil.—The sunflower (*Helianthus annuus*) has long been grown for its oil-seeds in Russia and India, and the cultivation has more recently been taken up in Germany and Italy. The plant grows readily in most soils, but prefers light, rich, calcareous land, unshaded by trees. In Russia, the seed is drilled into lines 18 in. apart, and the plants are thinned out to 30 in. apart in the rows, thus giving about 11,000 plants in an acre. The quantity of seed required for an acre is 4–6 lb., and the sowing takes place in September–October, the crop being ready to harvest in February. In England, it is recommended for any vacant ground, to be planted 6 in. apart and 1 in. deep, and to be earthed up when 1 ft. high, requiring no subsequent attention. The yield of seed is much increased by topping the plants, and the best manure is old mortar. Each plant produces about 1000 seeds, chiefly on the main head. Experimental culture in France gave a return of 1778 lb. of seed, yielding 15 per cent. of oil (275 lb.), and 80 per cent. of cake, from an acre; but the product varies considerably according to soil, climate, and cultivation, and the average may be roundly stated at 50 bush. of seed from an acre, and 1 gal. of oil from 1 bush. of seed. The percentage of oil to seed ranges from 16 to 28; and that of husk to kernel, from 41 to 60. The Italian cultivation is confined to the neighbourhoods of Piove and Conegliano, in Venetia. In Russia, the plant is most extensively grown in Kielce and Podolia, and the district of Birutch, in Voronej; the production of seed is now estimated at 8 million *poods* (of 36 lb.), from an area of 80,000 *dessatines* (of 13,067 sq. yd.) In Tartary and China, it is cultivated in immense quantities, but no actual statistics are available. In India (Mysore), 1 acre of land gives 11½ cwt. of seed, which yields 45 gal. of an oil which is there compared with ground-nut-oil, and applied to the same uses. The Russian seed is expressed on the spot, and the oil is largely employed for adulterating olive-oil. The purified oil is considered equal to olive- and almond-oil for table use. The chief industrial applications of the oil are for woollen-dressing, lighting, and candle and soap making; for the last-mentioned purpose, it is superior to most oils. It is pale-yellow in colour, thicker than hempseed-oil, of 0·926 sp. gr. at 15° (59° F.), dries slowly, becomes turbid at ordinary temperatures, and solidifies at −16° (4° F.). The cake is excellent food for cattle and poultry, and the stems yield a fibre (see Fibrous Substances—*Helianthus*, p. 961).

Tea-oil.—The seeds of the tea-plant, *Camellia Thea* [*Thea chinensis*] (see Tea), contain a considerable proportion of oil, as much as 1 cwt. being obtainable by industrial means from 3 cwt. of seed. The oil resembles that of the olive, burns with a clear, bright light, and is free from unpleasant odour. The general extraction of this oil is recommended to tea-planters. But there is every reason to believe that the "tea-oil" which figures largely in Chinese and Japanese commerce is not the product of the tea-plant, but of an allied species (*C. Sasanqua*, or *C. oleifera*). The Chinese assert that this plant is identical with the tea-plant, only cultivated differently; but they may have easily confounded the two plants, and additional confusion has arisen from the fact that the Japanese add *Camellia*-leaves to their tea, on account of their pleasant aroma. The *Camellia* is very largely cultivated in China, the shrubs being grown to a height of 8–9 ft. The seeds are crushed to a coarse powder, boiled, and pressed. The oil is employed locally for many domestic purposes, and is an important article of trade. Hankow exported 3640½ *piculs* (of 133⅓ lb.) in 1878, and 5826 *piculs*, value 11,442*l.*, in 1879; Shanghai, in 1879, imported 5792¼ *piculs*, and exported 2991½. Another species, *C. drupifera*, grows abundantly on the E. Himálaya, and under cultivation in Cochin China; in the latter country, its oil is used medicinally.

Tobacco-oil.—The seeds of the tobacco-plant (see Narcotics—Tobacco, p. 1325) contain about 30 per cent. of a fatty oil, which is extracted by powdering them, kneading them into a stiff paste with hot water, and pressing hot. The oil is clear, limpid, golden-yellow in colour, inodorous, and mild-flavoured; its density is 0·923 at 15° (59° F.); it remains liquid at − 15° (6° F.), dissolves in 168 parts of alcohol at 0·811 sp. gr., and saponifies readily. One authority excludes it from the drying oils; another considers its drying quality to be unusually developed, and recommends it for paints and varnishes.

Tucum-oil.—The fruit-pulp of the *tucum*, *aouara*, or *kiourou* (*Astrocaryum vulgare*), of Brazil and Guiana, yields an oil used for many different purposes. The palm is more important perhaps as a fibre-yielder (see Fibrous Substances—*Astrocaryum*, p. 920).

Tung-, Tree-, or Wood-oil.—This fatty oil is a product of the so-called "oil-tree" of China, Cochin China, and Japan (*Aleurites cordata* [*Elæococca vernicia*, *Dryandra cordata*]), and must not be confounded with the Malayan article, which is an oleo-resin (see Resinous Substances—Gurjun). The fruit capsules of the *t'ung* are filled with rich oil-yielding kernels, from which 35 per cent. by weight of oil may be obtained by simple pressure in the cold. The sp. gr. of the oil is 0·9362 at 15° (59° F.). It possesses several remarkable properties: heated to 100°–200° (212°–

392° F.) out of contact with the air, it retains its original limpidity after cooling, but in contact with the air, it solidifies almost instantaneously, melting again at 34° (93° F.), and exhibiting the same elementary composition; the cold-expressed oil rapidly solidifies by light in the absence of air; and its drying qualities exceed those of any other known oil. It is devoid of colour, odour, and flavour. The oil is produced in immense quantities in China; in the provinces of Ichang and Szechuen, it is one of the principal articles of native manufacture, and its importance in local commerce is shown by the following statistics:—Hankow, the chief market for the export trade, exported 336,053 *piculs* (of 133⅓ lb.) in 1878, and 203,820½ *piculs*, value 317,548*l.*, in 1879; Shanghai imported 69,223⅗ *piculs*, and exported 31,492⅗, in 1879; Chefoo imported 4011 *piculs* in 1878, and 2847 in 1879; Chinkiang imported 184,442 *piculs* in 1878, and 117,082 in 1879; Ningpo imported 29,652 *piculs* in 1878, and 13,915 in 1879; Wuhu imported 11,916½ *piculs* in 1878, and 6695 in 1879, in foreign craft, and, in the latter year, a quantity estimated at 3711 tons in native craft. In China, the oil is universally employed for caulking and painting junks and boats, and for varnishing and preserving woodwork of all kinds; also for lighting, though considered inferior to *Camellia*-oil (see Tea-oil) for this purpose, and in medicine. The oil is unknown to European commerce, but an attempt to naturalize the tree in Algeria has been projected. Its industrial value has been too long neglected.

Vegetable Tallow (Fr. *Suif d'arbre*).—At least two vegetable fatty substances are known by the name of "vegetable tallow."

(*a*) *Chinese.*—The vegetable tallow of China is produced by the "tallow-tree" (*Stillingia* [*Croton, Sapium, Excœcaria*] *sebifera*). It is a native of China and the adjacent islands, and has been introduced and naturalized in India and the warmer parts of America. In China, it is chiefly cultivated in the province of Chekiang, and the adjacent Chusan Archipelago, in Kiangse, and in Hoopih. In India, it thrives in the N.-W. Provinces and the Punjab, especially at Paonee, in Gurhwal; at Ayar Tali and Hawul Baugh, in Kumaon; and in the Kangra Valley. The tree flourishes equally well on low alluvial plains, in the rich mould of canals, in sandy soils, and on mountain slopes. Its fruits are about ½ in. in diameter, and contain 3 seeds, thickly coated with a fatty substance, whence the "tallow" is obtained. The ripe fruits are gathered at the commencement of the cold weather, November–December, when all the leaves have fallen, by means of a sharp crescent knife, attached to a long pole. The seeds are first picked from the stalks, and bruised in a mortar to loosen the shells, which are sifted away. The clean seeds in their fatty envelope are next placed in a wooden cylinder, open at the top, and with convex open wickerwork bottom, suspended within iron dishes 6–8 in. deep, containing water which is made to boil; the seeds are thus steamed for 10–15 minutes, when they are removed, and mashed in large mortars, and thence transferred to bamboo sieves, kept at a uniform temperature by means of live ashes. The tallow separates, and escapes through the sieves, forming a solid mass. (The seeds are usually passed through the steaming and straining processes a second time. Finally the seeds are themselves treated for their oil, as will be described presently.) The tallow now resembles coarse linseed meal, its brown colour arising from the thin skin between the seed and the tallow, which is separated by pounding and sifting. The tallow is next put between circles of twisted straw, 5–6 of which, laid upon each other, form a hollow cylinder, bound with bamboo hoops 3 in. wide. The straw cylinders when filled are placed in a rude press with their hoops attached. The tallow is forced out in a liquid state, and is collected in receptacles, where it solidifies on cooling. It is again melted, and poured into moulding-tubs, sprinkled inside with dried red earth, to prevent adhesion. When cold, it is turned out in masses of 80 lb., a hard, brittle, pure opaque white, tasteless and odourless fat. Its melting-point varies from 37° to 44° (98½°–111¼° F.), and its composition is almost pure stearine. The yield is about 20–30 per cent. of the weight of the seeds. Its chief and almost only application in China is for making candles, which are usually coated with wax; in India, it has been tried as a lubricator; and it is found to burn well, without smoke or smell. An immense native trade is carried on in it in China. Hankow exported 89,269 *piculs* (of 133⅓ lb.) in 1878, and 90,413½ *piculs*, 229,099*l.*, in 1879; Shanghai imported 46,611½ *piculs*, and exported 6003¼, in 1879; Chinkiang imported 44,987 *piculs* in 1878, and 42,943 in 1879; Ichang exported 843 *piculs*, 1119*l.*, in 1878, and 657½ *piculs*, 996*l.*, in 1879; Kiukiang exported 6207 *piculs*, 11,033*l.*, in 1878, and 4559 *piculs* in 1879; Wenchow exported 69 *piculs*, 416*l.*, in 1878, and 290¼ *piculs* in 1879; Wuhu imported 4814½ *piculs* in 1878, and 4287½ in 1879.

The oil previously alluded to as being obtained from the kernels of the seeds after removal of the tallow is extracted in the following manner:—The seeds are ground between mill-stones, which are heated to prevent clogging by the tallow still adhering. The mass is then winnowed, and the clean kernels are steamed, and mashed in a cumbrous edge-runner mill. The meal is steamed in tubs, made into cakes, and pressed, the whole course of operations being performed twice. The yield is about 30 per cent. of the cleaned kernels. The oil is used for varnishing umbrellas, anointing the hair, and medicinally; it burns well in lamps, but is inferior to some other oils in use for that purpose. The seed-husks and tallow-refuse are employed as fuel; the seed-cake forms a good manure, especially for tobacco.

(b) *Malayan.*—In Borneo, Java, and Sumatra, are several species of *Hopea*, producing nuts, which, when compressed, yield fatty oils, extensively used under the names of "vegetable tallow" and "vegetable wax." Three species of this genus are common in Sarawak; the one most valued for producing oil is a fine tree growing on the banks of the Sarawak river to a height of 40 ft.; its fruits are produced in the greatest profusion about December–January, and are as large as walnuts. These nuts are collected by the natives, and yield a very large proportion of oil, which, on being allowed to cool, takes the consistence of sperm, and in appearance very much resembles that substance. The natives at present only value this as a cooking oil; but when the demand for it in Europe becomes better known to them, they will doubtless increase their manufacture of it. In England, it has proved to be an excellent lubricator for steam machinery, far surpassing even olive-oil; and it has been used in Manilla in the manufacture of candles, and found to answer admirably. As it becomes more common, it will doubtless be applied to many other purposes. From the quickness of its growth, and the great profusion with which it bears its fruit, it will, should the demand for it continue, become a profitable object for cultivation, by which the quality and quantity would most likely be improved and increased. It is also found in Java and Sumatra. In Borneo, some 10 species are recognized by the natives, their nuts varying much in size. The kernels are covered with a hard shell, to separate which it is necessary to immerse them in water for 3–4 days. After the separation, they are exposed to the sun for about the same number of days, until the oil begins to exude; they are then pounded in a mortar, and boiled in water for some time; after which, the oil is expressed while hot. This oil has nearly the consistence, and something of the appearance, of tallow, but is generally yellower. It is found in the markets in rolls 1½–3 in. in diameter. It is used in the interior almost exclusively for lighting and culinary purposes. A vegetable tallow is also afforded by the seeds of *Tetranthera laurifolia*, widely dispersed over Tropical Asia, and the E. Archipelago, as far south as New Guinea. In Java and Cochin China, it is commonly used for making candles, notwithstanding its disagreeable odour. The exports of vegetable tallow from the state of Sarawak in 1879 were valued at 7305 dollars (of 4*s.* 2*d.*).

Both Chinese and Malayan kinds of vegetable tallow, like shea-butter, are glycerides, and contain about 95 per cent. of saponifiable matter, which has much less oleine in it than animal tallow.

(c) *African.*—A so-called vegetable tallow or butter is obtained in Sierra Leone from *Pentadesma butyracea*; the tree yields from its several parts, especially the fruit when cut, a yellow fatty juice. The fat of a species of *Pentadesma*, under the name of *kanya*, is used for culinary purposes in the neighbourhood of Zanzibar, and is said to remain sweet for a long time.

Walnut-oil (Fr., *Huile de Noix*).—The albuminous kernel of the walnut (see Nuts, p. 1360) affords some 50 per cent. of oil. It is said that it furnishes one-third of all the oil made in France; it is extensively prepared in the central and southern departments, notably Charente, Charente-Inférieure, and Dordogne, where it is commonly met with in barrels of 50 *kilo.* In both Spain and Italy, outside the olive-region, walnut-oil is largely expressed. It is of considerable importance in the hill districts of India, but is seldom seen in the plains. Cashmere and Circassia also include it among their industrial products.

The oil should not be extracted from the nuts until 2–3 months after they have been gathered. This delay is absolutely necessary to secure an abundant yield, as the fresh kernel contains only a sort of emulsive milk, and the oil continues to form after the harvest has taken place; if too long a period elapse, the oil will be less sweet, and perhaps even rancid. The kernels are carefully freed from shell and skin, and crushed into a paste, which is put into bags, and submitted to a press; the first oil which escapes is termed "virgin," and is reserved for feeding purposes. The cake is then rubbed down in boiling water, and pressed anew; the second oil, called "fire-drawn," is applied to industrial uses. The exhausted cake forms good cattle-food.

The virgin oil, recently extracted, is fluid, almost colourless, with a feeble odour, and not disagreeable flavour. Its sp. gr. is 0·926 at 15° (59° F.), and 0·871 at 94° (201¼° F.); it thickens to a butter-like consistence at −15° (5° F.), and solidifies to a white mass at −27½° (−17½° F.). In the fresh state, it is largely used in Nassau, Switzerland, and other countries, as a substitute for olive-oil in salads, &c., but is scarcely to be considered as a first-class alimentary oil. The fire-drawn oil is greenish, caustic, and siccative, surpassing linseed-oil in the last respect, and exhibiting the property more strongly as it becomes more rancid. On this account, it is preferred by many artists before all other oils. It affords a brilliant light; and may be used in the manufacture of soft-soaps.

Zachun-oil.—The seeds of *Balanites ægyptiaca*, of India, Egypt, Senegambia, and W. Coast Africa, afford an oil called *zachun* by the negroes.

Miscellaneous and Unenumerated.—The exports of unenumerated seed-oil from Holland were 18,787,000 *kilo.* in 1879. Dantzig exported 11,350 tons of oil-seeds, value 124,850*l.*, in 1879, chiefly to Holland and France. Russia exported 916,172 *chetverts* (of 5¾ bush.) of seed-oil in 1878. Venice exported 16,801 tons, value 765,194*l.*, of oil, and 3944 tons, value 79,114*l.*, of oil-seeds, in 1879.

In addition to the oils already specified in the preceding pages, the following plants are recorded as being capable of affording oil, the oleaginous part being the seed, unless otherwise specified :—

Acrocomia sclerocarpa, all over S. America.

Adenanthera pavonina, S. India, Bengal, and Burmah.

Allium sp. div., India; clear, pale, limpid, with strong garlic odour; used medicinally.

Amoora Rohituka, India and Ceylon; oil has many economic uses in Bengal.

Anda Gomesii, Brazil; medicinal.

Apeiba Tibourbou, Brazil, Venezuela, &c.

Arctium Lappa, the burdock, growing wild over Europe and Asia, gives 20 per cent. of oil.

Aspidium Filix mas (male-fern); obtained by treating the ether-extract of the tubers with water containing ammonia, and evaporating; thick, grass-green, liquid much below 0° (32° F.), used medicinally. (See Drugs, p. 811).

Astrocaryum acaule, Brazil.

Atropa Belladonna (see Drugs—Belladonna, p. 794); oil extracted in Wurtemburg, used for lighting and food; limpid, inodorous, sp. gr. 0·925 at 5° (41° F.), thickens at −16° (4° F.), and solidifies at −27½° (−19° F.).

Attalea Cohune, Honduras and Guiana, from the fruits, "Cohune-nuts."

Ballota nigra (black stinking horehound), proposed for cultivation in Savoy.

Bauhinia candida, India.

Bombax sp. div., India generally.

Bryonia callosa, India; extracted by boiling in water; a lamp-oil.

Carduus pycnocephalus, S. Europe and Réunion.

Celastrus sp. div., India, Brazil, &c.; deep-scarlet oils, used for burning in lamps, and medicinally.

Cerbera sp. div., E. and W. Indies, and S. America; *C. Manghas* [*Odollam*], oil used by Burmese and in India for lamps and anointing; *C. Thevetia*, "exile oil," naturalized in India.

Chironia scabrida, E. Indies.

Chrysobalanus Icaco, the *icaco* of Tropical America, and *ouaraye* of Senegal.

Cochlospermum Gossypium, India.

Connarus sp. div., India and Tropical S. America; sweet oil.

Cornus mascula (cornelian cherry), Europe and N. Asia.

Couepia dulcis, French Guiana.

Coula edulis, abundant on the Gaboon, is said to afford 53 per cent. of edible oil from its fruits.

Cynometra sp. div., India; wholly medicinal.

Cyperus esculentus; expressed from the tubers; yellow, mild, inodorous, sp. gr. 0·919, solidifies at 0° (32° F.), and saponifies readily.

Daphne Mezereum; by expressing the fruits; yellowish, drying oil, sp. gr. 0·8903 at 15° (59° F.), liquid at −16° (4° F.); contains 90 per cent. linoleine and oleine, and 10 per cent. stearine, palmitine and myristine.

Eriodendron anfractuosum, India, Cuba, &c.; clear, dark-brown.

Euphorbia Lathyris, France, Germany, and Switzerland, on the edges of fields and cultivated spots; 40 per cent. of a fluid oil, formerly used in medicine. *E. dracunculoides*, in India (*jy-chee*); 25 per cent. of the mature, husked seed; a drying oil equal to linseed-oil, but more fluid, does not become ropy with age, and emits scarcely any smoke while burning.

Feronia elephantum, India, Java, &c.

Fevillea sp. div., Brazil, Venezuela, and Tropical America generally; *F. cordifolia*, the *sequa*, affords a large quantity of semi-solid oil by pressing and boiling; the *abilla*-seeds of an allied Peruvian species contain so much oil that they are burnt as candles, and withstand considerable wind.

Heritiera sp. div., coasts of India, Africa, E. Archipelago, and cultivated in W. Indies.

Hesperis matronalis (dames' violet), Europe; greenish to brownish, sp. gr. 0·928, odourless, dries readily, quite liquid at −15° (5° F.).

Hura crepitans, W. Indies and India; a clear, pale, fluid, medicinal oil.

Hyoscyamus niger (see Drugs—Henbane, p. 812); pale green-yellow, thin, mild, inodorous, sp. gr. 0·913, scarcely soluble in 60 parts absolute alcohol.

Illicium anisatum (see Spices—Aniseed); a large quantity of fixed oil. (See also p. 1417.)

Impatiens sp. div., India, Europe, and N. America; for comestible and illuminating purposes.

Jatropha glauca, E. Indies; the seeds are collected when the capsules begin to split, and darken in colour; the fruits are placed between mats in the sun for a few hours to separate the seeds and husks, and the former are crushed and expressed; oil is fluid and light straw-coloured; used medicinally.

Kokoona zeylanica, Ceylon and the W. Peninsula; a lamp-oil.

Lactuca sativa (lettuce), India; clear, transparent and sweet.

Lecythis ollaria (see Nuts—Sapucaya, p. 1359).

Lepidium sativum (cress); brown-yellow, sp. gr. 0·924, thick and turbid at −6° (21° F.), solid at −15° (5° F.), dries slowly.

Litsæa [*Cylicodaphne*] *sp.*, Punjab, Himálaya, Java, &c.; the fruits of one tree give enough fat for 500 candles.

Livistona sinensis, N. Central America.

Lucuma mammosa, W. Indies.

Maclura aurantica (Osage orange); abundant, bland, limpid, resembling olive-oil, and burning with a steady flame.

Manicaria saccifera, French Guiana.

Mauritia flexuosa and *M. vinifera*, Brazil.

Mesua ferrea, the *naghassar* of India, and in Java; dark, thick, and freely deposits stearine; used in lamps, and medicinally.

Mimusops sp. div. (see Timber), India, Ceylon, and the Archipelago; yielded abundantly; used medicinally and by painters.

Monodora grandiflora, E. and W. Tropical Africa.

Myristica angolensis, the *combo* of Gaboon, 72 per cent.; *M. longifolia*, E. Indies, 54½ per cent.

Nigella sativa (see Spices—Cumin), cultivated in Belgium, Egypt, and India; oil dark-coloured and fragrant.

Ocimum basilicum, E. Indies, Java, &c.

Oreodoxa [*Areca*] *oleracea* and *O. regia*, Réunion and Guadeloupe.

Pachira aquatica, Guiana and the Antilles.

Pangium edule, E. Archipelago, yield a fatty oil by expression.

Parkia biglandulosa, E. Indies, 18 per cent.

Paulownia imperialis [*Bignonia tomentosa*]; the *toï*-oil of Japan.

Pekea ternatea, Antilles.

Perilla ocimoides, Japan, used for making water-proof papers.

Persea gratissima (alligator pear), Tropical America, W. Indies and India; an abundant oil for illuminating and soap-making may be expressed from the fruit-pulp.

Pithecolobium dulce (Manilla tamarind), Mexico, Philippines, and India; light-coloured oil, with consistence of castor-oil.

Polanisia [*Cleome*] *viscosa*, Tropical India, Java, &c.; 9 per cent.; light olive-green, very liquid.

Prinsepia utilis, India; an edible and illuminating oil.

Putranjiva Roxburghii [*Nageia Putranjiva*], Central and Peninsular India; oil is olive-brown, and soon deposits solid portion; used for burning.

Raphanus sativus (radish), India; resembles colza, and has the same uses.

Reseda luteola (see Dyestuffs—Weld, p. 868), dark-green, thin, nauseous odour and flavour, sp. gr. 0·935, dries rapidly, liquid at −15° (5° F.).

Rottlera tinctoria [*Mallotus philippinensis*] (see Dyestuffs—Kamala, p. 861), E. Indies, *polongo-* or *kalapa*-oil; clear, limpid, sherry-coloured; used medicinally.

Salvia Chio, Guatemala; a drying oil, superior to linseed.

Schleichera trijuga, Indian Peninsula, Ceylon, and Burma; a lamp-oil. (See also Timber).

Sterculia fœtida, India, Ceylon, Java, &c.; extracted by boiling in water; semi-solid, deposits much stearine, becomes rancid within 10 days; 15 per cent.

Symplocos cratægioides, Indus to Assam.

Tamarindus indica, E. and W. Indies; clear, bright, and fluid; gives a good light, without smoke or smell.

Telfairia pedata, Mauritius and Zanzibar, preferring light soil near water; each fruit contains 200–300 seeds, giving a nett weight of 50 lb., which yield 8 lb. of excellent bland oil; edible.

Thespesia populnea, most E. tropical countries, W. Africa, W. Indies, S. America, and Pacific Islands; deep-red, thick oil, used medicinally.

Thlaspi sp. div., proposed in France; 20 per cent.

Tilia parviflora, 30–40 per cent. by carbon bisulphide.

Trichilia capitata, Zambesi, large quantity of solid fat; also *T. emetica*, the *roka* of the Arabs.

Trigonella fœnum-græcum, 6 per cent., fœtid, bitter.

Vernonia anthelmintica, S. India; solid, greenish; used medicinally.

Wrightia antidysenterica, E. Indies, medicinal.

Ximenea sp. div., W. Africa; 70 per cent., good for soap-making.

Zea Mays (maize); limpid, yellowish; burns well, and is a good lubricator.

VEGETABLE OILS [*B. VOLATILE AND ESSENTIAL*].

Acorn-oil.—The fruits of *Quercus robur* (see Timber—Oak), when distilled with water, yield an essential oil of buttery consistence, and peculiar, strong odour.

Albahaca-oil.—The *Myroxylon peruiferum* (see Resinous Substances—Tolu balsam) affords an essential oil of sp. gr. 0·892 at 13° (55½° F.), with a pleasant, aromatic, sassafras-odour.

Allspice- or Pimento-oil.—Both the fruit and leaves of several kinds of allspice or pimento (see Spices—Pimento) afford essential oil. The oil is most commonly extracted from the fruits. These, dried before they are quite ripe, are ground, and distilled with water. The product amounts to about 3–4½ per cent., rarely almost 6 per cent.; analysis reveals the presence of 10 per cent. in the husks, and 5 per cent. in the kernels. The yield of oil from the leaves has not been ascertained, but it is said to be considerable, and that the leaves and young shoots, destroyed while gathering the crop of berries, would repay distillation. The oil has a sp. gr. of 1·037, and very closely resembles clove-oil. It is frequently used as a substitute for or adulterant of the latter, both in medicine, and in combination with other oils for scenting soap. The small yield of oil renders it incapable of competition with clove-oil (p. 1420), except as a substitute.

Almond-oil.—An essential oil known as "bitter-almond-oil" is obtained from the bitter almond (see Fruit—Almonds, p. 1022), which also yields a fatty oil, described on p. 1377. Though bitter almonds are the only commercial source of the oil, it is also afforded by many plants of the *Pruneæ* and *Pomeæ* tribes, by a species of *Vicia*, and probably some others. It does not exist ready-formed, but is a product of the decomposition of amygdaline in the presence of water and emulsine. The process is as follows. The unpeeled almond-kernels are first pressed to extract their fatty oil (p. 1377); the residual cake is then placed in salt water for about 24 hours, prior to distillation. Without due precaution, there is some difficulty in the distillation, owing to the presence of much albuminous matter. Pettenkofer avoids this by immersing 12 parts of powdered almonds in boiling water, by which the albuminous matters are coagulated, and the amygdaline is dissolved. The addition of an emulsion of only 1 part of either sweet or bitter almonds will then suffice to effect the decomposition at a temperature not exceeding 40° (104° F.). The yield by this process from small quantities will sometimes reach 0·9 per cent. Some manufacturers force steam through the cake enclosed in coarse sacking. In dealing with large quantities of cake, the yield of essential oil varies widely; the yearly average may fall to 0·74 per cent., or rise to 1·67 per cent., which, reckoning 57 lb. of cake to represent 100 lb. of almonds, means 0·42–0·95 per cent. on the latter. This fluctuation is due partly to the want of uniformity in the bitter almonds used, and partly to the admixture of sweet almonds. The action of the emulsine on the amygdaline in the presence of water is very rapid, 200 lb. of cake being completely exhausted by a 3-hours' distillation. The crude oil contains a proportion of hydrocyanic (prussic) acid, feebly combined, and which is gradually set free. This crude oil is employed by perfumers; but the oil for medicinal use is sometimes deprived of the hydrocyanic acid by a process of purification. Maclagan's process consists in shaking up with lime and sulphate of iron (ferrous), and redistilling; the loss is 10 per cent. The purified oil is very liable to oxidize, unless carefully freed from water by agitation with fused chloride of lime. The oil is colourless and thin, of peculiar odour, and burning aromatic flavour; its sp. gr. is 1·061–1·065 when crude, and 1·049 when purified; its boiling-point is 180° (356° F.); it dissolves in 300 parts of water, and readily in alcohol and ether; by exposure to the air, it is oxidized, and converted into benzoic acid.

An "artificial oil of bitter almonds," or "essence of mirbane," is prepared by the action of nitric acid on benzol (see Coal-tar Products, pp. 654–5). They may be distinguished by treating with an alcoholic solution of potash: the natural oil is converted into a benzoate of potash; the artificial becomes a resin insoluble in alcohol and in ether.

Aloes-oil.—A pale-yellow, mobile oil, sp. gr. 0·863, boiling at 266°–271° (511°–528° F.), is afforded to the extent of 2 fl. dr. from 500 lb. of aloes (see Drugs, pp. 791–3).

Amber-oil.—A volatile oil is obtained from amber (see Resinous Substances), as a residue in the preparation of succinic acid, in the proportion of about 6 oz. from 6 lb. The crude oil is thick and greenish-brown, with a characteristic, disagreeable, bituminous odour, caustic acrid flavour, and sp. gr. 0·922 at 15° (59½° F.). It is used in perfumery.

Angelica-oil.—The root of *Archangelica officinalis* (see Angelica, p. 334), by aqueous distillation, yields much essential oil (about 1 lb. from 150–200 lb. of root), with a penetrating odour, and flavour of the root.

Angostura-oil.—Angostura-bark (see Drugs—Angostura, p. 793), when distilled with water, affords about 0·75 per cent. of a pale-yellow oil, of peculiarly aromatic odour, mild and afterwards acrid flavour, sp. gr., 0·934, boiling at 266° (511° F.).

Aniseed-oil.—Essential oils are obtained by distillation from the fruits of *Pimpinella Anisum* (see Spices—Aniseed), and from the roots of *P. nigra* [*Saxifraga*]. The first-named is slightly yellowish, possessing in a high degree the odour and flavour of the fruits; its sp. gr. is 0·977–0·983; it solidifies at 10°–15° (50–59° F.) to a hard crystalline mass, and resumes fluidity at about 17° (62½° F.); dissolves readily in alcohol. The yield obtained is about 3 per cent. of oil from the best Moravian seed, 2·5–2·7 from Russian, and 2·3 from German. The oil from the root of *P. nigra* has a light-blue colour; it does not appear to be an article of commerce. Aniseed-oil is administered medicinally to both men and cattle; it is largely employed in the preparation of cordials, especially in Latin Europe and S. America; and is suitable for scenting soaps and pomatums. It is often adulterated with spermaceti and fennel-oil stearoptene, and with cheaper essential oils. It cannot be scientifically distinguished from star-anise-oil.

Anise- [Star-] oil.—The fruits of the star-anise or Chinese anise, *Illicium anisatum* (see Spices—Aniseed), distilled with water, furnish 4–5 per cent. of essential oil, identical in all chemical respects with that of aniseed, but possessing a slightly different flavour. It is used for the same purposes as aniseed-oil, and very commonly mixed with or substituted for it. The fruits are chiefly distilled in Europe, but China exports considerable quantities of the oil itself. Thus the shipments from Pakhoi which paid duty in 1879 were 800 *piculs* (of 133⅓ lb.), and the recorded value was 15,134*l.*; from Macao, an annual export takes place to Europe and New York, and an occasional one to Manilla, the figures in 1878 amounting to 470 *piculs*, at a price fluctuating between 180 and 325 dollars (of 4*s.*).

Asafœtida-oil.—Asafœtida (see Resinous Substances), distilled with water, gives a yellowish oil, of strong garlic odour, soluble in water, and readily in alcohol, boiling at 130°–140° (266°–284° F.).

Avens-oil.—The root of *Geum urbanum*, distilled with water, gives a greenish-yellow oil, of buttery consistence, and clove-like odour.

Balm-oil.—The oil or otto of balm, or of melissa, is obtained by aqueous distillation of the whole herb, *Melissa officinalis*. The plant is cultivated in England, and grows wild commonly in S. France. The oil is pale-yellow, thin, of pleasant, lemon-like odour, and sp. gr. 0·85–0·92. It is an esteemed perfume.

Moldavian balm (*Dracocephalum moldavicum*) yields about ⅛ per cent. of a strongly aromatic and very agreeable essential oil. The plant is cultivated in S. France, but its product is hardly known in commerce.

Bay-oil. See Laurel-oils, pp. 1422–3.

Bayberry-oil.—The leaves of *Myrcia acris* afford a volatile oil, which is often called "bay-oil" or "oil of bay-leaves," but more correctly "bay-berry oil," being quite distinct from the bay or laurel (see pp. 1422–3). The leaves are largely received from the island of St. Thomas (W. Indies), and distilled in America. A 200-gal. copper still, heated by either wet or dry steam, takes 200–300 lb. of the leaves at a charge, and works them off in 8–12 hours, giving 80–100 gal. of distillate. The oil comes over in two portions:—(1) light oil, sp. gr. 0·870–0·990; and (2) heavy oil, sp. gr. 1·023–1·037. The freshly-distilled oil has a rank odour, but after keeping for 3–6 months, it mellows, and has the characteristic fragrance of the best "bay rum."

Benzoin-oil.—The natives of the E. Archipelago distil a volatile oil from gum benzoin (see Resinous Substances), by heating it in an earthenware pot, tightly covered, and providing a small bamboo for the escape of the oil. Various inert substances are placed in the retort with the gum, but no water. The oil is highly valued locally as a perfume for the hair.

Bergamot-oil.—The oil or essence of bergamot is procured from the fruit-rind of *Citrus Bergamia*, a member of the orange family (see Fruit, p. 1025). The tree is cultivated at Reggio, in Calabria, and in Algeria, and is unknown in a wild state; it occupies low ground, near the sea. The soil is well irrigated, and cropped with vegetables, and lemon- and orange-trees are often interspersed among the bergamot-trees. The smooth, thin peel abounds in a peculiarly fragrant essential oil, which is obtained from the full-grown but immature (green) fruits, gathered in November–December. The oil was formerly extracted by distillation, or by expressing the rasped rind; but these processes have been superseded by the *écuelle*, a special instrument described in a separate section (see p. 1457). By this, about 7000 fruits can be treated in a day, the yield of oil being 2½–3 oz. from 100 fruits. It is much greener than that extracted by the older processes. During some weeks after extraction, it gradually deposits much greasy matter, termed "bergaptene," or "bergamot-camphor," which, after exhaustion by pressure, is distilled with water to recover the final portions of oil it contains. The fruits which have yielded their oil are subjected to expression, and the juice is concentrated and sold for making citric acid (see Acids, p. 48), while the ultimate residue is consumed by cattle. The oil is thin, mobile, of very fragrant odour bitterish flavour, slightly acid reaction, pale greenish-yellow colour (due to chlorophyll), and sp. gr. 0·86–0·88; its boiling-point ranges between 183° and 195° (361½°–383° F.); it dissolves clearly ¼ part of carbon bisulphide, and is inappreciably soluble in that body. It is never free from adulteration, either with oil distilled from the leaves or residual fruits, or with lemon-oil, or turpentine-oil, or even petroleum. It is shipped principally from Messina and Palermo, in bottles similar to those containing lemon-oil. It is extensively employed in perfumery.

Birch-oils.—An essential oil is extracted from the bark of the common birch (*Betula alba*), and another from its leaves. The tree or shrub inhabits high N. latitudes in Europe and Asia, being more common than any other tree throughout the Russian empire, and found in every wood and grove from the Baltic to the Eastern Ocean. It is numerous in Scandinavia, less so in Scotland, Iceland, and Greenland, and forms little woods at 6000 ft. in Italy. The extraction of birch-bark-oil is an industry of some importance in N. Europe and Siberia, and is conducted in the following manner:—An iron pot is filled up with bark, and covered with a close-fitting lid, through which is inserted an iron pipe. On this, is inverted a similar pot, and the rims are carefully fitted together, and well luted with clay. The two are then turned upside down, so that the pot with the bark in it is uppermost. The apparatus is half sunken in the ground, well banked up with a mixture of sand and clay, and a wood fire is kindled round it. When the distillation has continued long enough, the luting is removed, and the pots are separated, when the lower one is found to contain a thin oil floating on pyroligneous acid, or, when the bark has been very impure, on pitch. The yield of pure birch-bark-oil is about one-third by weight of the white bark used. To obtain a *centner* (120 lb.) of oil, 10–14 trees of 30–50 years old have to be stripped. Now that the value of standing trees is becoming better understood in Russia, the trees are not felled, as was formerly the custom, but, in many districts, are stripped standing, and left to grow on. In such cases, the outermost bark alone is removed, and that but partially. The underlayers blacken and die, but new bark is formed beneath them, and the growth of the tree continues. The oil should be kept in well-closed vessels, as it is somewhat volatile. It can be refined by boiling over charcoal, and filtering, when it becomes as limpid as linseed-oil, and can be used for similar purposes.

Recently the preparation of this oil has been carried on in Germany and Austria, where it is known as *Birkentheer*, *Birkenöl*, *Jucktenöl*, or *Döggut*. This oil is used almost exclusively in the preparation of Russia-leather (see Leather, p. 1236), to which it communicates a peculiar fragrance. The bark is also a valuable tanning material (see Tannin—Birch-bark).

The essential oil obtained by distilling the leaves of the birch with water is colourless, thin, of pleasant balsamic odour, a mild, sweetish, and afterwards peculiarly balsamic, acrid, and hot flavour; it becomes turbid at 0° (32° F.), but is not hard or crystalline even at −10° (14° F.); and is soluble in 8 parts of alcohol at 0·850 sp. gr.

Cajuput-oil.—A medicinal oil of some importance (see Drugs—Cajuput, p. 795) is obtained from the leaves of the *kayu-puti* or "white-wood tree" (*Melaleuca minor* [*Leucadendron Cajuputi*]). It is widely spread and abundant in the Indian Archipelago and Malayan Peninsula, and is also found in N. Australia, Queensland, and New South Wales. There are many varieties of it, and that grown in the island of Bouro, eastward of Celebes, is said to yield the best oil. The leaves somewhat resemble those of the common willow. They are plucked by hand, placed in baskets, and carried to sheds, where they are emptied into the stills. These are of the usual Malayan form. The leaves and water to be distilled are contained in a cast-iron circular rice-pan, around the margin of which is placed a roll of cloth, forming a tight joint for the reception of the condenser that fits down upon the pan. This condenser consists of a wooden tub without ends, into the top of which is dropped a conical copper tray, kept supplied with cold water; the products of evaporation condense upon the lower surface of the tray, and converging to its apex, fall into a spoon-shaped spout, which conveys them through a hole in the side of the tub to a receptacle. About 8000 bottles annually are produced in Bouro, valued at about 1 *guilder* (1*s.* 8*d.*) each. It forms almost the only export of this island. The receipts at Singapore in 1871 were:—3895 gal. from Celebes, 445 from Java, 200 from Manilla, and 350 from other places; total, 4890 gal. Of this, the greater portion was re-exported to Bombay, Calcutta, and Cochin China. The oil arrives here from Singapore and Batavia in common beer- and wine-bottles. It is a transparent mobile fluid, of light bluish-green colour (due to presence of copper, but rarely if ever in dangerous quantity), fragrant camphoraceous odour, and bitterish aromatic flavour; its sp. gr. is 0·926; it remains liquid even at −13° (8½° F.), and boils at 175° (347° F.); and dissolves readily in alcohol.

Very similar oils are derived from other species of *Melaleuca*. That of *M. ericifolia* is pale-yellow, sp. gr. 0·899–0·902; *M. Wilsonii*, sp. gr. 0·925; *M. parviflora*, amber-coloured, sp. gr. 0·938; *M. uncinata*, peppermint-odour; *M. genistifolia*, pale greenish-yellow; *M. squarrosa*, green colour, disagreeable flavour; *M. linariifolia*, light straw-coloured, pleasant odour and flavour, sp. gr. 0·903. The plant called *kayu-glum* by the natives grows very extensively on the Malay Peninsula, and produces a similar oil to *kayu-puti*, but darker in colour. Fisher has distilled considerable quantities of it, and states it to be in wide medicinal use in the East.

Camphor-oils.—See Camphor, p. 578.

Caraway-oil.—A valued essential oil is obtained from the seeds of *Carum Carvi* (see Spices—Caraway). Distillation is performed with water, and without previous comminution of the seeds. Dutch seed yields about 5½ per cent. of oil; German, 7 per cent.; and Norwegian, 5·8 per cent. In England, preference is given to oil distilled from home-grown seed; on the Continent, the oils from the caraways of Halle and Holland are esteemed finer than those procured in S. Germany. An inferior oil is extracted from the refuse of the fruit, being mixed with turpentine-oil before distilling. The oil is colourless or pale-yellow, thin, with strong odour and flavour of the fruit; its sp. gr. is 0·91–0·97. It consists of about ⅓ carvene, boiling at 173° (343½° F.), and having a sp. gr. of 0·861 at 15° (59° F.). Carvol, the odoriferous portion, boils at 224° (435° F.), and has a sp. gr. of 0·953 at 20° (68° F.). Caraway-oil is employed in medicine, but more largely as a scent for soaps.

Cardamom-oil.—The parenchyma of the albumen and the embryo of cardamoms (see Spices—Cardamoms) contain a varying percentage of essential oil, amounting to 5 in Madras cardamoms, and 3·5 in Ceylon. It is extracted by aqueous distillation. It is pale-yellow in colour, with the odour and flavour of the seeds; sp. gr. 0·92–0·94.

Cascarilla-oil.—The bark of *Croton Eluteria* (see Drugs—Cascarilla, p. 797), distilled with water, affords about 1·1 per cent. of essential oil, which is rarely extracted, the bark itself being used by perfumers. The oil is dark-yellow, with an odour of camphor, lemons, and thyme, an aromatic, bitter flavour, sp. gr. 0·938, and commencing to boil at 180° (356° F.).

Cedar-oil.—From the pencil-makers' shavings of American cedar (*Juniperus virginiana*), is extracted an essential oil, in the proportion of about 28 oz. from 1 cwt. of the shavings. The true Lebanon cedar (*Cedrus Libani*) affords an oil of very indifferent odour. Cedar-oil is a soft, white, crystalline mass, of peculiar aromatic odour, solidifying at 27° (80½° F.) after desiccation, and distilling below 282° (539° F.). It is extensively used for scenting soaps, and is generally employed in America in lieu of savin-oil, being often called "N. American savin."

Cedrat-essence or Citron-oil.—From the rind of the scarcely ripe fruit of the citron (see Fruit, p. 1023) is obtained an essential oil, either by distillation or expression, much esteemed in perfumery. It is thin, colourless, or yellowish, of pleasant lemon odour, sp. gr. 0·840–0·860, boiling at 160°–175° (320°–347° F.). It is prepared in small quantity, and much of that sold under the name is fictitious, as the rind is in great demand for "candying" (see Food Preservation, p. 1018).

Celery-oil.—By the aqueous distillation of the herb and fruits of the celery (*Apium graveolens*), is obtained a colourless or pale-yellow oil, of penetrating odour, warm sweetish flavour, sp. gr. 0·881, and readily soluble in alcohol. At Grasse (S. France), the wild plant only is used, and yields about 1 lb. of oil from 400 lb.

Chamomile-oils.—The flowers of the common or Roman chamomile (see Drugs, p. 798) afford 0·06–0·08 per cent. of essential oil by aqueous distillation. It is at first bluish, but becomes yellowish-brown in the course of a few months; it has a pleasant lemon-like odour, and boils at 175° (347° F.). The yield of this oil from an acre of flowers is estimated at about 8 lb. At Mitcham, near London, the entire plants, deprived of their best flowers, are distilled, after drying in open sheds, excluding direct sunlight. The stills hold 1000–2000 gal., and a charge occupies 6–8 hours. The distillation is conducted at the lowest possible temperature, and, so soon as the contents of the retort have reached the boiling-point, the fire is withdrawn. The finest and most fragrant oil comes over during the first 3 hours of the process, and the receiver is then changed.

An essential oil is also distilled from the flowers of the German chamomile (see Drugs—Chamomile, p. 799). It is thick, dark-blue in colour, with a strong odour of the flowers, and a hot aromatic flavour.

Cinnamon- and Cassia-oils.—An essential oil, erroneously called "white cinnamon," is obtained by the aqueous distillation of the bark of *Canella alba* (see Drugs—Canella, p. 796); it is a mixture of caryophyllic (eugenic) acid, an oil resembling cajuput, and an oxygenized oil. It is not a commercial article.

Essential oils of considerable importance are derived from the true cinnamon of Ceylon, *Cinnamomum zeylanicum* (see Spices—Cinnamon). Foremost is that yielded by the bark, to the extent of ½–1 per cent., which is extensively distilled (aqueous) in Ceylon, and rarely in England. It is a golden-yellow liquid, with powerful cinnamon odour, sweet and aromatic but burning flavour, and sp. gr. 1·035. It is largely used in perfumery. Ceylon ships some 15,000–40,000 oz. annually of this oil, chiefly to England. A century ago, the average yearly sales by the Dutch E. India Co. were but 176 oz. The leaves afford a brown, viscid, essential oil, of clove-like odour, sp. gr. 1·053, sometimes exported from Ceylon; and a third oil is supplied by the root,—a yellow liquid, lighter than water, with an odour of camphor and cinnamon, and a strong camphoraceous flavour.

Various species of *Cinnamomum* occurring in Tropical Asia afford the so-called "cassia-bark" (see Spices—Cassia). From this bark, is distilled, notably in China, an essential oil agreeing chemically with that of Ceylon cinnamon-bark, but of less agreeable odour, and sp. gr. 1·066. The yield by distillation is about ¾ lb. of oil from 1 cwt. of bark. The oil is an export of no small importance from some Chinese ports. Pakhoi shipped 66,650 lb. in 1877, and 200 *piculs* (of 133⅓ lb.) in 1879; Macao exported about 480 *piculs* in 1879. A large proportion comes to Great Britain, but Hamburg seems to be the most important destination. The oil is used for perfuming soaps.

Citronella-oil.—One of the "grass-oils," called "citronella," is obtained from *Andropogon nardus* [*A. Martini*], attaining a height of 6 ft. and more. It grows wild abundantly in Singapore, and a large area is under cultivation with it, both in Ceylon and Singapore. In Ceylon, it is cut for distillation at any time of year, but mostly in December–January. The leaves are distilled with water, and yield over 3 oz. of essential oil from 1 cwt. The pure oil is thin, colourless, with strong aromatic odour, and acrid citron-like flavour. It is a growing article of trade. The shipments from Ceylon were 622,000 oz., value 8230*l.*, in 1864; in 1874, they were 1,163,074 oz. to the United Kingdom, 5713 oz. to British India, and 426,470 oz. to the United States; total, 1,595,257 oz., in addition to 842 doz. and 33 packages to the United States. Its almost only application out of India is for scenting soap, the consumption being very extensive. The best kind bears the name of John Fisher (of Singapore, and 43 Mincing Lane). Fisher's 950-acre estate on the island of Singapore now produces about 1 million oz. yearly of this oil.

Oils from other species of *Andropogon* are described under Ginger-grass and Lemon-grass (pp. 1422, 1423).

Clove-oil.—An essential oil is obtained from the flower-buds and flower-stalks of cloves (see Spices—Cloves) by aqueous distillation. This distillation is largely carried on in England. The proportion of oil present may amount to 16–20 per cent., but to extract the whole, the distillation must be long continued, the water being returned to the same material. The oil is a colourless or yellowish liquid, with powerful odour and flavour of cloves, and varying in sp. gr. from 1·046 to 1·058. It combines well with grease, soap, and spirit, and is one of the most extensively-used oils in perfumery. In Germany, clove-oil is often adulterated with carbolic-acid (phenol).

Clove-bark-oil.—The bark of *Dicypellium caryophyllatum*, a native of Brazil, affords by aqueous distillation an essential oil bearing great resemblance in all its properties to clove-oil.

Coffee-oil.—Coffee-berries (see Coffee, pp. 691–722) contain a proportion of essential oil varying from 8 to 13 per cent. This is partially given off during the roasting process (see Beverages—Coffee, pp. 422–3), and at least half is wasted, the remainder producing the characteristic odour and flavour of the berries. By the existing method of roasting coffee, it is scarcely possible to collect the volatilized oil, on account of its being so largely emitted during the shovelling of the beans in the open air when withdrawn from the roasting-drums. It is suggested that the drums should be in connection with an exhauster, so as to condense the oil in a receiver, and at the same time cool the beans sufficiently to prevent ignition. It is thought that the oil might be profitably used in making liqueurs.

Copaiba-balsam-oil.—Copaiba-balsam (see Resinous Substances—Copaiba) contains 40–60 per cent. of volatile oil, according to its age and botanical origin. It is obtained by aqueous distillation. It is a thin, colourless body, resembling the balsam in odour and flavour, boiling at 245° (473° F.) or even higher, soluble in 8–30 parts of alcohol at 0·830 sp. gr., and varying in density from sp. gr. 0·88 to 0·91.

Coriander-oil.—The fruits of *Coriandrum sativum* (see Spices—Coriander) yield 0·7–1·1 per cent. of volatile oil, which is extracted by bruising them, and subjecting to aqueous distillation The oil is colourless or yellowish, with the odour and flavour of the fruits, sp. gr. 0·859–0·871, and boils (not constantly) at 150° (302° F.).

Cubebs-oil.—The fruits of *Piper Cubeba* (see Drugs—Cubebs, p. 809) yield 4–13 per cent. of volatile oil by aqueous distillation. This variation is due in part to the constitution of the drug, but also to the alterability of the oil. It is thick and colourless, the portion which distils last in rectifying having almost the consistence of butter; its sp. gr. is 0·936; it is composed of a small quantity of an oil ($C_{10}H_{16}$) boiling at 158°–163° (316½°–325½° F.), and two other oils (each $C_{15}H_{24}$) boiling at 262°–265° (503½°–509° F.); its odour is faint and aromatic, and it has a warm flavour of camphor and peppermint.

Other oils from *Piper spp.* are described under Matico and Pepper (pp. 1424, 1425).

Dill-oil.—The crushed fruits of *Anethum graveolens* (see Drugs—Dill, p. 810), submitted to aqueous distillation, yield 3–4 per cent. of essential oil, composed of two or more hydrocarbons. The oil is skimmed from the distillate, and the latter forms commercial dill-water. The oil may be used in mixtures for perfuming soap.

Elder-oil.—The flowers of the elder (*Sambucus nigra*) afford a very small percentage of essential oil by distillation. It has a buttery consistence, light-yellow colour, a strong odour of the flowers, and a bitter, burning, afterwards cooling flavour.

Elemi-oil.—Manilla elemi (see Resinous Substances—Elemi) affords nearly 10 per cent. of volatile oil by aqueous distillation. It is colourless, neutral, with a fragrant odour of the resin, an acrid flavour, sp. gr. 0·861 at 15° (59° F.), and boils at 166°–174° (331°–363° F.).

Eucalyptus-oils.—Essential oils of daily increasing importance are obtained by aqueous distillation of the leaves and branchlets of many species of *Eucalyptus* (see Timber). The oil of *E. amygdalina* (3·313 per cent.) is thin, pale-yellow, of pungent, coarse, lemon-like odour, mild, cooling, afterwards bitter flavour, sp. gr. 0·881 at 15° (59° F.), boils at 165°–188° (329°–370½° F.), becomes resinous in the air, deposits a stearoptene at −18° (0° F.), which melts at −3° (26½° F.); the oil is used in medicine, disinfecting, and perfumery. *E. oleosa*: 200 oz. from 1000 lb. of leaves and twigs, thin, fluid, pale-yellow; mild, camphoraceous, turpentinous flavour; mint-like odour; sp. gr. 0·911; boils at 161°–177° (322°–350½° F.). *E. sideroxylon*: limpid, thin, pale-yellow, odour and flavour like *E. oleosa*, sp. gr. 0·923, boils at 155°–178° (311°–352½° F.). *E. goniocalyx*:

pale-yellow colour, pungent, penetrating, rather disagreeable odour, very unpleasant flavour, sp. gr. 0·918, boils at 152°–175° (305½°–347° F.). *E. globulus*: 0·719 per cent., thin, very pale-yellow colour, cajuput-like odour, cooling, mint-like flavour, sp. gr. 0·917, boils at 149°–177° (300°–350½° F.), used medicinally. *E. corymboza*: colourless, slight odour of lemon and rose, bitterish, camphor-like flavour, sp. gr. 0·881 at 15° (59° F.). *E. obliqua*: reddish-yellow colour, mild odour, bitter flavour, sp. gr. 0·899, boils at 171°–195° (340°–383° F.), becomes turbid at – 18° (0° F.). *E. fissilis*: pale reddish-yellow colour, odour like *E. obliqua*, sp. gr. 0·903, boils at 177°–196° (350½°–385° F.). *E. odorata*: pale-yellowish, with greenish tinge, aromatic odour, sp. gr. 0·899–0·922, boils at 157°–199° (314½°–390° F.). *E. rostrata*: pale-yellow to reddish-amber, odour and flavour like *E. odorata*, sp. gr. 0·918, boils at 137°–181° (278½°–358° F.). *E. longifolia*: oily consistence, cooling, aromatic flavour, fragrant, camphor-like odour, sp. gr. 0·940, boils at 194°–215° (381°–419° F.). *E. viminalis*: pale yellowish-green, mild disagreeable odour, sp. gr. 0·921, boils at 159°–182° (318°–359½° F.). *E. citriodora*: yields fairly, and is a good cosmetic. *E. dumosa*: excellent for oil- and spirit-varnishes. All these oils are manufactured on an industrial scale by J. Bosisto, of Richmond, Victoria. They (that of *E. oleosa* is most commonly used) dissolve the following substances in a descending degree:—Camphor, rosin, mastic, callitris-sandarac, elemi, sandarac, kauri, dammar, asphalt, xanthorrhœa-resin, dragon's-blood, benzoin, copal, amber, anime, shellac, caoutchouc, bees'-wax; guttapercha is not dissolved.

Fennel-oil.—The fruits of *Fœniculum officinale* [*vulgare*] afford a volatile oil by aqueous distillation. It is pale-yellow, with a sweetish aromatic odour and flavour of the fruit, sp. gr. 0·968 at 20° (68° F.); solidifies below 10° (50° F.); may be used for perfuming soap. The plant grows wild in S. France, and is distilled entire in July–August, giving 1 lb. of oil from 500 lb.

Fusel-oil.—The name "fusel-oil" is applied to a series of volatile liquids obtained in the rectification of alcoholic liquors made by fermenting grain, potatoes, &c., and whose separation is a matter of great importance (see Alcohol, p. 212). The oil varies much in quantity and composition, according to its source; it is practically always present in greater or less degree in commercial spirits. It is employed industrially as a source of amylic alcohol, which is its chief constituent.

Galangal-oil.—The rhizome of *Alpinia officinarum* (see Spices—Galangal), by aqueous distillation, affords about 0·7 per cent. of an essential oil, with an odour and constitution resembling cajuput-oil, and readily soluble in alcohol.

Galbanum-oil.—Galbanum (see Resinous Substances) affords about 7 per cent. of volatile oil by aqueous distillation. It is colourless or slightly yellowish, with mild, aromatic flavour, galbanum-like odour, sp. gr. 0·904, and boils at 160° (320° F.).

Gale-oil.—The leaves of *Myrica Gale*, when distilled with water, give a brownish-yellow essential oil, thickish at 12° (53½° F.), of peculiar, pleasant, balsamic odour, mild, then hot and lastingly styptic flavour, sp gr. 0·876, soluble in 40 parts of alcohol at 0·875 sp. gr.

Garlic-oil.—The bulbs of garlic (*Allium sativum*), when distilled with water, afford a volatile oil, which does not seem to pre-exist in the plant. In the crude state, it is brownish-yellow, with an intense odour of garlic; it is slowly soluble in water, and suffers partial decomposition by rectifying. An identical oil is yielded by several *Cruciferæ*. (See also *Allium*, p. 1414).

Geranium-oil.—The name "geranium-oil" is properly confined to oils afforded by different species of *Pelargonium*, but is often applied also to ginger-grass-oil (p. 1422). *P. Radula*, the rose-leaved geranium, is cultivated in France, both in the south, and at Montfort-Lamaury, in the department Seine-et-Oise. It is propagated by slips taken in September, and generally planted out in February, though the latter may be done at almost any season. The cultivation is very easy, and, with proper manuring and irrigation, the plants grow 3–4 ft. high, and yield an abundance of foliage, which is reaped by a sickle. About 3000 plants occupy an acre, and they require renewing every 3–4 years. The leaves and flowers are distilled with water, 1 cwt. yielding about 2 oz. of essential oil. The oil obtained in Seine-et-Oise has a better odour than that produced in S. France. It is colourless, greenish, yellowish, or brownish, the last being most esteemed, boils at 206°–220° (421°–428° F.), and solidifies at 16° (61° F.); the odour closely resembles that of the rose. *P. odoratissimum* is much cultivated in Algeria and Valencia, and yields a very similar oil. It requires deep, well-worked, fertile soil, and succeeds well in the red soils of Sabel, in Alger, and in the cool, sandy soil of Staonéli. The slips are planted in lines, 18–26 in. by 8–10 in. apart, at the beginning of winter, and yield 3 cuttings annually. The cultivation is maintained for 3 years, and gives 250–300 and even 475 cwt. of leaves per *hectare* (of 2½ acres) per annum. The whole plant is cut down to within 4 in. of the ground. The first cutting, in May, requires 1200–1400 lb. of leaves to afford 1 lb. of essential oil, but in July, 800 lb. will give the same yield. All these geranium-oils are used in perfumery, and largely as adulterants of otto of rose (see Rose-oil, p. 1427). They are likewise themselves adulterated extensively with ginger-grass-oil (p. 1422).

Ginger-oil.—The rhizomes of *Zingiber officinale* (see Spices—Ginger), when distilled with water, afford a thin, yellowish, essential oil, with a strong odour of ginger, a burning aromatic flavour, sp. gr. 0·893, boiling at 246° (475° F.).

Ginger-grass-oil.—An essential oil known as "ginger-grass," often also as *rusa* or "rose-oil," and as "geranium-oil," is the produce of *Andropogon Schœnanthus*, a grass indigenous to N. and Central India. The leaves are distilled in the Khandesh collectorate of the Bombay presidency. The oil produced in the Namar district of the Nerbudda valley is sometimes called "grass-oil of Namar." The export of the oil from Bombay during the year ending March, 1867, was 41,643 lb. It is shipped to England, and to the ports of the Red Sea. Its largest consumption is for the adulteration of otto of roses (see Rose-oil, p. 1427).

Essential oil from other species of *Andropogon* are described under Citronella and Lemon-grass (pp. 1419, 1423).

Hop-oil.—The female flowers of *Humulus Lupulus* (see Hops, p. 1130), distilled with water, afford a fragrant essential oil. The yield from 120 lb. of New Kentish hops, according to Piesse, was 8 oz.; that from 3-year old Bavarian, 11 oz. The oil is thin, colourless or yellowish, with a penetrating narcotic odour, hot, slightly bitter flavour, sp. gr. 0·910; it is not yet used in perfumery.

Hyssop-oil.—On aqueous distillation of the herb hyssop (*Hyssopus officinalis*), an essential oil, without colour, of peculiar odour, acrid, camphoraceous flavour, and neutral reaction, is obtained; its sp. gr. is 0·88–0·98; in contact with the air, it becomes yellow, and changes to a resin; its boiling-point is 142°–162° (287½°–323½° F.). The plant is largely grown around Grasse (S. France), and affords 1 lb. of oil from 400–500 lb.

Ilang-ilang-oil.—A minute quantity of remarkably pleasant-odoured oil is distilled from the flowers of *Cananga odorata*, a common plant in the E. Indies, but especially in the Philippines, where it is cultivated for its perfume. The oil is largely adulterated with an oil distilled from the flowers of *Michelia Champaca*, a native of the same localities. The yield of oil obtained by German distillers in the Philippines is about 25 *grm.* from 5 *kilo.* of the flowers (or 0·5 per cent.). The tree may be cultivated very easily in all warm countries, and commends itself to Australian horticulturists. The annual European consumption is said to be about 200 *kilo.* in Paris, Nice, and Grasse, 50 *kilo.* in London, and 50 *kilo.* in Leipzig, Berlin, and Frankfort. According to one authority, "Macassar-oil" is coco-nut-oil in which the flowers of *Cananga odorata* and *Michelia Champaca* have been digested (see also Macassar-oil, p. 1394).

Iva-oil.—By the aqueous distillation of the whole herb *Achillea moschata* before flowering, is obtained a clear, yellowish, liquid oil, of very pleasant, strongly ethereous odour, and warm bitter flavour, boiling at 180°–210° (356°–410° F.).

Jasmine-oil.—The jasmine (*Jasminum odoratissimum*) is extensively cultivated for the delightful odour contained in the essential oil of its flowers. It is grown as a small bush, by grafting the Spanish variety upon 2-year old stems of wild jasmine. It requires moist soil or irrigation, and liberal pruning every year; it is planted in rows, with horizontal poles for support, and about 80 0 to an acre; the plants are not in full bearing till the third year after grafting, but when mature, every 1000 plants give about 60 lb. of flowers annually, or about 500 lb. an acre. The flowers appear in July–October, those of August–September being most fragrant. The flowers are grown chiefly in S. France, notably around Cannes; also in Algeria and Tunis. The essential oil may be obtained by aqueous distillation, repeatedly supplying fresh flowers to the same water; but the cost of production is extremely great, and it is more usual to impregnate fatty oils by the absorption process, described on p. 1456.

Jonquil-oil.—An essential oil is extracted from jonquil-flowers (*Narcissus Jonquilla*) by ether. It is yellow, of buttery consistence, and with a pleasant odour of the flowers.

Juniper-oil.—The berries of *Juniperus communis*, when distilled with water, afford a colourless or yellowish oil, with a strong odour of the fruit, sp. gr. 0·847–0·870, slightly soluble in alcohol. The oil of ripe fruits boils at 205° (401° F.), and deposits a stearoptene in the cold. The unripe fruits give in addition an oil boiling at 155° (311° F.). The plant grows in the N. regions of both hemispheres, but the supply of berries comes chiefly from S. France, and in a minor degree from Austria and Italy. The fruits are not mature till about the end of the second year after their appearance. Ripe berries distilled immediately give 0·4 per cent. of oil, which is increased to 0·75 per cent. by previous maceration in cold water.

Laurel-oils.—An essential oil is obtained by distilling the berries of the sweet bay (*Laurus nobilis*) with water, and is often called "bay-oil." It is greenish-yellow, of thickish consistence, with an odour of turpentine and laurel, sp. gr. 0·932.

Another essential oil is procured from *Oreodaphne opifera*, in British Guiana, and on the Orinoco, by boring holes into the heart of the tree. It flows out in a clear stream, and is collected in basins. When rectified and desiccated, it is colourless, with an odour of turpentine and lemons, and aromatic pungent flavour; its sp. gr. is 0·864; boiling-point, 150°–163° (302°–325½° F.); it is used medicinally, and is an excellent solvent of indiarubber. A third oil is distilled from the fruit of this tree.

Oreodaphne californica (the Californian bay laurel), is an evergreen tree indigenous to California and the Pacific slope, growing abundantly in the vicinity of ravines, and moist shady localities. All parts yield a volatile oil, but the leaves give most—4 per cent. by distillation. It is straw-coloured, limpid, with pungent aromatic odour, warm camphoraceous flavour, sp. gr. 0·936. It has medicinal virtues.

A fixed oil from the laurel is described under that section (see p. 1393).

Lavender-oil.—Several species of *Lavandula* are cultivated for the sake of their essential oil. *L. vera*, commonly called "female lavender," is a native of S. Europe, N. Africa, and Persia; it is the kind chiefly grown, and occupies a large area of ground in France, as well as at Mitcham (Surrey), and Hitchin (Herts), in England. *L. Spica*, or "male lavender," is raised principally on the Continent, and affords an inferior product, termed "oil of spike." A lavender plantation in this country should be sun-exposed, and away from hedges and trees, as these tend to keep the air too moist, and make the flowers liable to be cut off by spring frosts. The best soil is loam, with chalky subsoil. In October, slips from old plants are placed in previously-prepared beds, and kept carefully clipped for 12 months. At the end of this time, they are set out in fine weather, 3 ft. apart in rows 4 ft. apart (or 3547 plants on an acre). They are not yet allowed to flower, but are still clipped, and regularly dressed with short dung, or superphosphate of lime, to strengthen them. The harvest takes place in August, when the plants are cut down by the sickle, and immediately packed in quantities of about ½ cwt. in pieces of bast matting (see Fibrous Substances —*Raphia spp.*, p. 994, *Tilia*, p. 998), for protection from the sun during conveyance to the stills. The yield is greatest and best from 4-year-old plants; but it is a singular fact that the product from 2-year-old plants is larger than from those of either 1 year or 3 years. Sometimes the crop is continued on the same ground for 6 years in succession, by judiciously replacing old plants; but more commonly, some other crop is raised every fourth year. The yield of oil varies greatly with the season and the soil. The average at Mitcham is 10–12 lb. an acre. Perks, at Hitchin, removes the flowers from the stalks before distilling, and finds that though the operation of stripping entails an extra expense, the product is greatly improved in quality, and very little less in quantity. Usually the whole herb is thrown into the still, in which case, the oil is divided into 1sts and 2nds; the former, including about $\frac{15}{16}$ of the total, is reserved for making "lavender-water," while the latter serves for perfuming soaps and greases. The best French oil is got from flowers grown on the highest points in the department Alpes-Maritimes; 150–200 lb. of flowers give 1 lb. of oil in a good season. The oils of *L. Spica* and *L. Stœchas* are used by painters on porcelain, and in artists' varnishes. The oil produced in England fetches four times the price of any other. It is thin, pale-yellow, with a pleasant odour of the flowers, a burning, bitter, aromatic flavour, sp. gr. 0·876–0·880, boils at 185°–188° (365°–370½° F.), and dissolves readily in alcohol.

Lemon-oil and Citron-zeste.—The rind of the Lemon (see Fruit—Lemons, p. 1025), when rasped and subjected to expression, or when distilled, affords an essential oil, known as "essence of lemon," or "citron-zeste," according to the method adopted. The oil is extracted largely in the neighbourhood of Palermo, in Sicily, at Reggio, in Calabria, and at Mentone and Nice, in France. The fruits are used while still rather green and unripe, being then richer in oil; only small and otherwise unmerchantable fruit is employed. The operation is conducted in November–December. In Sicily and Calabria, the "sponge process" is adopted, as described in another section of this article (see p. 1457). The yield is very variable, 400 fruits affording 9–14 oz. of oil. The pulp and exhausted peel are pressed, to extract "lemon-juice," and then sometimes distilled. At Mentone and Nice, recourse is had to the *écuelle*, whose construction and use is also recorded in another portion of this article (see p. 1457). These kinds of oil are much superior to a third which is obtained by grating the peel of fresh lemons, or of those which have been submitted to the *écuelle*, and distilling with water. The oils obtained by the sponge and *écuelle* are thin liquids, of faint-yellow colour, exquisite odour, and bitterish aromatic flavour; their sp. gr. is 0·83–0·88, and their boiling point, 170°–180° (338°–356° F.). The oil (or essence) of lemon is shipped mostly from Messina and Palermo, in copper bottles, called "jars" or *ramieri*, holding 25–50 *kilo.* or more, sometimes in tin bottles of less size. The total quantity of lemon-, orange-, and bergamot-oils exported from Sicily in 1871 was 368,800 lb., value 144,520*l.*, about ⅔ coming to England; and the exports from Messina in 1877 were 306,948 *kilo.* The British imports of lemon-oil alone are estimated at 85,000–90,000 lb. annually. It is most extensively consumed in perfumery.

Lemon-grass-oil.—The essential oil known as "lemon-grass," "verbena," or "Indian melissa," is obtained from the leaves of *Andropogon citratus*, a large coarse grass, found under cultivation in various islands of the E. Archipelago, and growing wild on extensive tracts of land in Ceylon; it rarely or never bears flowers. It is grown especially for its oil in Ceylon and Singapore, on the same estates with citronella, and is commonly met with in gardens in India, Java, and the Moluccas. It is more highly esteemed than citronella-oil, and is produced in much less quantity. Ceylon exported 13,515 oz. of this oil in 1872, more than half of which went to the United States. The best brand is Fisher's (of Singapore). The most important use of this oil is for adulterating verbena-oil; it is also used for perfuming soaps and greases.

Other essential oils from *Andropogon spp.* are described under Citronella and Ginger-grass (pp. 1419, 1422).

Lilac-oil.—By ethereal extraction, the flowers of *Syringa vulgaris* yield an amber-yellow oil, with an odour of the flowers. For perfumery purposes, the oil is obtained by absorption with pure grease.

Linden-oil.—The flowers of the European lime or linden (*Tilia europæa*), described elsewhere (see Fibrous Substances—*Tilia*, p. 998), submitted to aqueous distillation, give a colourless or yellowish oil, with a strong pleasant odour of the flowers, and sweetish flavour; it dissolves readily in alcohol. It is imitated by perfumers.

Mace- and Nutmeg-oils.—Besides the fatty oils afforded by mace and nutmegs (see pp. 1396–7), they yield essential oils by aqueous distillation. That from mace is thin, yellowish, with a strong odour of mace, burning aromatic flavour, deposits no solid at −12° (10½° F.), begins to boil at 160° (320° F.), the temperature rising to 180° (356° F.). Nutmeg-oil is thin, nearly colourless, with strong odour and flavour of the seeds, sp. gr. 0·850, deposits no sediment at −7° (19½° F.), commences to boil at 160° (320° F.), the temperature rising to above 200° (392° F.). These oils are used for scenting soap.

Marjoram- or Origanum-oils.—The sweet marjoram (*Origanum Marjorana*) affords an essential oil by distilling the whole herb with water. It is cultivated for this purpose in S. France. The ordinary yield is 1 lb. of oil from 2 cwt. of the herb, but it varies exceedingly with the culture and season. The oil is thin, of light-yellow or yellowish-green colour, with a powerful odour of the herb and peppermint, of warm, acrid, slightly bitter flavour, sp. gr. 0·8854 at 17° (62½° F.), boils at 163° (325½° F.).

Wild marjoram (*Origanum vulgare*), collected in Kent, gives scarcely 1 oz. of oil from 70 lb. of the herb. The oil is brownish-yellow, with a strong odour of the herb, an acrid, aromatic flavour, and sp. gr. 0·86–0·90.

Both these oils are said to be used for perfuming soap, but it is more than probable that they are generally replaced by the essential oil of thyme (see Thyme-oil, p. 1431).

Matico-oil.—An oil is obtained from the leaves of *Piper angustifolium* (see Drugs—Matico, p. 818), by distillation. It is somewhat thick, pale-green, of strong, camphoraceous odour and flavour, and thickens and crystallizes by keeping.

Other oils from *Piper spp.* are described under Cubebs and Pepper (pp. 1420, 1425).

Meadow-sweet-oil.—The flowers of *Spiræa Ulmaria*, when distilled with water, afford a colourless oil, with an odour of salicylous acid, slightly burning flavour, readily soluble in alcohol, partly solidifying by cold. It is not availed of by perfumers.

Mehudee-oil.—An essential oil called *mehudee* is distilled by the natives of some parts of India, notably in Lucknow, from the leaves of *Lawsonia alba* (see Dyestuffs—Henna, p. 858). It is remarkably and delightfully fragrant.

Mignonette-oil.—The flowers of *Reseda odorata*, submitted to extraction by ether, yield a thick oil, of yellowish colour, and most pleasant odour. By perfumers, it is extracted by absorption.

Milfoil-oils.—Various parts of the common milfoil (*Achillea Millefolium*) yield essential oils by aqueous distillation. That of the flowers is dark-blue, sp. gr. 0·92. That of the herb is blue, of a deeper tint than chamomile-oil, thick, almost of buttery consistence when cold, of strong odour, slightly burning flavour of the herb, sp. gr. 0·852–0·917. That of the fruits is greenish. That of the root is colourless, or slightly yellow, with peculiar, disagreeable, somewhat valerian-like odour, and unpleasant flavour.

The oil obtained by aqueous distillation of the herb, flowers, or fruits of showy milfoil (*Achillea nobilis*) is thick, pale-yellow, of more refined and camphor-like odour than common milfoil, aromatic, camphoraceous, bitterish flavour, sp. gr. 0·97–0·98, and dissolves readily in alcohol.

Another *Achillea*-oil is described under Iva (p. 1422).

Mugwort-oil.—The root of *Artemisia vulgaris*, when distilled with water, gives a butter-like crystallizing oil, of pale greenish-yellow colour, penetrating peculiar odour, nauseous, bitterish flavour, and readily soluble in alcohol.

Other *Artemisia*-oils are described under Tarragon, Wormseed, and Wormwood (pp. 1431, 1432).

Mustard oil.—Besides the fatty oil obtained from mustard (see p. 1396), a volatile oil is produced (it does not pre-exist), by distilling macerated brown mustard-seed with water, which is added at a temperature not exceeding 50° (122° F.). The oil is colourless or yellowish, of intensely penetrating odour and flavour of mustard, sp. gr. 1·017, boils at 148° (298½° F.), dissolves slightly in water, readily in alcohol and ether, and in 3 times its weight of cold sulphuric acid at 168° Tw.

Myrrh-oil.—When myrrh (see Resinous Substances—Myrrh), is distilled with water, 100 lb. will yield about 8 oz. of thickish, pale-yellow essential oil, having an odour and flavour of myrrh.

Myrtle-oil.—The leaves, flowers, and fresh fruits of the myrtle (*Myrtus communis*), by aqueous distillation (in September), yield a yellowish or greenish-yellow oil, of great fragrance, about 5 oz. being obtained from 1 cwt. of leaves. Perfumers mostly replace it by an artificial compound.

Nasturtium-oil.—The seeds of *Nasturtium officinale*, under distillation, give an oil boiling at 120°–280° (248°–536° F.).

Neroli-oil.—The fresh flowers of the bitter orange (see Fruit—Oranges, p. 1025), by aqueous distillation, yield 0·6–0·7 per cent. of essential oil, the extraction of which is carried on chiefly at Grasse, Cannes, and Nice, in S. France; also in Algeria. The finest trees afford about 30 *kilo.* of flowers. The oil is commonly adulterated with bergamot and petit-grain (qq. v.), $\frac{1}{8}$ of the former and $\frac{3}{8}$ of the latter being added to $\frac{4}{8}$ of true neroli. The yield from 1 ton of flowers is about 40 oz., worth 20*l.*, the residuary water, known as "orange-flower water," or *aqua Naphæ*, is worth an additional 10*l.* The flowers of the sweet orange yield less than half the amount of oil; those of the shaddock (p. 1026) make a very good neroli. Pure neroli-oil is brownish, of most fragrant odour, bitterish aromatic flavour, sp. gr. 0·889 at 11° (52° F.). It is very largely used in perfumery.

Other oils from the *Citrus* genus are described under Bergamot, Cedrat, Lemon, Orange, and Petit-grain (pp. 1417, 1419, 1423, 1425, 1427).

Olibanum-oil.—When olibanum (see Resinous Substances—Olibanum) is subjected to aqueous distillation, it affords a thin, yellowish oil, of pleasant turpentinous odour, sp. gr. 0·866, and boiling at 162° (323½° F.).

Orange-oil.—The scarcely-ripe fruit of both the sweet and bitter variety of orange (see p. 1025) is made to yield an oil from the rind, by means of the "sponge" or the *écuelle* process (see p. 1457), which is largely produced at Messina and in S. France. That obtained from the sweet orange is termed *essence de Portugal*; that from the bitter, *essence de bigarade*; the latter is much the more valuable. Both are used in liqueur-making and perfumery.

Other *Citrus*-oils are described under Bergamot, Cedrat, Lemon, Neroli, and Petit-grain (pp. 1417, 1419, 1423, 1425, 1427).

Orris-oil.—Orris-root (see Perfumes—Orris-root), dried, and then subjected to aqueous distillation, affords an exceedingly minute quantity (about 0·1 per cent.) of volatile oil, not to be found in the living root.

Parsley-oil.—The fruits of the parsley (*Carum Petroselinum*), distilled with water, afford a thin essential oil, greenish-yellow when fresh, colourless when rectified, with an odour of the fruit, sp. gr. 1·01–1·04, solidifies at 2°–8° (35½°–46½° F.), boils at 160°–170° (320°–338° F.), and dissolves readily in alcohol. At Grasse (S. France), the yield is 1 lb. of oil from 250–300 lb.

Patchouly-oil.—An essential oil is extracted from patchouly or *pucha-pat* (*Pogostemon Patchouly* [*Plectranthus crassifolius*]), a native of Silhet, Province Wellesley, Singapore, various islands in the E. Archipelago, and Java. There are two kinds, known as *toun-tilâm* or *tilâm-outan*, and *tilâm-wangi*; the former is the common and less fragrant, the latter is the cultivated and more admired. Fisher, of Singapore, who produces about $\frac{4}{5}$ of all the patchouly-oil of commerce, proceeds as follows:—The plants are grown in rows 4–5 ft. apart, in stiffish clay containing a small percentage of silica. They are raised from cuttings struck in the open, and sheltered from the sun by coco-nut shells till rooted. The gathering is done in fine weather and after the dew is off; the tops and green parts are broken off by hand, rejecting all yellow or decayed leaves, and all the woody stems. The selected parts are carefully dried in the shade on bamboo racks, with frequent turning. When so far dried as to leave just sufficient moisture to favour slight fermentation, they are piled in heaps, and allowed to heat gently; they are again spread out and dried (but not to absolute dryness), and are immediately distilled. The distillation is effected by steam generated in a separate vessel, and at a pressure not exceeding 30 lb. a sq. in., the still being usually steam-jacketed to prevent condensation. The yield of oil is about ½ oz. from 1 lb. of leaves; it would be greater by high-pressure steam, but of ranker quality. This oil is sent to London in 22-oz. bottles. Quantities of the more or less inferior and mixed leaves are sent to France and Germany for distillation, but the oil from them is quite a different article. The sp. gr. of Indian and Singapore oils is 0·9554–0·9592, and of a French sample, 1·0119, at 15½° (60° F.). It is much esteemed for perfumery purposes.

Pepper-oil.—The fruits of *Piper nigrum* (see Spices—Pepper), when distilled with water, give a thin, colourless oil, of hot, peppery odour and flavour, sp. gr. 0·864, boiling at 167½°–170° (333°–338° F.).

Other *Piper*-oils are described under Cubebs and Matico (pp. 1420, 1424).

Peppermint-oil.—Peppermint (*Mentha piperita*) yields an essential oil second to none in commercial importance. The plant is found in several parts of England and the Continent, and is extensively cultivated in England, France, Germany, and N. America. It prefers good garden soil, and abundance of moisture, yielding a better oil in a temperate climate than in an arid one. The ground is well tilled some 8–10 in. deep, and the planting takes place in April–May, according to the season. The plants send out a number of runners, which take root at short intervals. These are cut off in spring when about 1 in. high, and are set out in plantations at about 1 ft. apart each way. If the soil is not very humid, or the weather wet, watering will be compulsory. Until July–August, the period of the first harvest, one or two weedings are necessary. After the cropping, runners start in all directions, take root, and cover the ground, sometimes even affording stems for a second gathering. Between August and November, one or two more weedings are required; and towards winter, the plants are covered with a light bed of straw sprinkled with mould or dung. In the second year, the plants have completely occupied the soil; they grow with great vigour, and attain a height of over 2 ft. Two weedings generally suffice during the second year; one crop is cut in July–August, and a second of less importance in the autumn, the usual precautions being taken before winter sets in. In the 3rd and 4th years, the growth relaxes, and the ground has become completely filled with an inextricable mass of runners and roots. The locality is then changed, and the soil is thoroughly well ploughed up; some few gardens, however, will last 5 years. The weight of the crop, and the yield of oil from the plants, vary exceedingly with the seasons. The 6-years' average on a French plantation of 31 *ares* of (119½ sq. yd.), including plants from 1 to 4 years old, was 145 *kilo.* of fresh plants per *are* all round, or say 115 cwt. from an acre.

The herb, when cut, is almost universally allowed to dry on the ground before distillation. This needs the greatest degree of care, for though an incipient fermentation may, and probably does, increase the quantity and improve the quality of the oil, any excess would result in total destruction. The advantage of sun-drying the herb before distillation has been proved by experiments on a large scale, the product being 7 per cent. greater, and of superior fragrance. The main reason for this appears to be that, in the fresh plant, the oil-cells are so strongly protected that it is difficult to rupture them and secure their contents, while the prolonged boiling to which the herb is subjected with this object tends to destroy the natural fragrance of the oil. Some extra cost is entailed for labour in drying; but as it is a common custom for small cultivators to hire the use of a still at so small a charge, irrespective of the weight, an advantage is gained in having the herb dry, as more can then be distilled at once. The best moment for distilling is when the flowers are blowing, the quality of the oil being then superior, though the quantity is perhaps greater somewhat later. The flowering lasts about a month, and the still-accommodation should suffice to complete operations within that time. Usually the entire herb is distilled, for though the leaves and tops afford the most and best oil, the exclusion of the stems reduces the product in quantity, and entails additional labour.

The stills used in Europe are most commonly heated by fire; but in America, preference seems to be given to steam-heating the herb in wooden stills. A good form of still for fire-heat is such as is used for distilling brandy from grape-marc in France, built into masonry, and protected from direct action of the fire, with a copper strainer fixed about 3–4 in. from the bottom for the support of the herb. The distillation is conducted at the lowest possible temperature, and the products are cooled and separated in the ordinary manner, as described on p. 1457. In England, the water that comes over with the oil is mostly allowed to run away, and none of it is used for a second charge. In France, preference is given to the water of former charges. The advantage of old water is that, being already saturated with essential oil, it will not abstract more from the fresh plant; but it is impossible to obtain oil of the highest quality with old waters. The duration of the operation depends upon the firing, and averages about 2½ hours. The spent herb is taken out, dried, and used as cattle-food in America; here it seems to be disregarded. The water remaining in the still after each operation becomes very foul; the still must therefore be washed out every 2–3 days. The yield of oil is extremely variable. In England, it is usually reckoned to average 8–12 lb. from an acre, or 2½–3½ lb. from a ton of dried herb, say 0·11–0·15 per cent.; but some growers pretend to get 6 lb. from a ton, or 0·26 per cent. The results obtained by M. L. Roze from his plantations in France were as follows:—In the 6 consecutive years 1856–61, 26,639 *kilo.* of the plant in flower, weighed within 24 hours of cutting, and distilled entire, gave a mean of 1 *kilo.* of oil from each 609 *kilo.* of plant, the maximum quantity required for 1 *kilo.* having been 638 *kilo.*, and the minimum 548 *kilo*; the mean would be 2⅕ lb. of oil from 1342 lb. of almost fresh herb. The average in America is said to be 7 lb. from an acre of plant, but Stearns makes it exceed the English yield.

The English localities where peppermint is cultivated are Mitcham, in Surrey (500 acres in 1850, 219 in 1864); Wisbeach, in Cambridgeshire; Market Deeping, in Lincolnshire (150 acres in 1871); and Hitchin, in Herts. At Mitcham, two varieties are distinguished: "black," having purple stems, hardier, more prolific, but inferior product; and "white," with green stems, a much more delicate and valued product. The chief French peppermint-gardens seem to be at Sens (department of Yonne), on the flats at the confluence of the Yonne and the Vanne. In Germany, Cölleda, near Leipzig, is the centre of a production of 40,000 cwt. of the herb annually. The cultivation in the American States of S. Michigan, W. New York, and Ohio, exceeds all the European localities combined. Michigan has 2100 acres under this crop, 2000 of which are in St. Joseph county, which possesses 100 distilleries, turning out 15,000-30,000 lb. of oil yearly. New York and Ohio total about 1000 acres between them. The annual crop of peppermint-oil for the whole world is estimated at 90,000 lb. One dealer despatched 57,365 lb. from America in 1870;

and the receipts at Hamburg in 1876 were 25,840 lb. from America, and 14,890 lb. from England. Its commercial value varies widely, Mitcham oil bringing twice or thrice the price of the best American; and even the Mitcham oil itself is by no means constant. A fertile source of depreciation is the presence of weeds among the herbs, necessitating laborious care when preparing the plant for distillation; sometimes other species of *Mentha* usurp the ground, and ruin the fragrance of the product. The American oil is frequently adulterated with castor-oil and alcohol.

Peppermint-oil is colourless, yellowish, or greenish; of peculiar odour; burning, camphoraceous, then cooling flavour; sp. gr. 0·84–0·92; boils at 188°–193° (370½–379½° F.); dissolves readily in alcohol; cooled to −4° (25° F.), sometimes deposits menthol or peppermint-camphor. It is used in medicine (p. 819), confectionery, perfumery (less in England than on the Continent), and largely by sanitary engineers for testing joints and traps.

Other oils afforded by *Mentha spp.* are as follows:—*M. Pulegium* (pennyroyal), sp. gr. 0·927, boils at 183°–188° (361½°–370½° F.). *M. viridis* (spearmint), see p. 1431. *M. australis*, resembles 2nd quality peppermint-oil. *M. gracilis*, with an odour of peppermint and pennyroyal, sp. gr. 0·914. *M. laxiflora*, sp. gr. 0·924, coarse odour; fiery, bitter, nauseous flavour. Much more important than these, is a peppermint of China and Japan, which E. M. Holmes considers most like *M. canadensis*. This plant is distilled at Canton, whence an export of 800 lb. of the oil, valued at 30*s*. a lb., was specified in 1872; there are also large plantations of it in Japan, and the oil (frequently adulterated) is shipped from Hiogo and Osaka. These Chinese and Japanese oils afford much more menthol than other kinds. Seeds of the plant and quantities of the camphor (menthol) yielded by it are imported into this country by T. Christy and Co., 155 Fenchurch St., London.

Petit-grain-oil.—The oil or essence of petit-grain is produced on a large scale by distillation of the leaves and young shoots of both the bitter and sweet varieties of orange (see p. 1025), the former being far the more fragrant and valuable. The leaves of the bitter orange are obtained in the Mediterranean lemon-districts, where lemons are mostly grafted on orange-stocks; the latter put forth shoots during the summer, which are often allowed to grow to a length of some feet, and are then cut off, bound in bundles, and conveyed to the distillery. The oil is very extensively employed in perfumery. Other *Citrus*-oils are described under Bergamot, Cedrat, Lemon, Neroli, and Orange (pp. 1417, 1419, 1423, 1425).

Pimento.—See Allspice, p. 1416.

Pine-oils.—An essential oil is distilled at Reichenhall, in Bavaria, and other places, from the leaves and twigs of *Pinus Pumilio*, which is much esteemed in medicine by the Germans. That from *P. sylvestris* is also recommended in certain throat diseases. (See also Turpentine-oil, p. 1431).

Poplar-oil.—The leaf-buds of *Populus nigra*, and other species, by aqueous distillation, give a colourless oil, of pleasant, balsamic odour.

Pyrethrum-oil.—The flowering herb of *Chrysanthemum* [*Pyrethrum*] *Parthenium*, subjected to aqueous distillation, affords a greenish oil, depositing stearoptene by keeping.

Rose-oil, or Otto [Attar] of Roses (Fr., *Essence de Roses*; Ger., *Rosenöl*).—This celebrated perfume is the volatile essential oil distilled from the flowers of some varieties of rose. The botany of roses appears to be in a transition and somewhat unsatisfactory state. Thus the otto-yielding rose is variously styled *Rosa damascena*, *R. sempervirens*, *R. moschata*, *R. gallica*, *R. centifolia*, *R. provincialis*. It is pretty generally agreed that the kind grown for its otto in Bulgaria is the damask-rose (*R. damascena*), a variety induced by long cultivation, as it is not to be found wild. It forms a bush, usually 3–4 ft., but sometimes 6 ft. high; its flowers are of moderate size, semi-double, and arranged several on a branch, though not in clusters or bunches. In colour, they are mostly light-red; some few are white, and said to be less productive of otto.

The utilization of the delicious perfume of the rose was attempted, with more or less success, long prior to the comparatively modern process of distilling its essential oil. The early methods chiefly in vogue were the distillation of rose-water, and the infusion of roses in olive-oil, the latter flourishing in Europe generally down to the last century, and surviving at the present day in S. France. The butyraceous oil produced by the distillation of roses for making rose-water in this country is valueless as a perfume; and the real otto was scarcely known in British commerce before the present century.

The profitable cultivation of roses for the preparation of otto is limited chiefly by climatic conditions. The odoriferous constituent of the otto is a liquid containing oxygen, the solid hydrocarbon or stearoptene, with which it is combined, being absolutely devoid of perfume. The proportion which this inodorous solid constituent bears to the liquid perfume increases with the unsuitability of the climate, varying from about 18 per cent. in Bulgarian oil, to 35 and even 68 per cent. in rose-oils distilled in France and England. This increase in the proportion of stearoptene is also shown by the progressively heightened fusing-point of rose-oils from different sources: thus, while Bulgarian oil fuses at about 16°–18° (61°–64° F.), an Indian sample required 20° (68° F.); one from S. France, 21°–23° (70°–73° F.); one from Paris, 29° (84° F.); and one obtained in making rose-water in London, 30°-32° (86°-89½° F.). Even in the Bulgarian oil, a notable difference is observed between that produced on the hills, and that from the lowlands.

It is, therefore, not surprising that the culture of roses, and extraction of their perfume, should have originated in the East. Persia produced rose-water at an early date, and the town of Nisibin, north-west of Mosul, was famous for it in the 14th century. Shiraz, in the 17th century, prepared both rose-water and otto, for export to other parts of Persia, as well as all over India. The Perso-Indian trade in rose-oil, which continued to possess considerable importance in the third quarter of the 18th century, is declining, and has nearly disappeared; but the shipments of rose-water still maintain a respectable figure. The value, in rupees, of the exports of rose-water from Bushire in 1879, were—4000 to India, 1500 to Java, 200 to Aden and the Red Sea, 1000 to Muscat and Dependencies, 200 to Arab coast of Persian Gulf, and Bahrein, 200 to Persian coast and Mekran, and 1000 to Zanzibar. Similar statistics relating to Lingah, in the same year, show—otto: 400 to Arab coast of Persian Gulf and Bahrein; and 250 to Persian coast and Mekran. And Bahrein —Persian otto: 2200 to Koweit, Busrah, and Bagdad; rose-water: 200 to Arab coast of Persian Gulf, and 1000 to Koweit, Busrah, and Bagdad.

India itself has a considerable area devoted to rose-gardens, as at Ghazipur, Lahore, Amritzur, and other places, the kind of rose being *R. damascena*, according to Brandis. Both rose-water and otto are produced. The flowers are distilled with double their weight of water in clay stills; the rose-water (*goolabi pani*) thus obtained is placed in shallow vessels, covered with moist muslin to keep out dust and flies, and exposed all night to the cool air, or fanned. In the morning, the film of oil, which has collected on the top, is skimmed off by a feather, and transferred to a small phial. This is repeated for several nights, till almost the whole of the oil has separated. The quantity of the product varies much, and three different authorities give the following figures:—(*a*) 20,000 roses to make 1 rupee's weight (176 gr.) of otto; (*b*) 200,000 to make the same weight; (*c*) 1000 roses afford less than 2 gr. of otto. The colour ranges from green to bright-amber and reddish. The oil (otto) is most carefully bottled; the receptacles are hermetically sealed with wax, and exposed to the full glare of the sun for several days. Rose-water deprived of otto is esteemed much inferior to that which has not been so treated. When bottled, it is also exposed to the sun for a fortnight at least.

The Mediterranean countries of Africa enter but feebly into this industry, and it is a little remarkable that the French have not cultivated it in Algeria. Egypt's demand for rose-water and rose-vinegar is supplied from Medinet Fayum, south-west of Cairo. Tunis has also some local reputation for similar products. Von Maltzan says that the rose there grown for otto is the dog-rose (*R. canina*), and that it is extremely fragrant, 20 lb. of the flowers yielding about 1 dr. of otto. Genoa occasionally imports a little of this product, which is of excellent quality. In S. France, rose-gardens occupy a large share of attention, about Grasse, Cannes, and Nice; they chiefly produce rose-water, much of which is exported to England. The essence (otto) obtained by the distillation of the Provence rose (*R. provincialis*) has a characteristic perfume, arising, it is believed, from the bees transporting the pollen of the orange-flowers into the petals of the roses. The French otto is richer in stearoptene than the Turkish, 9 *grm.* crystallizing in a *litre* (1¾ pint) of alcohol at the same temperature as 18 *grm.* of the Turkish. The best preparations are made at Cannes and Grasse. The flowers are not there treated for the otto, but are submitted to a process of maceration in fat or oil, 10 *kilo.* of roses being required to impregnate 1 *kilo.* of fat. The price of the roses varies from 50 *c.* to 1 *fr.* 25 *c.* per *kilo.*

But the one commercially important source of otto of roses is a circumscribed patch of ancient Thrace or modern Bulgaria, stretching along the S. slopes of the central Balkans, and approximately included between the 25th and 26th degrees of E. longitude, and the 42nd and 43rd degrees of N. latitude. The chief rose-growing districts are Philippopli, Chirpan, Giopcu, Karadshah-Dagh, Kojun-Tepe, Eski-Sara, Jeni-Sara, Bazardshik, and the centre and headquarters of the industry, Kazanlik (Kisanlik), situated in a beautiful undulating plain, in the valley of the Tunja. The productiveness of the last-mentioned district may be judged from the fact that, of the 123 Thracian localities carrying on the preparation of otto in 1877—they numbered 140 in 1850—42 belong to it. The only place affording otto on the N. side of the Balkans is Travina. The geological formation throughout is essentially syenite, the decomposition of which has provided a soil so fertile as to need but little manuring. The vegetation, according to Baur, indicates a climate differing but slightly from that of the Black Forest, the average summer temperatures being stated at 28° (82° F.) at noon, and 20° (68° F.) in the evening. The rose-bushes flourish best and live longest on sandy, sun-exposed (S. and S.-E. aspect) slopes. The flowers produced by those growing on inclined ground are dearer and more esteemed than any raised on level land, being 50 per cent. richer in oil, and that of a stronger quality. This proves the advantage of thorough drainage. On the other hand, plantations at high altitudes yield less oil, which is of a character that readily congeals, from an insufficiency of summer heat. The districts lying adjacent to and in the mountains are sometimes visited by hard frosts, which destroy or greatly reduce the crop.

Floods also occasionally do considerable damage. The bushes are attacked at intervals and in patches by a blight similar to that which injures the vines of the country.

The bushes are planted in hedge-like rows in gardens and fields, at convenient distances apart, for the gathering of the crop. They are seldom manured. The planting takes place in spring and autumn; the flowers attain perfection in April–May, and the harvest lasts from May till the beginning of June. The expanded flowers are gathered before sunrise, often with the calyx attached; such as are not required for immediate distillation are spread out in cellars, but all are treated within the day on which they are plucked. Baur states that, if the buds develop slowly, by reason of cool damp weather, and are not much exposed to sun-heat when about to be collected, a rich yield of otto having a low solidifying-point, is the result; whereas, should the sky be clear and the temperature high at or shortly before the time of gathering, the product is diminished, and is more easily congealable. Hanbury, on the contrary, when distilling roses in London, noticed that, when they had been collected on fine dry days, the rose-water had most volatile oil floating upon it, and that, when gathered in cool rainy weather, little or no volatile oil separated.

The flowers are not salted, nor subjected to any other treatment, before being conveyed in baskets, on the heads of men and women, and backs of animals, to the distilling apparatus. This consists of a tinned-copper still, erected on a semicircle of bricks, and heated by a wood fire; from the top, passes a straight tin pipe, which obliquely traverses a tub kept constantly filled with cold water, by a spout from some convenient rivulet, and constitutes the condenser. Several such stills are usually placed together, often beneath the shade of a large tree. The still is charged with 25–50 lb. of roses, not previously deprived of their calyces, and double the volume of spring water. The distillation is carried on for about 1½ hour, the result being simply a very oily rose-water (*ghyul-suyu*). The exhausted flowers are removed from the still, and the decoction is used for the next distillation, instead of fresh water. The first distillates from each apparatus are mixed and distilled by themselves, one-sixth being drawn off; the residue replaces spring water for subsequent operations. The distillate is received in long-necked bottles, holding about 1¼ gal. It is kept in them for a day or two, at a temperature exceeding 15° (59° F.), by which time, most of the oil, fluid and bright, will have reached the surface. It is skimmed off by a small, long-handled, fine-orificed tin funnel, and is then ready for sale. The last-run rose-water is extremely fragrant, and is much prized locally for culinary and medicinal purposes. The quantity and quality of the otto are much influenced by the character of the water used in distilling. When hard spring water is employed, the otto is rich in stearoptene, but less transparent and fragrant. The average quantity of the product is estimated by Baur at 0·037–0·040 per cent.; another authority says that 3200 *kilo.* of roses give 1 *kilo.* of oil.

Pure otto, carefully distilled, is at first colourless, but speedily becomes yellowish; its sp. gr. is 0·87 at 22½° (72½° F.); its boiling-point is 229° (444° F.); it solidifies at 11°–16° (52°–61° F.), or still higher; it is soluble in absolute alcohol, and in acetic acid. The most usual and reliable tests of the quality of an otto are (1) its odour, (2) its congealing-point, (3) its crystallization. The odour can be judged only after long experience. A good oil should congeal well in five minutes at a temperature of 12½° (54½° F.); fraudulent additions lower the congealing-point. The crystals of rose-stearoptene are light, feathery, shining plates, filling the whole liquid. Almost the only material used for artificially heightening the apparent proportion of stearoptene is said to be spermaceti, which is easily recognizable from its liability to settle down in a solid cake, and from its melting at 50° (122° F.)., whereas stearoptene fuses at 33° (91½ F°.). Possibly paraffin-wax (see Paraffin) would more easily escape detection.

The adulterations by means of other essential oils are much more difficult of discovery, and much more general; in fact, it is said that none of the Bulgarian otto is completely free from this kind of sophistication. The oils employed for the purpose are certain of the grass oils (*Andropogon* and *Cymbopogon spp.*), notably that afforded by *Andropogon Schœnanthus* (see Ginger-grass-oil, p. 1422), called *idris-yaghi* by the Turks, and commonly known to Europeans as "geranium-oil," though quite distinct from true geranium-oil. The addition is generally made by sprinkling it upon the rose-leaves before distilling. It is largely produced in the neighbourhood of Delhi, and exported to Turkey by way of Arabia; it is sold by Arabs in Constantinople in large, bladder-shaped, tinned-copper vessels, holding about 120 lb. As it is usually itself adulterated with some fatty oil, it needs to undergo purification before use. This is effected in the following manner:—The crude oil is repeatedly shaken up with water acidulated with lemon-juice, from which it is poured off after standing for a day. The washed oil is placed in shallow saucers, well exposed to sun and air, by which it gradually loses its objectionable odour. Spring and early summer are the best seasons for the operation, which occupies 2–4 weeks, according to the state of the weather, and the quality of the oil. The general characters of this oil are so similar to those of otto of roses—even the odour bearing a distant resemblance,—that their discrimination when mixed is a matter of practical impossibility. The ratio of the adulteration varies from a small figure up to 80–90 per cent. The only safeguard against deception is to pay a fair price, and to deal with firms of good repute.

The otto is put up in squat-shaped flasks of tinned copper, called *kunkumas*, holding 1–10 lb., and sewn up in white woollen cloths. Usually their contents are transferred at Constantinople into small gilded bottles of German manufacture, for export. The Bulgarian otto-harvest, during the five years 1867–71, was reckoned to average somewhat below 400,000 *meticals*, *miskals*, or *midkals* (of about 3 dwt. troy), or 4226 lb. av.; that of 1873, which was good, was estimated at 500,000, value about 700,000*l.* The harvest of 1880 realized more than 1,000,000*l.*, though the roses themselves were not so valuable as in 1876. About 300,000 *meticals* of otto, valued at 932,077*l.*, were exported in 1876 from Philippopolis, chiefly to France, Australia, America, and Germany.

Rosemary-oils.—The common rosemary (*Rosmarinus officinalis*) is a native of S. Europe and Asia Minor, growing abundantly wild in Spain, France, Germany, and Austro-Hungary, and under cultivation to a small extent at Mitcham, in Surrey. The cultivation resembles that of lavender, except that the plant requires longer to mature. The otto produced in England is valued at 10 times the price of Continental articles, but its quantity is so inconsiderable that it scarcely forms a commercial article. The market is chiefly supplied from plants growing wild in S. France, and Italy, as well as on the islands of Lesina, Maslinica, and Lissa, off the Dalmatian coast, where the peasants annually retort some 20,000 *funti* (of 1·2 lb.), and export 300–350 *quintals* of the oil viâ Trieste. In France and Italy, the plant is gathered in summer, but not while in flower; generally the entire herb is distilled, but sometimes the flowering tops only are selected for the operation. In Dalmatia, the biennial shoots are cut in May, sun-dried for about 8 days, and deprived of their leaves. The latter are then moistened with water, and treated in copper stills over naked fires. The yield from 1 cwt. of fresh herb is about 24 oz. of oil, but is subject to great variation. The oil is colourless or yellowish, with a somewhat camphor-like odour and flavour of the herb; sp. gr. 0·886–0·933; dissolves readily in alcohol. It has a very wide use in perfumery. Trieste supplies 34,000–40,000 lb. annually of the oil to Europe and America.

The so-called "wild rosemary" or "Labrador tea," *Ledum palustre* (see Narcotics—*Ledum*, p. 1308), gives an essential oil by aqueous distillation.

Rosewood- or Rhodium-oil.—By aqueous distillation, the root and stem of *Convolvulus scoparius* and *C. floridus*, growing in the Canaries, afford an essential oil, in the proportion of about 3 oz. from 1 cwt. The oil is thin, pale-yellow, with an odour of roses and cubebs, and a bitter aromatic flavour. It has disappeared from commerce, and is completely replaced in perfumery by an artificial compound.

Rue-oil.—The whole herb of *Ruta graveolens*, submitted to aqueous distillation, affords a colourless oil (about 1 lb. from 150–200 lb.), with strong odour and flavour of the herb, sp. gr. 0·831, congealing at $-1°$– $-2°$ ($30\frac{1}{4}°$–$28\frac{1}{2}°$ F.), and boiling at 228°–230° ($442\frac{1}{2}°$–446° F.). It is principally employed in aromatic vinegars (see p. 335).

Saffron-oil.—The stigmata of *Crocus sativus* (see Dyestuffs—Saffron, p. 866), by aqueous distillation, yield a thin yellow oil, with an odour of saffron, which is slowly converted into a solid mass that sinks in water.

Sagapenum-oil.—By distilling sagapenum (see Resinous Substances—Sagapenum) with water, it affords a thin, yellow oil, with a garlic-like odour at first, then becoming turpentinous, drying to a translucid varnish, and dissolving readily in alcohol.

Sage-oil.—The whole herb of sage (*Salvia officinalis*), by aqueous distillation, yields a greenish-yellow oil, with the odour and flavour of the herb, sp. gr. 0·864, boiling at 130°–160° (266°–320° F.) It is rarely employed, but is a useful perfume. The plant grows both wild and cultivated around Grasse (S. France), and yields 1 lb. of oil from 300 lb.

Sandal-wood-oil.—The essential oil which carries the delightful perfume of sandal-wood (see Perfumes—Sandal-wood) is extracted in Mysore in the following manner. The roots yield the largest quantity and finest quality, and next in value is the dark central wood of the tree. The chips and billets are distilled with water in a large globular clay pot, with an open mouth, about $2\frac{1}{2}$ ft. deep, and $6\frac{1}{2}$ ft. in circumference at the bilge. When charged, the mouth of the still is closed with a clay lid, having a small central hole, through which is passed a bent copper tube, about $5\frac{1}{2}$ ft. long, for the escape of the vapour. The lower end of this tube is carried into an ordinary crude condenser. The white or sap wood is rejected for distilling. The operation is carried on for 10 days and nights, the water being occasionally renewed from the heated overflow of the condenser. The yield from good wood is at the rate of $2\frac{1}{2}$ per cent.; European distillers do not succeed in getting more than 30 oz. from 1 cwt. The oil is transparent, of pale-yellow colour, resinous flavour, sweet peculiar odour, sp. gr. 0·980. It is in great request as a perfume.

Sassafras-oils.—Essential oils are obtained from the root-wood and root-bark of *Sassafras officinale* (see Drugs—Sassafras, p. 823). These oils are largely distilled in America. The charge of a still, about 11 bush. of chips, yield 1–5 lb. of oil, according to the quality of the root, and the proportion of bark present. The wood of the root gives 1–2 per cent., while the bark of it affords double that amount, and the stem and leaves of the tree yield scarcely any. The commercial oil is derived entirely from America, the quantity annually produced in Baltimore, the chief market for a radius of 300 miles, being 15,000–20,000 lb.; it was 20,200 lb. in 1876. The oil is colourless, yellow, or reddish-brown, according to the character of the root used; it has the odour of sassafras, and sp. gr. 1·087–1·094. When cooled, it deposits crystals of sassafras-camphor (see p. 578). It is used in America to give a pleasant flavour to drinks, tobacco, and soaps.

Australian sassafras (*Atherosperma moschatum*), growing abundantly in gullies near the coast in Victoria and Tasmania, gives a thin, unctuous, pale-yellow oil by aqueous distillation of the bark; its odour resembles sassafras and caraway, with a bitter aromatic flavour, sp. gr. 1·04, boiling at 230°–245° (446°–473° F.)

Savin-oil.—The branchlets and fruits of *Juniperus Sabina*, distilled with water, yield a colourless oil, with strong odour and flavour of the shrub, sp. gr. 0·89–0·94, boiling at 155°–161° (311°–322° F.). In S. France, 1 lb. of oil is obtained from 300–400 lb. The yield from young branches is 1·30 per cent. fresh, and 2·5 per cent. dry; from the fresh berries, 10 per cent. The oil is used medicinally, and is often adulterated with turpentine-oil.

Other *Juniperus*-oils are described under Cedar and Juniper (pp. 1419, 1422).

Spearmint-oil.—The common garden mint or spearmint (*Mentha viridis*) is a fragrant perennial cultivated plant of Europe, Asia, and N. America. It is cultivated in the United States in the same manner as peppermint (see p. 1425). H. G. Hotchkiss, of Lyons, Wayne Co., New York, makes some 1000 lb. of the essential oil annually. Its sp. gr. is 0·91–0·93.

Spike-oil.—See Lavender-oil (p. 1423).

Sweet-flag-oil.—The rhizome of *Acorus Calamus* (see p. 190), when distilled with water, affords a pale- to dark-yellow oil, with strong penetrating odour of the root, aromatic, bitter, burning, camphoraceous flavour, sp. gr. 0·89–0·98, dissolving readily in alcohol, and boiling at 195° (383° F.)

Tansy-oil.—The herb and flowers of *Tanacetum vulgare*, distilled with water, yield a thin yellow oil, having the specific odour of the plant.

Tarragon-oil.—The leaves of *Artemisia Dracunculus*, distilled with water, give an oil of 0·935 sp. gr., boiling at 200°–206° (392°–403° F.). The plant is cultivated on a large scale near Grasse (S. France), yielding two crops yearly (July and October); its yield of oil is 1 lb. from 300–500 lb., according to season and locality.

Other *Artemisia*-oils are described under Mugwort, Wormseed, and Wormwood (pp. 1424, 1432).

Tea-oil.—An essential oil is extracted from tea-leaves by distilling with water, shaking the distillate with ether, pouring off the ether solution, and evaporating; it is lemon-yellow, of strongly narcotic, tea-like odour and flavour, and solidifies on keeping. It is not to be confounded with the fatty oil extracted from the seed (see p. 1411).

Thyme-oil.—All varieties of the thyme afford fragrant essential oils, but this is especially the case with the wild or lemon-thyme (*Thymus Serpyllum*). The cultivated variety (*T. citriodorus*) of this species is not utilized by perfumers; its oil is golden-yellow, with a pleasant odour of lemon and thyme, and an aromatic, bitter flavour; sp. gr. 0·89–0·91. The species cultivated for the sake of its odour is the common or garden-thyme (*T. vulgaris*). This plant is extremely abundant on the arid wastes of Languedoc; it is collected from the rocky hills in the department of Gard, S. France, and distilled chiefly in the villages around Nîmes. The entire herb is used, and the process is carried on both in May–June, when the plant is in flower, and again in the autumn. The yield is about 1 per cent. of oil; this is deep reddish-brown, becoming colourless but slightly less fragrant on re-distillation. Both the former (*huile rouge de thym*) and the latter (*h. blanche de t.*) are met with in commerce. Some 11,938 lb. of thyme-oil were consumed in England in 1839, and 7553 lb. in 1844. The oil is used medicinally (chiefly veterinary), and in perfumery under the name of "origanum" (see p. 1424); one of its constituents, thymol, is a valued disinfectant. It is often adulterated with oil of turpentine, or fraudulently deprived of its thymol before sale.

Turpentine-oil.—A volatile oil pervades all parts of the numerous species of *Pinus* (see Timber), and is mostly obtained from the resinous exudations (see Resinous Substances) by dry or aqueous distillation. The commercial oils are commonly distinguished as:—"French," from *P. maritima* and *P. Pinaster;* "German," from *P. sylvestris*, *Abies pectinata*, and *A. excelsa*; "Venetian," from *Larix europæa;* and "English," from *P. Tæda* and *P. australis.* They are thin, colourless, with strong specific odour and flavour, sp. gr. 0·850–0·880, boil at 150°–160° (302°–320° F.), scarcely soluble in water, sparingly in alcohol, readily in ether.

Fatty oils from *Pinus spp.* are described on p. 1408.

Valerian-oil.—By aqueous distillation, the root of *Valeriana officinalis* (see Drugs, p. 826) gives a thin, neutral, yellowish oil, with an odour of the dried root, sp. gr. 0·90–0·96, readily soluble in alcohol.

Wintergreen-oil.—All parts of *Gaultheria procumbens*, a little creeping plant of N. United States and Canada, possess a pleasant aromatic odour and flavour, due to the presence of an essential oil. The leaves are submitted to aqueous distillation in a copper vessel (tin-plate is better, and wood probably would be found even more satisfactory), the water being used repeatedly. The yield is about 0·66–0·80 per cent. According to the latest returns, 828 lb. of this oil was distilled in the United States. It is pale-green, of the same composition as birch-bark-oil (see p. 1417), sp. gr. 1·17, and is employed medicinally. It is sometimes adulterated with sassafras-oil and chloroform in large proportion.

In Java, *G. punctata* and *G. leucocarpa* are abundant on the tops of many of the volcanoes, and their leaves yield oils scarcely distinguishable from the Canadian wintergreen-oil: the proportion from the former is 340 grm. of oil from 59 lb. of fresh leaves, or about 1·15 per cent.; and from the latter, 40 grm. from 65 lb., or 0·012 per cent.

Andromeda Leschenaultii, common hill-plant in Ceylon; oil closely resembling Canadian wintergreen, but containing less of the peculiar hydrocarbon oil found in the Canadian product, and therefore superior, but the commercial demand would hardly repay its preparation.

Wormseed- and Wormwood-oils.—The flowers of *Artemisia Cana* and *A. Lippii*, by aqueous distillation, yield a colourless or yellowish oil, with an odour of the drug, an acrid, burning, aromatic flavour, sp. gr. 0·925–0·945, boiling at 175° (347° F.) after rectification. The leaves and flowers of *A. Absinthium*, by aqueous distillation, give a dark-green oil, with odour and flavour of the plant, sp. gr. 0·973, boiling at 205° (401° F.), and readily soluble in alcohol. The United States produced 170 lb. of this oil, according to the latest returns.

Other *Artemisia*-oils are described under Mugwort and Tarragon (pp. 1424, 1431); see also Drugs—Wormseed, p. 826.

Miscellaneous.—The following plants have been ascertained to afford volatile oils, exhibiting the properties stated:—

Aristolochia Serpentaria, root: light-brown; with odour and flavour of valerian and camphor.

Arnica montana (see Drugs, p. 793), flowers and root: former blue or brownish-green, latter brownish-yellow.

Asarum europæum, root: thickish; yellowish; valerian-like odour; burning acrid flavour.

Backhousia citriodora: in forest tracts of S. Queensland; the lemon-scented leaves deserve distillation.

Bursera gummifera, resin (see Resinous Substances—Gomart): resembles turpentine-oil.

Carapa guianensis (see Crab-oil, p. 1386): unctuous; colourless; very bitter flavour; solid at 4° (39° F.).

Chenopodium ambrosioides, herb: pale- to greenish-yellow, colourless when rectified; very thin; great light-refracting power; strong odour of the herb; aromatic peppermint-like flavour; sp. gr. 0·902; boils at 179°–181° (354°–358° F.); readily soluble in alcohol.

Cochlearia officinalis, C. Danica, and *C. Anglica*, herb: sp. gr. 0·942; with pungently acrid odour and flavour of the green herb in the highest degree.

Curcuma longa, root: thin; citron-yellow; penetrating odour and hot flavour.

C. Zedoaria, tubers: pale-yellow; turbid; thick; peculiar, fragrant, camphor-like odour; bitter, hot, camphoraceous flavour.

Dahlia purpurea, tubers: yellowish; strong odour of the tubers; sweetish, sub-acrid flavour; becomes thick like butter.

Daucus Carota, root: peculiar, strong, penetrating odour; similar, warming, disagreeable flavour; sp. gr. 0·886.

Eriostemon squameum, leaves: pale-yellow; similar but milder odour and flavour than rue.

Hedwigia balsamifera, balsam: yellow; pleasant turpentinous odour; hot flavour.

Lycopus europæus, herb: green; butter-like; odour of the herb; acrid flavour.

Mercurialis annua, dried herb: thickish consistence.

Nigella sativa (see also p. 1415), seeds: colourless, with bluish fluorescence; mixed odour of fennel and bitter almonds.

Oenanthe Phellandrium, fruits: yellowish to brownish; thin; penetrating odour and flavour of the fruit; sp. gr. 0·852.

Osmitopsis asteriscoides, flowers: thin; yellowish, rectified colourless; penetrating odour of camphor and cajuput; burning, rancid flavour; readily soluble in alcohol; sp. gr. 0·921; boiling-point, 178° (352½° F.).

Pastinaca sativa, fruits: clear, colourless; not unpleasant odour; aromatic flavour; sp. gr. 0·8672 at 17½° (63½° F.).

Peucedanum Oreoselinum and *P. ostruthium*, herb of former: strong, aromatic, juniper-like odour; sp. gr. 0·840; boiling-point, 163° (325½° F.). Root of latter: thin; colourless to pale-yellow; penetrating odour; warm, camphoraceous flavour.

Philadelphus coronarius, flowers: by ether; golden-yellow; narcotic in quantity; delightful odour when diffused.

Pittosporum undulatum, flowers: limpid; colourless; extremely agreeable jasmine-like odour; disagreeably hot and bitter flavour.

Prostanthera Lasianthos, and *P. rotundifolia*, leaves: former, greenish-yellow; mint-like odour and flavour; sp. gr. 0·912. Latter, of darker colour; and 0·941 sp. gr.

Ravenala sp., of Madagascar, and *R. amazonica*, in Guiana: blue pulpy aril surrounding the seeds.

Thuya occidentalis, the green parts: colourless to greenish-yellow; camphoraceous odour and flavour; sp. gr. 0·925; boiling-point, 190°–197° (374°–386½° F.); readily soluble in alcohol.

Tropæolum majus, fruits: yellow; peculiar, aromatic odour; acrid, burning flavour; inflames the skin more than mustard-oil; contains sulphur; boils at 120°–130° (248°–266° F.).

Zieria Smithii, leaves: pale-yellow; odour and flavour of rue; sp. gr. 0·950.

MINERAL OILS.

Mineral oils include the following products:—Peat-oils, or the hydrocarbons which may be distilled from peat; shale-oils, or similar bodies obtainable from bituminous shales; coal-tar-oils, or allied products of the distillation of the tar obtained in making illuminating-gas; and, most important by far, the large series of petroleums or rock-oils found ready-formed in certain geological strata in many parts of the world.

Peat-oils.—Before the introduction of American petroleum, the distillation of oils from peat was a remunerative industry in this country; but where petroleum, bituminous shale, or oil-coal can be had in abundance, the profitable utilization of peat-oil in this manner is impossible in the present state of our knowledge and appliances. Of the bog-peats formerly distilled by the Irish Peat Co., 100 ton, in close retorts, gave 2 ton 15 cwt. of tar, yielding 409 gal. of refined oils and paraffin; by kiln treatment, 2 ton 8 cwt. of tar, affording 304 gal. of oils and paraffin. Dense mountain peat from Antrim, in Dr. Hodge's experiments with 50 tons, produced at the rate of 4·44 per cent. of tar. The very dense bituminous peat cut by Sir James Matheson, in Lewis, one of the Hebrides, returns, from 100 tons, air-dried, by close retort, 2097 gal. of tar, equivalent to 1629 gal. of crude oil, 999 gal. of which may be secured in the refined state. This was highly profitable when the oil sold at 2*s.* a gal., but the production of oil has long been discontinued even here, and the tar is used in the ship-yards.

Shale-oils.—Beds of dark, coaly-looking mineral, known as "bituminous" or "bituminiferous" shales, occur in this country in the Tertiary, Cretaceous, Oolitic, Triassic, and Carboniferous formations. These vary in quality and aspect, according to the proportion of mineralized organic matter present, ranging from a mere argillaceous mineral almost to coal. The beds vary in thickness and in character; they are interstratified with sandstones, limestones, coals, &c.; and are mined much in the same way as coal. Many of the Oolitic and Wealden shales, though valuable for some purposes, are useless as sources of illuminating-oils, and it is those of the Carboniferous system that are chiefly distilled for the production of paraffin and paraffin-oils. Bituminous shales occur in most British coal-fields. Their production in 1880 was as follows:—

The shales of the lower coal-measures of Linlithgow, Lanark, Ayr, Fife, and Midlothian are those most largely raised for distilling. Superior shales are recognized by their lightness and toughness, or "boardiness," in mining phraseology, and by their brown streak. Those in use yield a quantity of crude oil varying from 18 to 80 gal. a ton. This branch of manufacture is discussed at length in the article on Paraffin.

An earthy lignite occurring within a small portion of the Saxon Thuringian brown-coal formation, between Weissenfels and Zeitz, forms the material for a large mineral oil and paraffin industry, dealing with some 36,000 tons of tar annually, and producing about 12,500 tons of paraffin-oils, 6000 tons of gas- and lubricating-oils, 5000 tons of paraffin, and 3600 tons of accessory products. This lignite contains nests and branches of a fusible hydrocarbon (pyropissite), yielding as much as 66 per cent. of tar on distillation.

Coal-tar-oils.—The extraction and utilization of the oils contained in coal-tar will be found fully described and illustrated in the article on Coal-tar Products, pp. 641–684.

Petroleum, Rock-oil, Naphtha, or Mineral Tar (Fr., *Bitume liquide*; Ger., *Erdöl*, *Steinöl*).—These names are applied with little discrimination to a class of liquids occurring in various geological formations and geographical localities; possessing a more or less limpid, oily consistence, a strong bituminous odour, a usually dark yellowish-brown colour, a sp. gr. ranging from 0·8 to 1·1; and composed of hydrocarbons varying in constitution and boiling-point in almost every case, as will be noticed further on. Very closely allied products are asphalte or native bitumen (see p. 341), and ozokerit or earth-wax (see Wax—Ozokerit).

Origin and Occurrence.—The origin of petroleum has been a subject of much speculation among geologists. The most widely accepted notion is that it is due to the very slow decomposition of organic remains, animal, vegetable, or both combined. But the occurrence of any organic detritus in such formations as the Silurian, in sufficient quantity to account for the enormous yield of oil, is doubted by many. Another attempted explanation of its origin is the percolation of sea-water to depths where the temperature is sufficiently high, in contact with such minerals as iron and its sulphides, to form carburets, in support of which is adduced the frequent occurrence of petroleum and similar products as accompaniments of volcanic action. A third plausible argument refers the formation of all the members of this hydrocarbon series to the condensation of carbon vapours escaping from a depth in the earth on meeting with hydrogen combined as water, the new compound becoming condensed to various degrees according to local circumstances. Reflecting on the vast geological distribution of petroleum, it is only reasonable to suppose that more than one cause has been instrumental in its production. All experience hitherto gained tends to prove that, though in a few unimportant cases, the creative agency, whatever it may be, seems to be still at work, yet in the great majority of instances, the active formation of the article is a work of the far past, and that we are recklessly exhausting the supplies which have been countless ages in course of collection.

Petroleum is found in strata of almost all ages, from Silurian upwards. In Canada, it occurs mainly in the corniferous limestone of the Lower Devonian, also more or less in the bird's-eye limestone of the Lower Silurian, and the Lower Helderberg limestone of the Upper Silurian. In the United States, it is obtained chiefly from Devonian and Carboniferous formations; in S. California, from Tertiary shales; in Trinidad, from Tertiary lignites; in Persia and the Caspian region, from Tertiary shales and limestones; in Burma, from shallow Tertiary and Post-tertiary clays and lignites.

Commercial Sources.—Petroleum has been discovered in W. Staffordshire and in Scotland. It is obtained at Bechelbronn and Schwabwiller, Department of Bas-Rhin, France. Germany possesses petroleum-springs affording a limited quantity near Lüneburg, in Alsace; borings are being made in the district S. of Celle, in Hanover, where those reaching 60 ft. in depth are yielding 4 cwt. of oil daily, of improving quality; and an experimental sinking near Heide, in Holstein, has struck a flowing well giving a superior product. The oil-wells of Italy number about 5, situated in the Valley of Cocco, in the Abruzzi, and at Riva-Nazzano, near Voghera, in Piedmont. The exploitation has been on a primitive scale hitherto, and the production trifling.

The resources of the previously-cited localities appear insignificant in comparison with those of a portion of E. Europe embracing parts of Hungary, Galicia, Bukowina, Roumania, and Moldavia. Dr. H. Gintl, a great authority in these matters, considers this petroleum (and ozokerit) region uniform in origin and history with the similar formation in the Caspian and Trans-Caucasian countries. He declares that the whole N. flank of the Carpathians, from Librautowa, in Neu-Sandezer, to Sloboda, in Kolomea'er, or a length of over 270 miles, will be found to yield petroleum and ozokerit; some 13,500 wells in about 126 localities, give a yearly yield of about 520,000 *centners* (of 110¼ lb.) of petroleum, and 360,000 *centners* of ozokerit, representing a capital of about 600,000*l.* There are 9 districts of Galicia where petroleum is obtained, the principal being Boryslav, where are situated 3200 of the 4000–5000 wells now being worked. The ground is divided into very small lots, of different ownership; the wells are sunk very near together, and, in this district, to very shallow depths, 18–25 fathoms being the average, and 65 fathoms the maximum. In 1873, Boryslav produced 200,000 cwt. of crude petroleum, and Wolanka, 20,000 cwt.; the total value (including a larger quantity of ozokerit) was 462,000*l.*, and the total labour employed was 9000. The common method of working is to sink a shaft down to the stratum of plastic clay; with favourable soil and little water, the sides are lined with 2-in. boards; so far as the clay extends, the only lining used is wicker-work. The ordinary dimensions of the shafts are 26 in. × 32–37 in., and 20 in. × 36 in. when lined with wicker. The sinking is always carried on with the aid of ventilators and air-tubes; no light is admitted, except while cutting through ozokerit, when a safety-lamp is used. Large quantities of gas are always present in the workings. The petroleum is usually met with at a shallower level than the ozokerit. When oil is struck, operations are temporarily suspended. The pit is covered with boards, so that the well may not cool, and the oil is then extracted by a crude arrangement of buckets and winding apparatus. The average daily yield of a well is 30 gal., but some give 140 gal. When the flow stops, the well is usually deepened, so as to obtain a second supply. Between the marl strata and sandstone strata, are often deposits of ozokerit, whose working will be described in another article (see Wax—Ozokerit). In the district of Bóbrka, which, according to Dr. Gintl, is by far the most advanced, the petroleum is found in a conglomerate containing rounded quartz particles as large as lentils, the whole being a porous mass perfectly free from lime, and emitting much smoke and a strong odour of petroleum when burned. Wells sunk 66 ft. have produced 3000 cwt. of petroleum monthly for a considerable time. The depth first driven does not exceed 50–200 ft., but as the yield decreases, they are deepened to 800–1000 ft. This is the only district where anything like the American system has been introduced. Boring-rods making a 6-in. or 7-in. hole are used, and generally worked by steam. The petroleum is drawn off by 2-in. tubes. A rule obtains that where ozokerit occurs, there petroleum also will be found; but the converse does not hold. The wells are far less productive than those of America, though the latter do not yield ozokerit. The petroleum obtained is distilled in the ordinary way, so as to afford a good burning-oil.

Petroleum has been known in Roumania and Moldavia for at least 50 years, and was collected by the peasants for use as wagon-grease, and in medicine. It was first distilled to produce a lighting-oil in 1857–8, and was sent into commerce both by rail and by the Danube. The Roumanian petroleum-field lies on the southern slopes of the Transylvanian Carpathians, from Kolibas to Rimnik Sarat, the most important points being Kolibas, Baikoiu, Pukureti, Tintea, Duftinesti, Sarate, and Rimnik Sarat. All these occur in the Miocene. The largest and deepest wells are in Sarate, and give some 3500 barrels yearly. The wells of Sarate, Kolibas, Pukureti, Duftinesti, and Tintea, lie only 10–18 *kilom.* from the Plojesti railway-station. Over an area of some 25 acres in Baikiou, the natives utilize the inflammable vapour escaping from the earth for cooking purposes. Petroleum is usually struck at a depth of 250–550 ft. The sinking of the shafts and extraction of the oil are performed in the most primitive manner. The oil is of the denser character, its sp. gr. being 40°–48° B. It is refined at Sarate and Plojesti, affording about 40 per cent. of 1st quality lighting-oil, 20 per cent. of 2nd, 22½ per cent. of paraffin, and 17½ per cent. of residue. The raw petroleum is largely sent to Vienna, Peat, and Odessa, and some refined to Constantinople. The quality from different wells varies widely. Thus while the raw material from Sarate gives 40 per cent. of 1st quality petroleum at 42° B., the Plojesti product gives 35 per cent. of 1st quality petroleum, and 15 per cent. of benzine at 55° B. It is considered certain by Dr. Gintl that the whole Miocene formation of Roumania will be found to yield not only petroleum but ozokerit.

The Moldavian petroleum-field occupies a triangular area of over ½ million acres, bordered by the rivers Trotus and Taalin. The principal localities are Moinesti, Salante, and Comonesti, lying 25–30 *kilom.* S.-W. of the railway-station of Bacâu. Trial holes have also been sunk at Slanicu, about 7 *kilom.* S. of Okna, but hitherto without much result. The geological formation is Eocene, and bears a general resemblance to that of Galicia. In Salante and Comonesti, the wells strike oil at 150–250 ft.; in Moinesti they reach a depth of 400 ft. The whole operations are conducted in the rudest possible manner. The petroleum sells at the rate of about 1*d.* per 2½ lb. on the spot. The oil is somewhat darker-coloured than the Galician. It is almost free from paraffin, and has the low freezing-point of − 20° (− 4° F.), so that it is admirably adapted for street-lighting in winter. The sp. gr. of the raw petroleum is 1·307; of the distilled, 0·742. Distillation is but little carried on in Moldavia; there are some 10 distilleries in Salante and Moinesti, but the bulk is exported in the raw state to Roumania, Bukowina, and Galicia. The raw petroleum affords by distillation about 35½ per cent. of 1st quality lighting-oil, 30½ per cent. of 2nd quality, 17½ per cent. of tar, and 16½ per cent. of residue. The annual production is estimated by Dr. Gintl at 4000 barrels from Moinesti and Comonesti, 2000 from Salante, and 1000 from various other spots. The import of Moldavian and Roumanian petroleum into Austria by the Lemberg-Jassy railway has risen from 500 barrels in 1870 to 2350 in 1876.

Russia possesses a large territory affording petroleum. This has been officially estimated at 14,000 sq. miles, which is an obvious exaggeration. The present chief seats of the oil industry are Baku, at the S.-E. end of the Caucasian mountains; Kertch, on the Kouban river; and the neighbourhood of Zarskia Kolodza, about the centre of the S.-W. slopes. The petroleum is found in the Tertiary beds overlying Miocene, the wells having a depth of 280–350 ft. The wells and their production in 1875 were:—Kouban district, 42 wells, 230,500 *poods* (of 36 lb.); Terak, 29 wells, 22,160 *poods*; Dagestan, 11 wells, 6200 *poods*; Apsheron peninsula (Baku), 119 wells, 6,265,728 *poods*; S. of Baku on the Caspian shores, 72 wells, 125,000 *poods*; total, 273 wells, 6,649,588 *poods*, or 105,550 tons. The extent of the Caucasian petroleum deposits is quite an unknown figure, but the indications imply an immense area, and borings have been almost everywhere successful in reaching oil. The Mogan steppe and the country around Shemaka are alluded to in a recent consular report as offering unusual inducements to prospectors, especially as about $\frac{9}{10}$ of the land is desert, utterly useless for agriculture, and purchasable at a low figure. At present everything is done in a most primitive manner; but an American firm proposes laying a pipe from Baku and the Mogan steppe to the Black Sea. Great quantities of petroleum are now allowed to run to waste. A peculiarity of the Baku petroleum is its high sp. gr., as compared with American having the same boiling-point. It gives 10 per cent. more light than American, and is more readily drawn up the wick to the flame. The high sp. gr. is availed of by manufacturers of lubricating-oil, who send into European markets an oil of 0·940 sp. gr., without any extraneous addition.

Petroleum-springs occur in Zante, one of the Ionian Islands; probably large supplies might be obtained, if proper means were adopted. In Italy, traces of petroleum, at present unprofitable, are found at Monte Zolo, and Combe di Sassatello. Egyptian petroleum has a sp. gr. of 0·953; it affords a fine lubricator, free from tarry matter, but is inferior as an illuminator. Of Indian localities, the most important is Independent Burma. Here petroleum is chiefly found near the village of Ye-nang-gy-oung, on the banks of the Irawadi. Upwards of 100 wells exist, having a common depth of 210–240 ft., occasionally increasing to 300. The wells are square shafts, 3–4 ft. across, lined with timber. The oil issues spontaneously, in inexhaustible quantities, the annual yield exceeding 11,000 tons, much of which reaches England. Petroleum-wells occur also in the British Burmese districts of Akyab, Kyouk-hpyu, and Thayet-myo, many being worked very successfully by means of British capital. Oil has been worked in the neighbourhood of the coal-fields of

S. Lakhimpur, in Assam. Two spots in the Rawal Pindi district of the Punjab afforded 2756 gal. in 1873-4. Formosa possesses large oil-grounds, which are monopolized by the Chinese Government; the oil is very slightly coloured, and of low sp. gr., and burns in lamps without being refined. Petroleum is assuming some importance as a Japanese product. It occurs principally in the provinces of Echigo, Shinano, Uyo, and Totomi. Many hundred springs are met with in Echigo; in individual spots, some 60–100 are at work. The borings vary from 2 to 600 ft. in depth. At Kanadoza, the oil flows out on the actual surface of the ground, and costs nothing but collecting. About 90 per cent. is obtained by rectification. The yield is estimated at about 750 gal. daily. The oil is of two kinds:—(*a*) clear, containing 8 per cent. of light oil, 33 per cent. of burning-oil, 48 per cent. of heavy oil, and 12 per cent. of residue; (*b*) dark, containing 9 per cent. of lamp-oil, 58½ per cent. of heavy oil, and 32½ per cent. of residue. In Shinano, the daily yield of some 40 wells is 350 gal. of oil, mostly dark-coloured, and affording only 13 per cent. of burning oil. A refinery has been erected at Niigata, capable of turning out some 4000 gal. daily, and drawing its supplies from Totomi province, a distance of 100 miles by water.

It is convenient to note that all the petroleum found in the E. United States of America is contained in a belt parallel with, and considerably to the westward of, the Alleghany mountains. The Canadian oil regions are situated in the western part of the Dominion, in the counties of Lambton, Bothwell, and Kent, Ontario province. They extend from Lake Erie to Lake Huron, and from the St. Clair river eastward for about 70 miles. The most prominent points of production are Petrolia (Lambton county), Oil Springs (Bothwell county), and Bothwell (Kent county). The petroleum is here found in a flint-bearing limestone, varying in construction, and largely composed of the marine shells and other fossils peculiar to the "corniferous" beds. The sp. gr. of the oil is 33°–43° B. (0·863–0·815 sp. gr.). The rock near Petrolia shows the following strata:—Yellow clay, 5–15 ft.; compact blue clay, 50–100 ft., resting on a thin crust of limestone, resembling stalagmite; gravel, 2–8 ft.; slate, 15 ft.; corniferous limestone, 40 ft., giving surface wells; slate, 30 ft.; limestone, 40 ft.; slate, 30 ft.; corniferous limestone 250 ft., where all the oil is found; hard blue sandstone, 4 ft.; and finally a vein of salt water, seemingly inexhaustible, as it has been penetrated for 500 ft. in several places, without yielding a barrel of oil. The entire production of the Canadian oil region is about 2500 barrels a day.

The Ohio and W. Virginia oil regions are confined to two definite belts of anticlinal geological disturbance, one extending from Newport (Ohio) northward through Washington and Morgan counties, and southward about 40 miles into W. Virginia, through Ritchie, Wood, and Wirt counties, and embracing the productive points of Horseneck, Sandhill, Volcano, White Oak, and Burning Springs; and another smaller belt lying a few miles farther west. The minimum width of the belt is about 2½ miles. The special features of this region are that oil is found in crevices at a certain fluid level, without the slightest regard to the character of the rock in which the crevices exist. Where a natural crevice is not reached by the drill, a torpedo seldom fails to open connection with one. No surface-water is found in the wells, and often no salt water. At Volcano, especially, the oil is pumped clear. It ranges in sp. gr. from 28° to 40° B. (0·889–0·829 sp. gr.), and oils of all gravities are found, indiscriminately, even in wells side by side. A section of the strata in W. Virginia and Ohio is of no value as an indication of the oil level. The production of the whole region is about 500 barrels a day.

Kentucky and Tennessee have afforded enormous quantities of oil from surface wells. A well on Crocus Creek, Cumberland county (Kentucky), at 191 ft., gave 300 barrels a day for a time; and those on Boyd's Creek, Barren county, those stretching from the Cumberland river through N.-W. Kentucky, and those in Overton county (Tennessee), indicate the probability of a large production if thoroughly developed. But the presence of sulphur in the oil, the remoteness from large consuming centres, the cost of transport, and the competition of the Pennsylvanian wells, have conspired to check extended operations here.

In Massachusetts, some wells have been sunk near Lee.

The oil basin of Shoshone (Wyoming) covers an area of about 40 acres, within which, are many points whence gas and oil are continually issuing. The oil is intensely black, and no means of decolorizing it have yet been found. On distillation, it gives 47 per cent. of kerosene flashing at 65½° (150° F.), 32 per cent. of neutral and lighter-coloured lubricating-oil, and 12 per cent. of dry coke. The sp. gr. is 20° B. (0·935); flash-test, 145½° (294° F.), and fire-test, 161° (322° F.). The Beaver basin is situated some 25 miles due east. The oil here is much lighter-coloured, varying from pale-yellow to light-mahogany. It has proved to be a good lubricant, with no unpleasant odour. It is said that millions of tons of hardened petroleum are lying about the surfaces of these basins.

The Pennsylvania oil-region proper comprises the districts of Tidioute, West Hickory, New London, Colorado, Enterprise, Titusville, Shamburg, Pithole, Petroleum Centre, Story Farm, Rouseville, Oil City, Reno, Franklin, and East Sandy, besides the Lower oil-fields, and sundry outlying districts.

In Tidioute, the first wells were sunk upon the banks and islands of the river, and yielded quantities of oil at 100–150 ft. Subsequently the sand rock was found under the hills on each side, and the best wells were bored there. The rock brought to the surface in Warren county was an open, porous conglomerate of small pebbles and a cementing matter composed of alumina and silica, friable on exposure, and capable of holding much oil. A well on the island at Tidioute drilled to 1000 ft. showed no sand below 125 ft. The best wells at Tidioute and Triumph Hill have given 400 barrels a day, and the thickness of the sand bed is not fully known, as it has only been pierced for 50–60 ft. The wells on the hill-land of the Economy tract, opposite Tidioute, merit special examination; their oil came from a region above the river level, a marked exception to all the experiences gained in the oil-region.

In the West Hickory oil area, a small quantity of heavy oil of 27° B. (0·895 sp. gr.), not exceeding 12–15 barrels per well, was obtained at a depth of 400 ft. When this ceased, a 3rd sand of 55 ft. was found at 750 ft., and very large quantities of oil have been drawn from a well of 400 barrels maximum.

The New London wells are not very large, but their production is steady and uniform. The thickness of the sand rock is 40–55 ft., at a depth of about 650 ft.

Colorado wells have, in some cases, reached 150 barrels a day, and the sand rock is found on the flat, with a thickness of about 40 ft., and at an averago depth of 525 ft. The area here is probably far from being yet determined.

Enterprise has a few scattered wells, which have produced a small quantity of oil for a long time, from a sand rock 17–38 ft. thick, at a depth of about 450 ft.

The Titusville oil districts are:—1. The Watson, Guild, and Parker Flats, which gave much of the yield between 1859 and 1864. 2. The Drake Well, whose oil was found in a crevice, the well being subsequently drilled deeper, and tapping a 10-ft. sand at 150 ft., and a 55-ft. one at 370 ft., but no 3rd sand was found at 480 ft., nor in adjoining wells at 550 ft. 3. Church Run, where the sand rock does not seem to occupy quite the same geological horizon as that on the flats; the wells, while never exceeding 300 barrels, have produced largely and lastingly, the sand rock being 60–75 ft. thick, and found on the run at a depth of 480 ft. 4. In the Octave District, the wells are small but durable, and the area has not been fully defined; the sand rock is 50–70 ft. thick, at a depth of about 875 ft. 5. Miller Farm afforded some oil in 1864 from shallow wells in the 1st sand, but the quantity was inconsiderable. 6. Pleasantville. 7. National Wells have struck the 3rd sand, about 15 ft. thick, at 745 ft. on the run; the wells do not exceed 30 barrels, but the production has been considerable. 7. West Pithole wells have found a 14-ft. sand at 730 ft.

Shamburg, once a noted centre, is now nearly exhausted. The sand rock, on the run, is 60–75 ft. thick, at a depth of 775 ft. While the largest wells in this section did not reach 500 barrels, probably no locality has contained so many good wells. A marked peculiarity of the great stretch of oil-rock, of which Shamburg forms a part, is the existence of "black" and "green" oils, so called, side by side in the same territory, so that the surface line between the two classes of wells can be sharply defined. The following figures represent a minute section of a well in this district:—At 38 ft., was met a soft slate rock; 70 ft. 1st sand rock; 71 ft., water crevice; 91-112 ft., crevices; 130 ft., bottom of fine white sand rock 60 ft. thick; 132 ft., bluish-grey sand rock; 152 ft., bottom of ditto; 153 ft., slate rock, good drilling to 245 ft.; 245–256 ft., hard dark slate and sand to 278 ft.; 278 ft., hard pebble sand crust 18 in. thick; 280–289 ft., hard grey sand and slate; 289 ft., 2nd sand rock, hard pebbles, 11 ft. thick; 300 ft., bluish sand and white pebbles 5½ ft. thick; 305½ ft., grey and white shells for 29½ ft.; 338–440 ft., blue sandy rock, mixed with slate; 420–480 ft., blue and red rock alternately; 505 ft., hard blue rock crust, 15 ft. thick; 520 ft., 3rd sand, very hard, white and yellow pebbles, 10 ft. thick; 530 ft., mud vein; 545 ft., through 3rd sand 25 ft. thick, two crevices, and gas very strong; 545–575 ft., blue sand and slate to 605 ft.; 608 ft., hard crust 2 ft. thick; 610–636 ft., blue slate; 636 ft., hard white sand mixed with pebbles, a hard crust 4–5 ft. thick; 640 ft., top of 4th sand; 648–654 ft., hard pebble; 654 ft., large gas vein and show of oil; 655 ft.. bad mud vein; 668 ft., through 4th sand, 28½ ft. thick; 745 ft., hard crust of slate, 6 in. thick; 745–748 ft., hard slate; 748 ft., hard shell, yellow pebble, and good gas vein; 750 ft., slate rock; 768 ft., slate and hard shells; 776 ft., top of 5th sand; 776–8 ft., pebble rock, open and porous; 778 ft., crevice, gas vein, and good show of oil; 781 ft., rock darker; 783 ft., dark rock, gassy; 784 ft., rock porous; 792 ft., white and yellow pebble, crevice, oil, and gas; 794 ft., rock white, coarse, and porous; 806 ft., mud vein; 828–830 ft., white and yellow pebble; 830 ft., hard, close, white sand; 834 ft., slate and sand mixed; 835 ft., bottom of well.

The sand rock of Pithole, though unusually productive, had a small area in comparison with beds of more recent discovery. The Frazier and Grant wells flowed at the rate of 700 and 450 barrels a day. The sand rock on the flats of Pithole creek is 14–20 ft. thick, and at 600 ft. The chief centres in this district are:—1. Cash Up, though of small extent, was remarkable for its yield; the 1st well when drilled deep gave 1100 barrels a day. 2. Bean Farm had small wells, but proportionately lasting. 3. Bull Run and Cow Run are underlaid with a highly productive sand rock; the famous Noble well here gave 2500 barrels a day.

The Petroleum Centre oil claims overlie a fine bed of sand rock, 45 ft. thick, at 950 ft.

At Story Farm, over 180 wells, producing nearly 1 million barrels of oil, were drilled within 500 acres. The territory is now exhausted. The sand rock here is 40–45 ft. thick, at 480 ft. On the Blood, Rynd, and Tarr farms, the sand rock is 38–58 ft. thick; it has yielded enormously in former times, some of the wells giving 1000–4000 barrels a day.

Rouseville wells have struck the 3rd sand, 27–42 ft. thick, at 550 ft.; four wells on a single acre have given over 100,000 barrels of oil. The valley of Oil Creek, after producing over 110 million dollars' worth of oil from an area of less than 3 sq. miles, obtained with extraordinary waste, is rapidly declining.

At Oil City, along the creek and river-flats, fairly productive wells have been found, the 3rd sand being 20–55 ft. thick, at about 475 ft.

At Reno, the sand rock was found on the Charley Run at about 500 ft. On Sage Run, the sand rock is 18–20 ft. thick, at 900–1000 ft., and the wells have yielded up to 300 barrels each daily.

The wells of Franklin and Sugar Creek find their oil in the uppermost oil-producing sand rock on the great slope from the north-west. The rock is met with at a depth of 260 ft., beneath the flat; it is geologically higher than that of Oil City, and 50–80 ft. thick. The sp. gr. of the oil ranges from 30° to 32° B. (0·879–0·868), the most productive well giving 150 barrels a day. At Foster, the 3rd sand, 12–14 ft. thick, is struck at 610 ft.; at Scrub Grass, it is 18–20 ft. thick, at 615 ft.

East Sandy, the connecting link between the Upper and Lower oil-belts, comprises Gas City, where the sand rock was 60 ft. thick, at 850 ft.

The great Lower oil-belt has a length of some 21 miles, beginning at Triangle City (Clarion county) and apparently terminating at St. Joe (Butler county). After leaving Karns City, it splits into two well-defined beds, known as East and West. The entire width of the belt does not exceed 3 miles, but the productive area is uninterrupted, instead of being in detached spots, as in the Upper belt. The sand rock dips so rapidly in one section that the wells are there drilled to 1600 ft. An idea of the relative position of the sand rock along the belt from the upper end southward may be gained from the following data:—Turkey City, sand on flat, 20 ft., at 1150 ft.; Ocean Level of Pump Station, Turkey City, at 1179 ft.; St. Petersburgh, 26 ft., at 1241 ft.; Blanchard and Siggins' well, 26 ft., at 1063 ft.; Eddinger farm, 24 ft., at 1150 ft.; Peter King farm, 23 ft., at 1000 ft.; Casino well, 36 ft., at 1065 ft.; Murray well, 30 ft., at 1027 ft.; Bear Creek, 33 ft., at 1170 ft.; Karns City, at 1230 ft., the 3rd sand, 26 ft., at 1440 ft., and 4th sand at 1535 ft.; Modoc wells, 12–15 ft., at 1450 ft.; William Moore farm, at 1560 ft.; Armstrong Run, 3rd sand 7½ ft., at 1263 ft.; Millerstown, at 1550 ft.; James M'Cready farm, at 1530 ft.

Between the main belts of sand rock which are the great centres of production, are isolated localities, which have been more or less explored. The most prominent are:—1. Near Lowell, heavy oil at 150 ft., and gas, but no oil, at 900 ft. 2. Slippery Rock Creek, many productive wells, some up to 50 barrels, but not lasting; oil was heavy. 3. Oil Spring Reservation, surface oil. 4. Well at Limestone, at 1050 ft., gave much gas, and oil of 45° B. (0·806 sp. gr.), at first about 5 barrels a day. 5. Wells on Cow Run, about 450 ft. deep, on main belt of anticlinal in the Ohio region. 6. Wells on Duck Creek are part of same belt. 7. Utica, 7 barrels of heavy oil daily. 8. Leechburg, a gas-well, 1200 ft. deep, supplying fuel to the manufactories. 9. Tarentum, where the salt-wells, 450 ft. deep, have always found more or less petroleum within 350 ft. of the surface; some produce 8–10 barrels a day, the oil separating by the subsidence of the brine, and imparting no flavour. 10. Hosmer Run, wells found much oil at 500 ft. 11. Edinburg, a 10-barrel well, at 260 ft., heavy oil. 12. 13. Meadville, gas-well, 6-ft. sand, at 350 ft., no other sand at 1000 ft. 14. Stewart's Run, gas at 150 lb. pressure in 2nd sand, at 150 ft.; 3rd sand not found at 825 ft. 15. Cherry Run, coal-seam, 75 ft. above creek-bed. 16. Erie, about 27 gas-wells, at 450–1200 ft., average 600 ft.; one well, at 585 ft., small quantity of oil at 28° B. (0·889 sp. gr.). 17. Middlesex, small well of heavy oil. 18. Little Scrub Grass, 3rd sand at 1000 ft., and penetrated 30 ft. 19. Newell's Run, one well 5 barrels, at 525 ft.; another 10 barrels, at 236 ft. 20. Kinzua Creek, coal-bed at 600–700 ft. above the river, 4 ft. cannel, 7 ft. fire-clay, and 4 ft. bituminous coal. 21. Cherry Grove, coal-seam. 22. Bradford, a little oil and gas in a few wells in the valley. 23. Mecca, heavy oil, shallow wells, and limited yield. 24. Bully Hill, 25-ft. sand rock, one well 100 barrels. 25. Millerstown, coal at 240 ft. above the river. 26. Thorn Creek, a well that produced largely for a short time. 27. Brown and Co.'s well, 8 barrels, at 660 ft. 28. 29. Corry, gas-well, 950 ft. deep. 30. 31. 32. Wilcox, heavy oil, at 1691 ft. 33. North Rocks, conglomerate outcrop, 40–50 ft. thick. 34. Olean, 1st sand at 300 ft., 2nd at 450, 3rd at 780; last very thin, some oil, much gas. 35. West Hickory, heavy oil, small wells. 36. Smith's Ferry, oil 27°–33° B. (0·895–0·863 sp. gr.); product of wells, 25–90 barrels a week. 37. Winter's Farm, a good sand at 600 ft., 56 ft. thick, drilled 1670 ft. without finding oil, torpedoed at 600 ft., and small yield obtained. 38. Gas-well 3 miles N.-E. of East Sandy, a good sand rock of 42 ft., much gas, no oil. 39. Gas-well half-way between Gas City and Linesville. 40. Hiram Heath farm, trace of oil. 41. The Newton gas-well, 786 ft. to 3rd sand; gas production, 4 million cubic feet a day. 42. Octave District, sand rock 50 ft. thick, wells 890 ft. deep. 43. The Drake well, found oil in surface sand at 71 ft., subsequently drilled to 480 ft., but never afterwards produced much. 44. Walbridge Farm, sand rock 25 ft. thick; one well 5 barrels a day of oil at 42° B. (0·819 sp. gr.), at 750 ft. 45. Johnson Farm, 8 barrels a day, at 930 ft. 46. Cowanshannock well, no oil, much gas. 47. Fredonia, gas-well. 48. Niles, gas-wells. 49. Painesville, gas-well, 40 ft. drift clay and gravel, 648 ft. Erie shales and soapstone, 12 ft. Huron shale, very black and bituminous, with strong smell of oil, 720 ft. total depth. 50. Rock City, fine exposure of conglomerate. 51. Blyson's Run, small show of oil. 52. Little Whitely Creek, 150 ft. deep. 53. Panama, exposure of conglomerate. 54. Howeville, gas-well. 55. White Oak, oil at 80–380 ft., 26°–28° B. (0·901–0·889 sp. gr.); the same gravity oil found in one well at 300 ft., and another at 600. 56. Sugar Creek, salt spring; well sunk to 300 ft. struck oil, which mixed with the brine, and rendered it valueless. 57. Groce Farm, small well 700 ft. deep. 58. 59. 60. Sage Run, hill wells 800–1000 ft. deep, sand rock 60 ft. thick. 61. Dunkard's Creek wells. 62. Panama, at 550 ft., 6 ft. in 2nd sand; surface sand 75 ft. thick, at 344 ft.; 1st sand 30 ft., at 461 ft. 63. Jamison Farm, sand 13 ft. thick, well 240 ft. deep, small yield of oil of 48° B. (0·792 sp. gr.); well drilled to 550 ft., but no more sand found. 64. 65. Kinzua Creek, 5 or 6 wells.

While the precise location of the horizon at which the Pennsylvanian oil is found can only be determined by an examination of its entire area, a few deductions from such prominent facts as are not likely to be seriously affected by future work will be of value in conveying some idea of the nature of the search required. It is particularly desirable to obtain an accurate impression of the relative size and location upon the surface of such areas as outline the oil-bearing rocks below. It will be observed that these spots are isolated and disconnected, and, with the exception of the stretch of the great Lower oil-fields, do not comprise any continuous belt. To present this more clearly, it may be stated that, out of 3115 sq. miles of land in Pennsylvania, embracing everything which, by general acceptance, can be denominated as the oil-region, only 39½ sq. miles have actually produced oil; that is to say, all the territory that now is or has been producing could be contained in an area of 25,000 acres.

Whether the component materials or the great body of this oil exist in the sand rock where it is found, or at a depth beyond the present reach of the drill, is not a question of direct importance. What is being sought for is the location of the vent-holes by which this oil reaches within drilling distance of the surface of the earth, whether such vent-hole consists of an open sand rock or sponge as in Pennsylvania, or of an anticlinal or system of broken rocks as in W. Virginia. From the fact that coal and similar minerals are mined in continuous beds, stretching often over counties and states, it would be natural to suppose that the sand rocks of the separate oil districts are connected in the same way. The extent of the beds of the upper sand rocks, near the surface of the earth, is so much greater than that of the oil-bearing rock, that the proposition is substantially true so far as they are concerned, with the exception that they are not found at a positively uniform horizon, but overlap and underlie each other at the edges.

A well drilled anywhere in the region will find a 1st sand; and sometimes a 2nd, and invariably some "mountain sands," as they are called, are found even above these. Oil has been found in small quantities in the 1st and 2nd sand rocks, in detached spots, and from the earliest wells, but the bulk of the product has been obtained from the 3rd sand. From the means within reach at present for defining the position of this rock, there is every reason to believe that it is situated approximately throughout the region under consideration on the same geological horizon.

The productive ground in the Pennsylvania region is an area overlying, at 500–1500 ft., a bed of porous conglomerate, 3–75 ft. thick, the thickest part of the rock giving the best well, and this thickest part being generally found in the centre of the area, the rock tapering off at the edges.

When a well is drilled in an untried locality, and the 3rd sand rock is found of any thickness, whether with much or little oil, this well is followed by others situated in different directions from it, until the thickest part of the sand rock is discovered, and a good well is the result; and it is not long before the edge, where the rock thins out, can be mapped on the surface of the ground above it. There is, therefore, within reach of the drill, no continuous bed of oil-bearing sand rock, but a series of scattered disc-shaped deposits. These separate and detached beds of 3rd sand rock are lens-shaped, being thin at the edges, as before stated.

The use of the term "oil-belt," has led to some misconception; lines which were run across the surface of the country for many miles, in courses varying from N. 14° E. to N. 22° E., have been found to intersect the surface directly over these producing beds of 3rd sand, but in separate places, and widely apart. The value of this discovery is doubtless confined to the extent of the conformity of these lines with the general course of the current which transported the material to form the deposit.

It would seem that all the oil rocks of the region, even if they be disconnected and scattered through the strata at irregular distances, lie at about the same general geological horizon.

The lowest sand rock as yet reported by any oil driller is in Jonathan Watson's deep well, which was drilled on the flat, in the City of Titusville, at a point 1195 ft. above sea-level, and in which a sand 20 ft. thick and containing some green oil, was said to have been passed through at a depth of 1976 ft. This sand was described as a white pebble conglomerate, similar in every respect to the ordinary 3rd sand. The next is the reported 3rd sand of Watson's well at a depth of 1507 ft. from the surface. The lowest 3rd sand of the oil-region proper is found at Tidioute, at a depth of 140 ft. below the first bench on the river, but not at a corresponding depth under the hills on either side. The sand rock there, if it be the same, is considerably higher; but when penetrated, in the hopes of finding the river-sand, only "knocked the bottom out of the well." No small amount of oil has been produced from a 1st sand at Tidioute, found on the river at a depth of less than 100 ft. On the river-bank of the Economy tract, a well struck in a crevice at 99½ ft., in 1861, produced oil steadily for 8 years; and 4 other producing wells in the vicinity were not over 150 ft. in depth. From Enterprise and Titusville to Oil City, the 3rd sand, which is found at an average depth of 450 ft., follows nearly the fall of the water-shed, being found at Oil City at a depth of 475 ft., and along Oil Creek almost uniformly between these points. At Petroleum Centre, there appears to be a similar deviation; also at Church Run, near Titusville. Surface oil has, likewise, been found in the 1st and 2nd sand rocks on Oil Creek. The Drake well found the sand at 71 ft., and produced for some time 25 barrels a day. Some wells at Miller farm also found oil for a short time at 225 ft., in what was probably a split 1st sand.

The fall of the sand rock progresses uniformly through intervening sections to Scrub Grass, on the Allegheny river. Here, it is found, that while the oil-bearing sands on Beaver creek are also apparently uniform in general horizon with the dip or fall north of them, yet from this point southward along the belt, the dip is so much more rapid, that without the fortunate coincidence of the lowest line of water-shed being with tho direction of the development, the wells would, before this, have attained a very undesirable depth.

The explanation of the phenomenon of a 4th sand, as it is called, which is found on the cross-belt from Armstrong Run to Greece City, and its precise geological location, requires the closest research. Whether it is a separate sand rock deposited by a cross-current on a lower horizon, or whether it is only a divided 3rd sand, is yet a matter of question. The formation immediately above it is almost identical with that above the 3rd sand of the grand belt. A thin hard shell which caps it is found in a similar position at Millerstown. The levels taken so far seem to indicate that it occupies the same position as the 3rd sand. The 4th sand at Karns City is 25 ft. thick, of a red and yellow colour, and lies about 70 ft. below that known as the 3rd sand.

America is at this moment supplying almost all the world's needs of petroleum. But it is producing in reckless haste, at a positive loss to the community at large, and regardless of all consequences save the present bountiful supply. Considering the short life of the best territory that has been found, and the relative smallness of the productive area in proportion to the entire region, it is a serious question, even in the face of the enormous output of to-day, whether the United States will continue to supply petroleum to the next generation. The total exports of petroleum from the United States in 1879 were 25,874,000 gal. crude, and 349,128,000 gal. refined.

The exports of refined from New York (in gallons) in the years 1878 and 1879 respectively were thus distributed:—Great Britain, 29,918,226 and 47,186,757; Germany, 48,374,179 and 64,130,182; Norway and Sweden, 3,928,374 and 5,480,157; Russia, 1,811,288 and 2,670,900; Denmark, 5,886,528 and 5,809,642; Belgium, 11,251,387 and 16,156,629; Holland, 8,623,656 and 11,010,971; Spain, 6,783,785 and 7,693,336; Portugal, 1,356,800 and 1,973,427; Gibraltar and Malta, 2,480,342 and 1,857,396; Italy, 3,018,291 and 2,449,128; Austria, 5,807,423 and 9,989,863; Greece, 1,594,220 and 1,513,650; Turkey in Europe, 4,537,276 and 3,605,440; Turkey in Asia, 2,922,550 and 1,404,660; India, nil and 8,502,080; China, Japan, &c., 24,615,545 and 18,803,770; E. Indies, 8,861,345 and 23,688,516; Egypt, 1,555,666 and 3,749,843; Canary Islands, 109,033 and 82,976; other African ports, 1,719,518 and 2,359,170; Australia, 2,476,982 and 2,277,346; New Zealand, 811,993 and 352,260; Sandwich Islands, 32,000 and 45,850; Brazil, 3,497,578 and 4,220,973; Argentine Republic, 1,632,985 and 1,742,857; Chili and Peru, 1,062,115 and 936,872; Colombia (New Granada), 2640 and 38,060; Venezuela, 421,182 and 527,152; other S. American ports, 33,500 and 26,100; Central America, 164,718 and 216,008; Mexico, 546,921 and 850,583; British N. America, 312,329 and 237,645; Cuba, 2,144,292 and 735,942; British W. Indies and Guiana, 1,227,602 and 1,388,057; other W. Indies, 804,058 and 987,118; totals, 190,406,227 and 254,701,316 gal.

In addition, the exports of crude oil in the same years were:—France, 12,900,049 and 17,931,418; Antwerp, 170,320 and 140,506; Bremen, 1,102,060 and 2,133,847; Norway and Sweden, 46,324 and nil; Spain, 113,000 and 1,873,167; Cuba, 344,786 and 1,680,800; totals, 14,576,539 and 23,759,738 gal. The naphtha exports were:—Great Britain, 4,871,170 and 7,674,523; France, 2,732,418 and 4,864,165; Germany, 712,531 and 1,110,776; other Europe, 1,314,756 and 1,800,010;

various ports, 109,926 and 81,567; totals, 9,740,791 and 15,531,041 gal. And the shipments of residue to all ports were 3,006,694 and 4,670,854 gal.

Philadelphia ranks second in importance for the shipment of petroleum. The exports thence of refined in 1879 (in gallons) were:—Austria, 6,552,054; Belgium, 14,241,302; Brazil, 87,501; Denmark, 1,491,304; French W. Indies, 2000; Germany, 27,623,838; England, 1,874,056; Gibraltar, 1,561,591; British W. Indies, 12,456; other British possessions, 116,000; Italy, 17,143,725; Japan, 1,855,200; Netherlands, 8,079,697; Portugal, 688,771; Spain, 122,544; Cuba, 27,557; Porto Rico, 5000; Norway, 267,332; Sweden, 461,633; Turkey in Europe, 100,000; Egypt, 56,530; Colombia (New Granada), 52; Venezuela, 18; total, 82,370,211 gal. The exports of crude were:—France, 2,666,665; Germany, 368,600; Spain, 179,481; Cuba, 1500; Sweden, 25,257; total, 3,241,503 gal. And of naphtha and benzine:—France, 1,617,451; Germany, 243,853; England, 773,866; Sweden, 114,857; total, 2,750,027 gal.

The total shipments from Baltimore, the only other centre of importance, were:—44,874,861 gal. in 1877, 37,712,900 in 1878, 23,322,482 in 1879, and only 14,780,980 in 1880.

Of the W. Indian Islands, Trinidad, Cuba, and Barbadoes are known to possess petroleum-deposits, but they have been turned to little account; Barbadoes exported 2424*l.* worth in 1877, and 1437*l.* in 1878. Venezuela produces large quantities of rich bitumen fit for distilling, and minor contributions of petroleum; a remarkable outburst of petroleum occurs between the Rio Tara and Zulia, one hole out of many giving 240 gal. an hour. In the neighbouring republic of Colombia (New Granada), petroleum is met with between Escuque and Bettijoque. Peru has afforded petroleum from time immemorial. The Argentine Republic has recently commenced to develop its resources in petroleum at Laguna de Labrea, in Jujuy, where numerous springs exist. In S. Australia, a remarkable petroleum district has just been opened out on the banks of the Coorong, about 6 miles north of Salt Creek. A number of Australian capitalists have begun to work the petroleum-springs in the Poverty Bay district of Auckland, New Zealand, and other springs are known of on the same coast.

There are three principal localities, each producing a distinct kind of oil:—(1) The Sugar Loaves, in Taranaki province; (2) Poverty Bay, on the E. coast of the province of Auckland; (3) Mauntahi, Waiapu, East Cape. The oil from the first has a very high sp. gr., 0·960–0·964 at 15½° (60° F.). It has thus too much carbon in its composition for its commercial success as an illuminating-oil, but is capable of producing a valuable lubricating-oil. It resembles oil occurring in Santa Barbara county, California. The second kind, from Waiapu, Poverty Bay, is a true paraffin-oil, resembling the Canadian oil. By three successive distillations, and treatment with acids and alkalies, about 65 per cent. of a good illuminatiug-oil is obtainable, with a sp. gr. of 0·843. The third produces a pale-brown oil, nearly or quite transparent, of sp. gr. 0·829 at 15½° (60° F.), burns well, contains only traces of paraffin, and produces 84 per cent. of an illuminating-oil, fit for kerosene-lamps, by a single distillation; by two more distillations, 66 per cent. of the crude oil has a sp. gr. of 0·811, which is that of common kerosene. At Sugar Loaf Point, Taranaki, the petroleum oozes from cracks in trachyte breccia. Wells have been bored to the depth of many hundred feet, but no steady supply of oil has been obtained. Crude oil has a sp. gr. of 0·962 at 15½° (60° F.), and yields, by fractional distillation, oils having the following gravities:—2 per cent. of oil of sp. gr. 0·874, 10 per cent. at 0·893, 8 per cent. at 0·917, 60 per cent. at 0·941; or a total of 80 per cent. distilled off, with 6·1 per cent. solid bitumen, 12·4 per cent. fixed carbon, and 1·5 per cent. ash.

The following is an analysis of the petroleum found at Waipawa River, Poverty Bay, Auckland:—2 per cent. of oil of sp. gr. 0·809 (colourless), 16·0 per cent. at 0·826 (nearly colourless), 16·0 per cent. at 0·836 (pale-yellow), 19·0 per cent. at 0·850 (dark-yellow), 11·0 per cent. at 0·850 (brown, [solid at 4½° (40° F.)]), 8·0 per cent. at 0·864, 21·25 per cent. paraffin-oil; or a total of 93·75 per cent. distilled off, and 6·25 per cent. of residue in the retort (pitch).

At Waiapu, East Coast, Auckland province, the crude oil has a sp. gr. of 0·872 at 14½° (58° F.); boiling-point, 143° (290° F.); flashing-point, 110° (230° F.); a sample with a sp. gr. of 0·829 gives 40·0 per cent. of oil of sp. gr. 0·800 (colourless), 33·0 per cent. at 0·826 (pale-coloured), 12·5 per cent. at 0·840, 6·25 per cent. at 0·860, and 4·25 per cent. at 0·870; or a total of 96·00 per cent. distilled off, and 4·00 per cent. of residue in the retort. Another analyis yielded 12·20 per cent. of sp. gr. 0·820 (fine lamp-oil), 37·75 per cent. at 0·853 (inferior lamp-oil), 26·69 per cent. of lubricating-oil, 16·00 per cent. of paraffin; or a total of 90·64 per cent. distilled off, and 9·36 per cent. bituminous residue.

Boring and Pumping Oil-wells.—Ready-formed outlets for petroleum are rarely found, and usually the earth has to be bored for a considerable depth to reach the productive level, and the oil then generally requires to be pumped out. This branch of the subject divides itself into four principal heads—the "rig," the well, drilling-tools, and pumps.

The Rig.—The rig is composed of a derrick, band-wheel, bull-wheel, sand-pump reel, sampson-post, walking-beam, and engine-house. The present derrick is built "balloon-frame," 16–20 ft. sq.

at the base, and 60–72 ft. high, resting on hewn oak sills 12 by 18 in., framed and pinned at the corners; the four corner-posts are of pine plank 10 by 2 in., spiked together at right angles, and connected with cross-ties and diagonal braces of 8 by 1½ in.; the top holds the usual cast-iron derrick-pulley, and a ladder to reach it is constructed upon one side.

The bull-wheel now in use has four main arms of oak, 8 by 2½ in., passing clear through the shaft, and locked and keyed; the false arms between, 6 by 2 in., wedge upon each at the shaft, and are firmly held by the three thicknesses of pine boards forming the outer rim.

The total length of oak shaft is 10½–12 ft., its diameter 13 in., its length between wheels 6–7 ft., diameter of wheels 6½–7 ft., and bearing-pin on ends 2½ by 4 in.

The brake is a simple iron strap applied under the bull-wheel; a wooden pawl is made to fall from above, against the arms, as a permanent stop, when desired.

The band-wheel is built of inch pine lumber, surfaced to a uniform thickness, the present diameter being about 7 ft.; the rope-pulley on one side is 5 ft., and the face of the wheel 9 in. The grooves of the rope-pulleys on both band- and bull-wheels are made of hard wood, and, to ensure a perfect outer circle, the edges are turned off after the wheels are firmly mounted on the shaft and revolved on temporary bearings.

The sand-pump reel has always been the most awkward part of a well-rig; acting as a friction-pulley against the band-wheel with the bevelled face necessitated by the different angle of the shaft, its tendency was to self-destruction, even when most carefully and securely fitted up. A solid wheel of hard wood with wooden keys is sometimes used; also a piece of casing as a shaft, with a cast-iron pulley keyed upon it. The best reel is an oak shaft, about 8 ft. in length, 8 in. in diameter, with arms of the wheel passing through the shaft and enclosed with an iron rim.

The sampson-post and walking-beam have gradually increased in size, until the one is a post 20 in. sq., and the other 24–26 ft. in length, with a section at the centre of 30 by 18 in. The great weight of the walking-beam has, perhaps, some of the effect of a fly-wheel, where a fly-wheel nevertheless is not found to be a practical success. The utmost care is needed in making the foundation of the sampson-post and band-wheel frame perfectly solid and substantial; two long hewn sills for the latter, not less than 12 by 20 in. in section, pass clear under the derrick-sills; the jack-posts, cap, and braces of the band-wheel frame, being of pine 10 by 12 in., the cap bolted through to the sill.

The Well.—Col. Drake's invention of the driving-pipe affords the best means of passing through soft overlying earth to the rock. The pipe used at present is 8 in. in diameter, of 1-in. cast-iron, driven down into the earth in sections of 8 ft. in length, connected with wrought-iron bands, heated and shrunk on. Putting down a thin iron pipe of 6 in. diameter below the lowest fresh-water vein, and retaining the surface-water by a water-packer between the outside of the pipe and the wall of the well, enables the driller to proceed without annoyance from this source, and, when the well is completed, to take his tubing out of the well at pleasure, still keeping the water permanently from the oil-bearing rock. In fact, the entire operation of drilling and pumping is carried on through the casing, and not until a well is finally abandoned is the casing withdrawn.

The modern water-packer is a great improvement on the bag of flaxseed formerly used; the weight of the column of water presses the leather against the sides of the well, forming an effectual stopper. By means of a left-handed thread, it can be loosened in a few minutes, and drawn out of the well without difficulty.

Drilling-Tools.—A set of drilling-tools, as used to-day, weighs 1800–2600 lb., and costs about 70*l*. It consists of a temper-screw, rope-socket, auger-stem, sinker-bar and substitute, the jars, two bits, a round reamer, a flat reamer, and two wrenches. The temper-screw varies little from that in former use, except in size, the present length being about 5 ft. The auger-stem, sinker-bar, and substitute are respectively 24, 14, and 5 ft. in length, the last being used in starting a well. They are made in the body, of common round iron (2½–3 in.), with boxes and pins of Norway iron. Pins are 2¾ in. in length, 2⅜ in. in diameter, 8 threads to the in., and with the least possible taper, to prevent being loosened by the constant jar, which also has a tendency to crystallize the iron in the pins and boxes, making it necessary to renew them at intervals.

The jars are made entirely of Norway iron 2 in. sq., with the exception of the inner faces and ends of the slotted openings, which are lined with steel, the whole being heated red-hot and carefully annealed, to effect a thorough union of the metals. The stroke of the jars has been reduced to 12 in. and their total length is about 6 ft.

The bits are made of Norway iron, with 40 lb. of steel on the point, which is drawn to a width of 5½ in., more or less, according to the size of the well. The flat and round reamers are made also of Norway iron, with more steel on the point.

There are also various extra tools for different purposes.

The hollow reamer is for straightening a crooked hole. A spud or spoon for enlarging the well around a stuck tool, is simply half a hollow reamer; a slip-socket is to drop over the head of a tool that is fast, with dogs or teeth to fall out and catch under the collar; a horn-socket, or tapering iron tube, is to drive and wedge upon the head of any fastened iron. All these, with many others, often especially devised and constructed for the purpose, are required at various times in sinking a well. The cable used is 6-in. untarred manilla rope.

The sand pump has two improvements: (1), the valve with a drop-stem to open it on reaching the bottom of the well; and (2) the piston which keeps its place at the bottom of the pump while being lowered, but when drawn up, fills the pump by its suction with the loose debris and water.

Pumps.—The main improvements under this head are included in the two items of sucker-rods and valves. The old style of sucker-rods with fish-tail ends has passed out of use, the rivets constantly becoming loose and dropping into the working barrel having given great annoyance. To remedy this, the joint is made without any rivets; the wood is driven into a metallic socket and widened at the end with a wedge, an intermediate piece of small tubing making a screw connection between the two sockets.

The valves in use are a plain standing valve at the bottom of the working barrel, and a 3- or 4-cup valve, or a water-packer of some kind; special valves are made for gas when it predominates largely in a well, and to meet the several conditions which occur. The body of the sucker-rod is made of the best upland ash, 1½ in. in diameter, and 24–28 ft. long.

Transportation.—The first producing wells being found upon the flat land of Oil creek and the Alleghany river, the removal of the product was not a matter of great difficulty, as flat-boats conveyed the oil down stream to the nearest railroad. The railroads gradually extended their branches along the valleys of the region, but the oil produced from inlying valleys or remote spots had to be conveyed in barrels by teams, often a distance of 10–12 miles, and at great cost.

To remedy this, recourse was had to conveyance in pipes, and a 4-in. cast-iron pipe with leaded joints was laid in 1861 from Titusville, four miles down the creek. Owing to imperfect construction, it was a failure, and all projects of the kind were abandoned until 1865, when Samuel Vansyckle conceived the extension of the tubing of the well, as it were, to the station desired, and laid the first line of 2-in. tubing six miles in length, from Pit-hole to Miller farm. The success of this line caused the matter to be taken up by others, and the length of lines in the Pennsylvanian oil-region now reaches an aggregate of nearly 2000 miles, and 15 separate companies are engaged in the transportation of oil by pipe from the wells to the railroad.

The tubing in common use for well and shipping purposes is made of wrought-iron plates, of No. 6 or 7 wire gauge, heated in a furnace, and closed around a cold iron core; the joint in the lap-weld tubing is formed by passing it, while hot and soft, through a series of rollers, which first turn up the edges, and then press or weld them down upon each other. In butt-weld tubing, the edges are simply heated to a white heat, and then rolled together. Tubing for oil purposes must stand a test of 1200 lb. a sq. in. of internal pressure, a strength which is attained only by lap-weld.

In a pump for a pipe-line, the essential elements are a long stroke, a small oil-cylinder, and a large steam-cylinder. The air-chamber also must be proportioned to the work of the line, for the capacity of the pump is substantially the capacity of the line. There should be no obstruction in the line, especially at the point of delivery; a simple bend of the pipe at the receiving-tank will add many lb. pressure to the pump. All stop-cocks and connections should be free-way stop-cocks.

The experience acquired in the construction and management of pipe-lines in the oil region has shown the comparative economic value of this method of transportation. The adoption of this method is based upon the quantity of the fluid to be carried being ample and correspondingly cheap. To arrive at an estimate of the relative values of railroad and pipe-line transportation, it is necessary, in the computation of the working capacity and required force of a pipe-line, to note that 75–80 per cent. of the pumping force required by a pipe-line is necessary to overcome the friction dependent on the velocity of flow. Also, that in building a line, if the pipe were made very heavy, one pump would force it a long distance, and save the cost of labour and fuel attendant on intermediate stations; but that, if there were a great many intermediate stations, the pipe could be made very light, and the expense of construction be greatly reduced, the cost of fuel and labour being proportionately increased. The mean length of line which can be operated to advantage by one pump, with the lines at present in use, is about 15 miles; with care in the construction of the line, it could be extended to 20 miles.

In the construction of ordinary lines, which are of equal thickness for their entire length, there is just twice the amount of iron used that is actually required. The area of internal section of a 3-in. pipe is 7·06858344 sq. in.; contents of line (20 miles), 105,600 ft., 38,776 gal., or 901 barrels; to deliver 3600 barrels a day would require a velocity of flow of 5 ft. a second. Weisbach's formula to ascertain the head required to overcome friction, is as follows:—

$$\left(\cdot 0144 + \frac{\cdot 01746}{\sqrt{v}}\right) \times \frac{l}{d} \times \frac{v^2}{5\cdot 4} = h'$$

h' = head required in feet.
v = velocity in feet per second.
l = length of the line in feet.
d = diameter of the pipe in inches.

This formula applied would be

$$\left(\cdot 0144 + \frac{\cdot 01746}{\sqrt{5}}\right) \times \frac{105600}{3} \times \frac{25}{5\cdot 4} = 2473\cdot 9$$

In practice, this is found to be, for these long pipes, about 25 per cent. in excess, where the route is carefully selected, and the line is properly laid. As these lines follow vertically the contour of the ground in a hilly country, this is somewhat remarkable, especially when it is considered that no account is taken of any increased friction for the rise of the line in many places above the hydraulic mean gradient, from the highest point to be overcome to the point of delivery.

If the line be enlarged at every five miles,

5 miles of 3-in. pipe will require a friction-head of	618·5 ft.
5 „ $3\frac{1}{4}$ „ „ „	570·9 „
5 „ $3\frac{1}{2}$ „ „ „	530·0 „
5 „ 4 „ „ „	464·0 „
Total	2183·4 ft.

Being a saving in head of nearly 300 ft.

An equivalent to this gain may be obtained by a reduction of the diameter of the pipe at the pump, or by an increased velocity, thus:—

	Velocity.	Friction-Head.	Contents of Section.
		ft.	bbls.
5 miles $2\frac{3}{4}$-in.	5 ft. 9 in. a sec.	674·9	187
5 „ 3 „	5 „ 0 „ „	618·5	225·2
5 „ $3\frac{1}{4}$ „	4 „ 2 „ „	570·9	264·5
5 „ $3\frac{1}{2}$ „	3 „ 6 „ „	530·0	306·8
		2394·3	983·5

Being still less than the friction-head required for a continuous 3-in. pipe.

It will also be found that the reduced line contains 983·5 barrels instead of 901; and since the element of friction represents the greatest resistance to be overcome, the enlargement will cause a constant reduction of velocity, and therefore of friction.

In 20 miles of straight pipe there will probably be elevations to overcome. Assuming 400 ft. as an extreme, and adding it to the head required, the total head will be:—

	Head Required.	Pressure on sq. in.
	ft.	lb.
At the pump, $2\frac{3}{4}$-in. pipe	2794·3	1212
Beginning of second 5 miles, 3-in. pipe	2119·3	919
„ third 5 „ $3\frac{1}{4}$ „	1500·9	651
„ fourth 5 „ $3\frac{1}{2}$ „	930·0	403

The head of 400 ft. is carried through all the sections, in the absence of given levels of any actual line; otherwise the heads and pressures for the last two or three sections would be very much reduced.

Weisbach's formula was based upon the results obtained with water; by multiplying the pressures given by the difference in sp. gr. of water and the oil of commerce, 0·7972, we get:—

	Pressure on sq. in.	Thickness of Metal in Pipe.	Weight of Pipe per ft.
	lb.	in.	lb.
1st section	969	0·167	6·709
2nd „	735	0·138	5·537
3rd „	521	0·093	3·799
4th „	322	0·071	2·910

The first section will contain 177,117 lb. of iron; 2nd, 146,176 lb.; 3rd, 100,320 lb.; 4th, 76,824 lb.; total, 500,437 lb.

The weight of the line, if made of the ordinary 2-in. tubing in the usual manner, would be 387,235 lb.; and its capacity for delivery would be but 1000 barrels a day, against 3600 in the line described. The work of the line would equal 366,291,200 gal. raised 1 ft. high in 24 hours, requiring for its exertion a horse-power of 77 for water, and 62 for oil.

From these data, the following estimate of the cost of a 20-mile pipe may be made:—

500,437 lb. iron @ 9 cents, delivered on ground	$45,039 33
10,000 lb. fittings @ 20 cents	2,000 00
Laying pipe in trench 2 ft. deep, 6400 rods @ 60 cents	3,840 00
70 h.-p. boiler, pump and station, complete	10,000 00
Telegraph line	2,000 00
1000-barrel tank, iron	1,000 00
Sundries	1,120 66
(£13,000)	$65,000 00

To move this 3600 barrels of oil a day would require the direct services of four men; two engineers relieve each other at the pump every 12 hours, one man receives the oil from the wells and keeps the gauges, and one man receives and ships the oil at the railway-station.

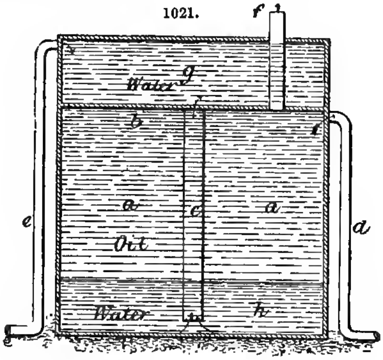
The cost of an engine and train of 36 tank-cars, which would be required to carry 3600 barrels of oil, would exceed the cost of the entire pipe-line, exclusive of any estimate of the cost of the roadway, which is about ten times the cost per mile.

With an ample supply of the fluid, and the required number of 20-mile sections, the estimate made would cover any distance required.

Storing.—The storage of petroleum in bulk is generally effected in huge tanks made of boiler-plate, varying in capacity from 8000 to 25,000 barrels (of 42 gal.). The top is more usually of wood than of iron. Wooden tops are often recessed so as to hold a body of water, or are covered with earth. Tops are always provided with man-holes, giving entrance to the tank for cleaning and repairs. The supply-pipe, which may conduct the oil from wells many miles distant, feeds at the top of the tank, near the man-hole; and draw-off taps are fixed at about 1 in. above the bottom. A distance of at least 200 ft. should separate tanks, in case of fire.

This system has proved quite ineffectual in preventing the ignition of stored petroleum by lightning, and in confining the fire when once it has broken out. Relying upon the fact that petroleum will not ignite unless it is vaporized, E. A. L. Roberts, of Titusville, Pennsylvania, has devised a lightning-proof tank, as shown in Fig. 1021: *a*, oil-space; *b*, diaphragm; *c*, balance-pipe; *d*, filling and emptying oil-pipe; *e*, inlet and overflow water-pipe; *f*, vent-pipe; *g*, water layer above the oil; *h*, water layer beneath the oil. The tank is first filled with water by the pipe *d*, entering the tank immediately under the diaphragm; the admission of water is continued until it has passed up the balance-pipe *c*, and filled the space *g*, driving out the air by the vent *f*. Petroleum is then forced through *d*, displacing the water, which passes up *c* into *g*, the surplus escaping by the outlet *e*. Sufficient water is left to form a layer of about 6 in. on the bottom, and at least as great a depth remains above the diaphragm. When the vent *f* is closed, no air can mingle with the petroleum, and no evaporation can take place. In order to draw oil out, water is forced in by *e*.

1021.



A plan projected by Denny embraces the storage in both bulk and barrels, so as to be free from danger of ignition by any ordinary occurrence, such as lightning, and to confine the fire and the burning material in case of a conflagration. The cisterns are constructed of concrete, with vaulted roofs, preferably below the surface of the ground; if above, the walls must be kept moist, to prevent leakage. For storage in bulk, a number of tanks are formed of concrete, communicating by siphon-pipes, into and out of which the oil is passed by pumps. The barrels are stored in long concrete vaults, closed by a double system of airtight doors, made of light sheet iron, and so arranged that if one is blown out, the second will fall into its place. Supposing the doors to act, in case of an explosion, the first door will be blown away, when the second resumes its place, shutting off air, and smothering the fire; should the doors not act, the burning oil will flow along a passage specially provided for it into an immense cistern, and meantime the air-supply can be cut off by banking up earth in the doorways.

With regard to the material for the construction of petroleum receptacles, Dr. Stevenson Macadam states that lead will spoil lamp-oil in a week, or less if bright; iron does not detract from the illuminating qualities, but deepens the colour, and causes a rusty deposit; zinc, solder, and galvanized iron are all deleterious. Metals which do not seriously damage the oil, but which still cause its deterioration by contact prolonged for months, are tin, copper, and tinned copper, common solder containing lead being excluded from use in their manufacture. Stoneware, slate, and enamelled iron are recommended as superior to all metals.

A very curious circumstance, which may be turned to some practical account, is that the addition of a little powdered soapwort (*Saponaria officinalis*), digested in water, causes petroleum to form a solid mucilage, and that the subsequent application of a little phenol (carbolic acid) causes it to resume perfect limpidity.

Separation of the Constituents, and their Uses.—Crude petroleum is usually a dark greenish-brown liquid, of somewhat offensive odour, having a density varying from 40° to 48° B. (0·820–0·782 sp. gr.), and composed of not less than 30 distinct hydrocarbons capable of separation by heat. To prepare the oil for commerce, it is freed from both the heaviest and the lightest members. The operations are directed to the separation of the following matters:—(1) The light oils, which are highly volatile and inflammable; (2) the heavy oils, which do not illuminate well, but are good lubricators; (3) tarry matters; (4) colouring matters; (5) malodorous matters. This involves 3 or 4 distinct processes:—(1) Fractional distillation; (2) agitation with sulphuric acid; (3) agitation with hydrates of soda and ammonia; (4) washing with water; (5) occasionally a second distillation after the acid and alkali treatment.

The distillation is effected in an iron still, provided with a condenser-coil. (Several forms of still used in fractionizing coal-tar will be found described on pp. 641–4, and much information bearing upon the subject is scattered throughout the article on Coal-tar Products, pp. 641–684; see also Paraffin.) The matters first issuing from the still are very volatile gases, which escape condensation at ordinary temperatures, but which, by cooling and compressing, may be converted into the volatile liquids rhigolene and cymogene. As the distillation proceeds, the issuing matters take a liquid form at ordinary temperatures, and increase in density, from 95° B. (0·629 sp. gr.) downwards. These oils may be separated according to their densities as they come over; but it is more usual first to collect in one receiver all the oils that pass over between 95° and 65° B. (0·629–0·723 sp. gr.), constituting (*a*) "crude naphtha," and to effect the breaking-up of this crude naphtha by a subsequent operation. When the distillate shows a density of 65°–59° B. (0·723–0·748 sp. gr.), it is run into the (*b*) "kerosene" tank, until the density reaches about 38° B. (0·838 sp. gr.), or the colour deepens to yellow. The next portion is then collected as (*c*) paraffin-oil, until nothing but pitch or coke remains in the still, the density of the last products being about 25° B. (0·906 sp. gr.). The distillate (*a*) "crude naphtha," by redistillation, is broken up into "gasolene," or "light naphtha," ordinary "naphtha," and "benzine." The "kerosene" or lamp-oil, forms the bulk of the product. This is agitated with about 2 per cent. by volume of sulphuric acid, to remove the disagreeable odour and a portion of the colour. Thus partially cleansed, it is washed with water, then with alkali (hydrate of soda or ammonia) to correct the remaining traces of acid, then with water to remove the taint of alkali. Sometimes it is redistilled at a higher temperature than before to remove the small percentage of naphtha or benzine still present. Finally it is exposed in open tanks, under glass, to the sun, for 24 hours or so, to complete the bleaching and sweetening. The extra price at which kerosene is sold tempts many distillers to neglect the separation as just detailed, and to mix as much benzine and naphtha as possible with the kerosene. The tendency of this is to reduce the flashing-point (see p. 1479) in a remarkable degree, and to render the oil totally unsafe for illuminating purposes; an oil flashing at 113° F. was reduced to 103° F. by the addition of 1 per cent. of naphtha, and to 83° F. by the addition of 5 per cent., while with 20 per cent., the mixture actually burned at 50° F. The annexed table shows at a glance the densities, proportions, uses, and relative market values of the several products of the fractional distillation of crude petroleum:—

Product.	Density.	Percentage.	Application.	Price per gal.
Cymogene ..	105°–115° B. (0·603–0·578 sp. gr.)	..	Artificial freezing	6*s.*
Rhigolene ..	95°–105° B. (0·629–0·603 sp. gr.)	..	Anæsthetic	4*s.*
Gasolene	80°–95° B. (0·673–0·629 sp. gr.)	1½	Air-gas lamps	9–18*d.*
Naphtha	65°–80° B. (0·723–0·673 sp. gr.)	10	An adulterant of kerosene	2–4*d.*
Benzine	60°–65° B. (0·744–0·723 sp. gr.)	4	Paints and varnishes ..	6–8*d.*
Kerosene	38°–60° B. (0·838–0·744 sp. gr.)	55	Lamp-oil	10–12*d.*
Paraffin-oil ..	25°–38° B. (0·906–0·838 sp. gr.)	19½	Separated into paraffin and a lubricating-oil ..	7–9*d.*

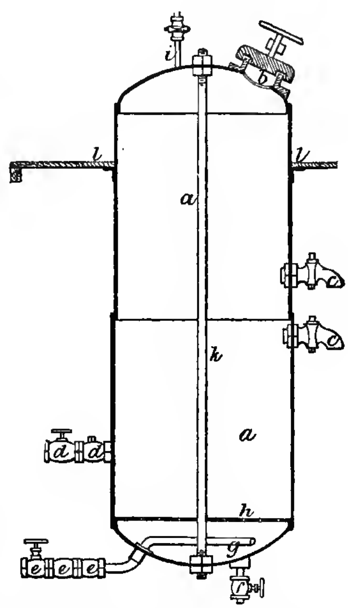
The substance called "vaseline" is the residue from the distillation of petroleum, purified by an elaborate process. It is a pale-yellow, translucent, slightly fluorescent, semi-solid, of sp. gr. 0·840 at 54° (129° F.), insoluble in water, slightly soluble in alcohol, freely in ether, and miscible in all proportions with fixed and volatile oils. Being unchangeable, it has been proposed as a basis for ointments, perfumes, and other compounds where fat is usually employed.

GENERAL CONSIDERATIONS.

Improved Modes of Extraction. *Animal Fats.*—One of the most important operations under this head is the manufacture of tallow and lard from animal fats. The process is usually termed "rendering," as applied to the fats themselves. These fatty matters are contained in animal tissue, into whose composition water largely enters. The simplest method of separating them from each other is by heating the fat in an open pan over a fire, at a temperature considerably above the boiling-point of water, 100° (212° F.), constantly stirring the mass, whereupon the animal tissue dries and cracks, allowing the pure fat to run out, and become separable by mere straining. This process, however, requires careful watching, as the tallow is apt to be discoloured by overheating, and, unless the fat be very new, is certain to evolve noxious odours.

The methods employed on a large scale may be divided into two, according as it is desired to save the animal tissue in a solid form, or not. If it be so desired, a very suitable apparatus is that used by Dole, of Bristol, and made by Miles, engineer, Bristol, shown in Fig. 1022. The apparatus consists of a strong iron cylinder *a*, provided above with a charging-hole *b*, closed by a sliding cover; a man-hole near the bottom, for the discharge of solid refuse; two taps *c* for drawing off pure fat; water feed-valves *d*; steam feed-valves *e*; and water draw-off valve *f*. Steam at a pressure of 60–80 lb. is introduced at *e*, and circulates in the coil *g* below the perforated false bottom *h*, *d* supplying water when necessary. The vent-tap *i* regulates the pressure, and permits the blowing off of steam. The apparatus being charged, steam is introduced for 6–8 hours. With a heavy charge, the fat can be drawn off by the upper of taps *c*, being floated to that level if necessary by letting in water. With a light charge, it is considered better to draw off all liquids together by the lower tap *c*, and skim off the fat when cold. The apparatus is strengthened by a stay-bolt *k*, and has a stage at *l*.

1022.

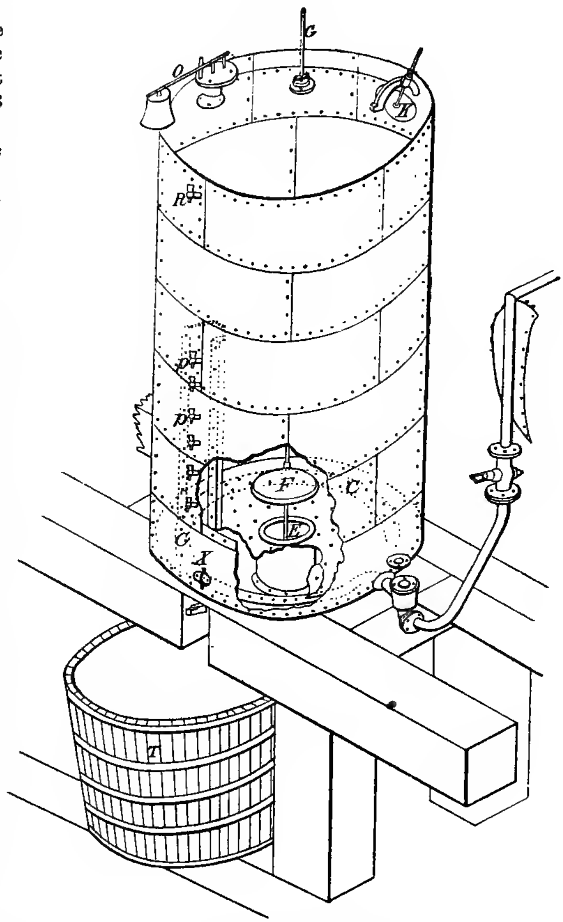


Another modification, which produces a very pure tallow, is described under Butterine (p. 1362). Its disadvantages are the necessity for the comminution of the fat, and the length of time required by the process, i. e. the large amount of plant necessary to "render" a few tons of rough fat. Its advantages are the almost complete freedom from noxious vapours (hence it is strongly recommended by Dr. Ballard), and the great purity of the product.

When the saving of the animal tissue is a matter of no moment, it is better to "render" the fat in the presence of water and steam. This can only be completely done under slight pressure (boiling the comminuted fat upon water in an open vessel only extracts part of the tallow, &c.), and is most suitably effected in a vessel such as that shown in Fig. 1023. The apparatus consists of a series of steam-tight cylinders of 1200–1500 gal. capacity, formed of boiler-plate, with a length about 2½ times greater than the diameter, and provided with false bottoms. The operation proceeds thus:—The cylinder is fed through the man-hole K with crude fatty matters to within about 2½ ft. of the top. The man-hole is secured, and steam is admitted by the foot-valve into the perforated pipe C. The safety-valve O is set at the required pressure, and frequent testing of the state of the contents of the cylinder is made by opening the try-cock R. An excess of condensed steam in the cylinder will be indicated by the spurting ejection of the fatty matters, when the regulating-cock X must be opened, and the condensed steam be drawn off into the tub T, till the escape of fatty matter from R has ceased. After 10–15 hours' continued steaming, the steam is shut off, and such as remains uncondensed in the cylinder is let out by the try-cock and safety-valve. After due rest, the fatty matters separate out and form the uppermost layer, and are drawn off through the cocks *p* into ordinary coolers. The fat being emptied from the cylinder, the cover F is raised by the rod

G from the discharging-hole E, and the residue falls into the tub T. Should the residue retain any fat, it is returned to the cylinder with the next charge. The pressure of steam commonly used is 50–75 lb. a sq. in., sometimes advancing to 100 lb., though this last figure is excessive, and calculated to injure the quality of the fat by decomposing the animal matters present. The yield obtained is considerably greater than by the ordinary methods, being stated at 12 per cent. extra for lard, and 6 per cent. for tallow. On the other hand, it is almost necessary to wash the fat with fresh water, and remelt and settle it, to remove the last traces of animal matter held in suspension by the unseparated water, and having a tendency to putrefy.

1023.



Another modification of the steam process is to subject the rough fat to the action of about ¼ its bulk of water, containing 2–3 per cent. of sulphuric acid, boiling the whole by steam at atmospheric pressure, i. e. in an open, or loosely closed, lead-lined tank. There exists, however, a prejudice against tallow or lard in whose preparation any chemicals have been used.

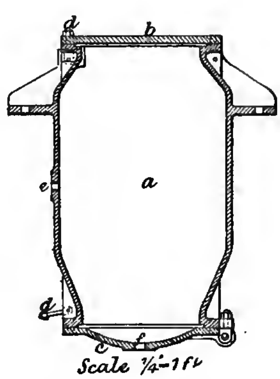
In all cases, it is highly desirable to render the fat as soon as possible after its removal from the animal's body, since the animal tissue rapidly decomposes, and sets up fermentation, producing rancidity in what would otherwise be a neutral fat, and also injuring the colour, &c., of the ultimate product. The different kinds of fat should also be sorted, and each description melted separately. In large establishments, such as the Union stockyards of Chicago, the stockyards at St. Louis, and the packing-houses of Cincinnati, where thousands of beasts are killed every day, there is a row of these digesters, each one allotted to its own kind of fat, which is placed therein a few minutes after the death of the animal. In this way, is secured great uniformity in the various grades of tallow and lard produced. The waste liquor, containing large quantities of nitrogenous matter, is sold for manure.

Many soap-makers "render" rough fat in a soap-copper (see Soap) by the simple action of wet steam upon it, while the cover of the copper is secured by bolts or weights. When all the tallow has been skimmed off, a weak impure solution of caustic soda, technically known as "half-spent leys," is run in, and the whole is boiled. The object is to saponify the last remaining portions of tallow, and the discoloured imperfect soap is used in lower grades of the pure article. The process, however, is a wasteful one, since large quantities of the soda are used up in forming ammonia, by its action upon the nitrogenous animal tissue, and this ammonia, being volatile, escapes with the noxious vapours, and thus a valuable fertilizing agent is lost. As far as concerns the avoidance of noxious odours, rendering by steam has undoubted advantages, and it is altogether a more rapid and satisfactory process.

The foregoing descriptions of the various processes for the "rendering" of beef-, mutton-, and pig- fat, apply equally, *mutatis mutandis*, to that of kitchen-stuff, ship's-grease, &c. In these cases, however, the liability to rancidity, and production of noxious fumes, is much greater than with fresh fat.

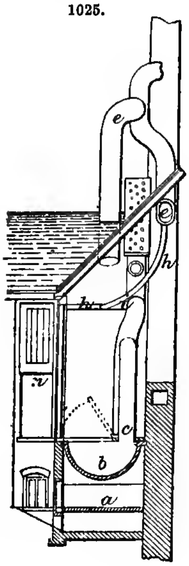
A large quantity of fat, known as "bone-fat," "bone-grease," or "bone-tallow" is now extracted from bones, and is chiefly used by the soap-maker. The common method of extracting the fixed fat from bones by boiling in open vessels has been described under Manures (p. 1256). A great improvement consists in the application of steam in closed vessels, as adopted by most large firms. The form used by Morris and Griffin, at Wolverhampton, is shown in Fig. 1024 It is composed of a $1\frac{1}{8}$-in. iron cylinder *a*, 6 ft. long by 3 ft. 6 in. in greatest diameter, furnished with hinged doors *b c* at top and bottom, which are tightly closed during operations by $1\frac{1}{4}$-in. screw-threaded bolts and nuts *d*, and further provided with 2-in. tap-holes at *e* and *f*. The bones are introduced at the top door *b*, which is then secured; steam at about 141° (286° F.) is introduced for 40 minutes; the steam is shut off, and that remaining in the cylinder *a* is let out into a condenser; $\frac{1}{2}$ hour later, the fat is drawn off by the tap *f* at the bottom of the cylinder; the bottom door *c* is then opened, and the bones are allowed to fall upon the floor below. The boues are rendered much more brittle than by ordinary boiling, and are much drier and more easily ground, requiring no previous storing (see Manures, p. 1256). The cylinder shown will steam at a charge $46\frac{1}{2}$ cwt. of bones, yielding 87–88 lb. of fat per ton.

1024.

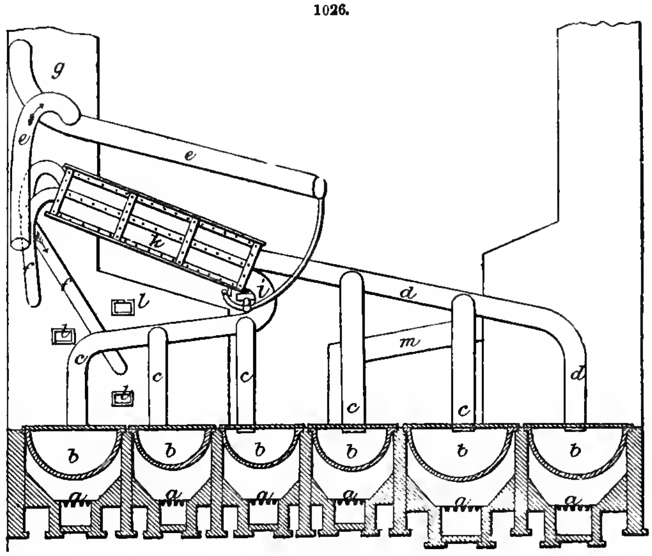


One of the best and most inoffensive arrangements of the bone-boilers for a large establishment is that adopted at Adams' knackery, in Birmingham, erected under the direction of Dr. Alfred Hill, and shown in Figs. 1025, 1026. A set of six pans are set and heated in the usual way. They are enclosed above in a sort of closet, formed by a wooden partition, reaching up to the roof of the building and down to the front of the top of the pans. Opposite each pan, is a shutter in the partition, which can be slid up whenever it is requisite to obtain access to the pan. Each pan is closely covered with a wooden lid, and from the upper and back part of each pan, beneath the cover, starts a pipe leading to a 10-in. main running the whole length above the pans and within the hopper, receiving contributions of vapour from each pan. This pipe finally has exit outside the

1025.



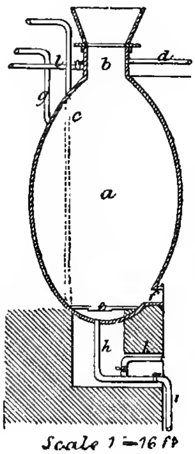
1026.



building; it here communicates with an oblong condenser, made of sheet iron, filled with coke, measuring 14 ft. long, 3 ft. in vertical section, and 14 in. in horizontal section, inclined a little in its long diameter. At the lower end, it receives the pipe from the boilers; and from its lower border, another small pipe conveys away the water produced by the condensation of the vapour, the cooling agent being the outer air, to which the condenser is exposed on all sides. The upper end of the condenser communicates by two air-pipes with the flues from the fire-places. When the pan-lids are raised, the escaping vapour rises to the roof, and is conveyed from the interior of the closet into the chimney-shaft, by escape-steam pipes provided for the purpose. The reference-letters indicate: *a*, fire-holes; *b*, boiling-pans; *c*, steam-pipes; *d*, main steam-pipe; *e*, escape-steam pipes; *f*, air-pipes; *g*, chimney-shafts; *h*, condensed-steam pipes; *i*, water-trough; *k*, wrought-iron condenser; *l*, doors for cleaning smoke-flues; *m*, smoke-flues; *n*, closet with sliding door.

The form of digester employed by Proctor and Ryland, of Birmingham, for extracting both fat and gelatine from bones, is shown Fig. 1027. It consists of a (duplicate) egg-shaped iron vessel *a*, capable of holding 6–7 tons of bones; at the upper end, is a short neck *b*, surrounding the charging-hole, which is closed by a tight-fitting cover; here enters the steam-pipe *c*, which descends to the bottom of the digester, here also the waste-steam pipe has its exit. At the bottom of the digester, is a wooden false bottom *e* for supporting the bones, and on one side is a man-hole *f* for reaching the false bottom and removing the boiled bones. Cold water can be introduced by the pipe *g*. The liquid matters are withdrawn by the pipe *h*, separating into two branches, with appropriate taps the one *i* leading to a drain, the other *k* to a tank. The bones are first boiled in water by the admission of free steam; when sufficiently boiled, steam is turned off, and time is allowed for the fat to separate; cold water is then let in by *g* to raise the fat to the level of the pipe *l*, when it escapes into a receptacle. The water is next run off from the digester by the pipes *h i* into a drain, the top cover

1027.



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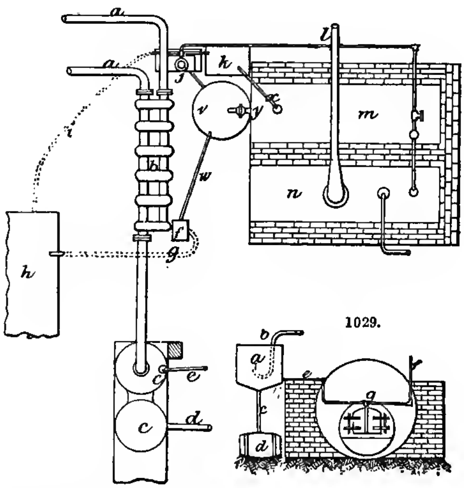


1029.

is fastened down again, and the bones are steamed at a pressure of about 50 lb. for the extraction of the gelatine; the gelatine is drawn off by the pipes *b k*, and the bones are finally removed by the man-hole *f*. The bones are in a less friable condition than when the form shown in Fig. 1023 is used, and they require to heat somewhat before being ground.

(For a further and desirable process of purification, see Refining, p. 1460.)

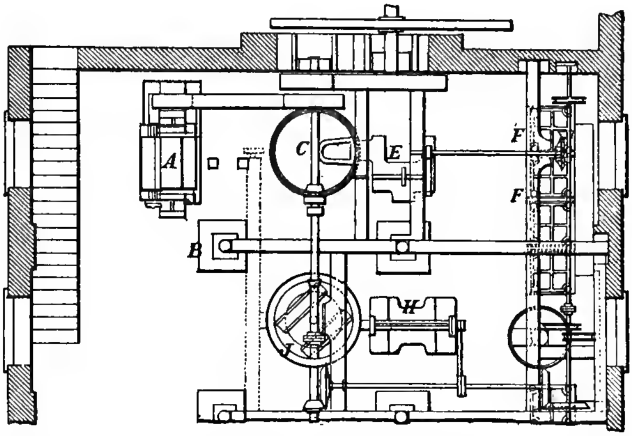
The calcining of bones has been described under the article Blacks—Bone-black, p. 453. One of the best arrangements for separating bone-oil from the other products of the distillation is shown in Fig. 1028. The pipes leaving the retorts first ascend, then bend downwards into a wide iron pipe, running horizontally about 1 ft. above the retorts, and containing water. Here the first condensation takes place. The vapours next pass by the pipes *a* to a continuous condenser *b*, such as is used in gas-works, and exposed to the outer air. Passing hence, the vapour, still containing condensable matters, is conducted through two coke scrubbers *c*, fed by a pipe *e* with trickling streams either of water, or of ammoniacal liquor, raised by the pump *j* from the well *k*, which receives it from the scrubbers, the liquor being thus made to circulate till it is sufficiently strong. The washed gas escapes at *d* for further treatment elsewhere. The liquors from the condenser *c* are received in *f*, where the first rough separation of bone-oil and ammonia-liquor takes place, the former floating while the latter sinks. The oil flows away at the surface by the 1-in. pipe *w* to a barrel *v* sunk in the ground; the liquor escapes by the larger pipe *g*, which is bent siphon-like, and dips into the liquor below the oil, the top of the siphon being at the same level as the pipe that carries off the oil. The liquor is conveyed to the receiver *h*. It still contains much oil, which is more completely separated by pumping the whole through the pipe *i* into a subsiding-vessel *m*, provided with taps as at *y* for drawing off the oil at intervals into *v*, while the liquor is pumped out through the pipe *x* (reaching to the very bottom of the tank) and pipe *l* into the still *n*. Its further treatment does not come within the scope of this article (see p. 232). The oil in *v* contains some ammonia worth recovering. It is therefore raised by the pump *j* into a tank *a* (Fig. 1029) above *b*, and the ammonia is washed out by injecting steam through the perforated pipe *b*; the liquor collects at the bottom, and is drawn off by *c* into a barrel *d* for conveyance to *n* or *h*.

The oil is variously dealt with. At some works, it is barreled and sold ; at others, it is mixed up with manures, or used as fuel. In the last case, it is pumped into *a* (Fig. 1029) and conducted by the pipe *e*, as wanted, to the boiler fire, into which it is showered by a steam-jet issuing from *f* at *g*, at right angles to the opening of *e*, at the furnace-mouth. This seems to answer the desired end very well. As the oil resembles mineral oil in some of its characteristics, it does not saponify readily, if at all, and is chiefly valuable as a coarse lubricant.

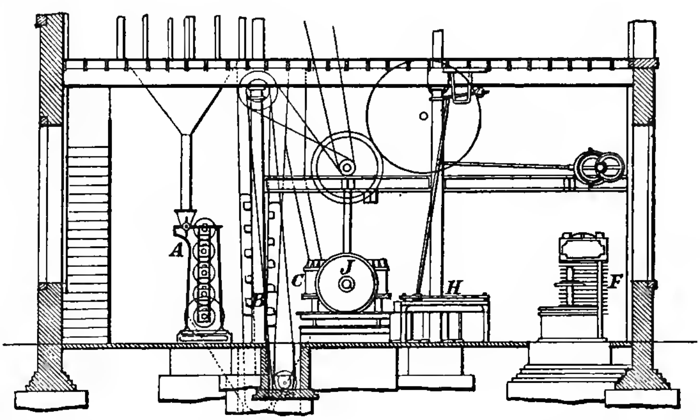
Vegetable Fixed Oils and Fats.—A detailed account of oil-mill machinery will be found in Spons' Dictionary of Engineering, p. 2482. It is here proposed to supplement it by the addition of such modern improvements as have since come into use. The class of machinery there shown in Figs. 5907 and 5908 is being rapidly replaced by the system introduced by Rose, Downs, and Thompson, of Hull, in 1874. Indebtedness is acknowledged to this well-known firm for the subjoined descriptions and illustrations of improved apparatus for extracting the oil from various oleaginous seeds and nuts, and converting the pulp into cake for feeding cattle.

The arrangement of the mill is shown in plan in Fig. 1030, and in elevation in Fig. 1031. The seed or other material passes through the following course:—It runs from an upper floor through the roll-frame A, by which it is crushed 3 or 4 times; it is then taken by the elevators B to the kettle C, where it is heated and damped. From beneath the kettle, it is drawn, in quantities sufficient to make a cake, by a box which conveys it to the moulding-machine E. Here it undergoes preliminary compression, the objects of which are (1) to increase the number of cakes which may be inserted in the presses at one time, enabling 18 12-lb. cakes to be made where 4 8-lb. cakes were formerly made, and (2) to ensure uniform size and weight, and uniform density or consistence throughout. The cakes are removed from the moulding-machine, and put into the press F, 3 or 4 of which are required to each moulding-machine. The pressure is applied either by means of hydraulic pumps, or by a high-and-low-pressure accumulator; but unless extreme care is used with the latter, it gives too rapid a pressure, squirting out the seed at the side of the plates, and exercising a destructive effect upon the cloth employed. The pulsation caused by the pumps working directly to the press-cylinder is more akin to the action of a wedge, and seems to extract the oil better than the dead pressure given by the accumulator. If the latter is used, a small cylinder may be applied to give the preliminary pressure in the moulding-machine, in lieu of a cam. After remaining under pressure about 25 minutes, the cakes are withdrawn, and after being stripped of the cloth, are pared by the machine H, which completes the manufacture

1030.



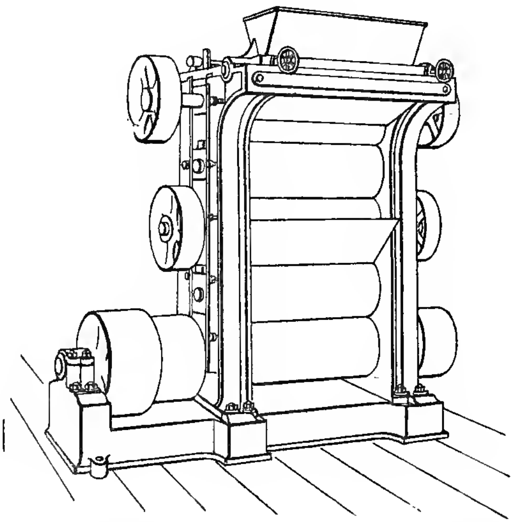
1031.



of the cakes. The parings fall under a very small pair of edge-running stones J, which automatically discharge them, when sufficiently ground, into an elevator conducting to the kettle, where they are worked up with fresh seed. In a mill with 4 presses, 2 men and a boy in the press-room can make 6 tons of cake in 11 hours, a rate of production requiring 6 men by the old process. The saving in steam-power is about 30 per cent., chiefly due to the absence of the heavy edge-runners, which also effects an economy of space. About 2 per cent. more oil is extracted, and the cakes are improved in appearance by not having the structureless texture caused by the trituration of the seed under edge-runners.

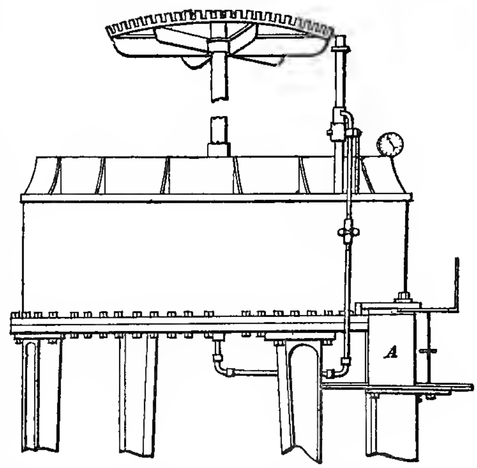
Having described the general routine of the process, some details may be added concerning the working of the several machines. The roll-frame Fig. 1032, consists of 4 or 5 chilled-iron rolls, each 3 ft. 6 in. long by 16 in. in diameter, placed one above the other. These rolls are used for crushing all the seed that passes through one set of presses making $5\frac{1}{2}$–$6\frac{1}{4}$ tons linseed-cake per spell of 11 hours. The seed passes into the hopper in the usual manner, and is distributed to the crushing-rolls by a fluted feed-roll the same length as the crushing-rolls, placed at the bottom of the hopper. When the seed passes the feed-roll, it falls on a guide-plate that carries it between the 1st and 2nd roll. After passing between these rolls and being partly crushed, it falls on a guide-plate on the other side, which carries it back between the 2nd and 3rd rolls, where it is crushed more fully. It then falls on another guide-plate, which carries it between the 3rd and 4th rolls, where it is ground more fully; then it falls on a 4th guide-plate, and is conveyed between the 4th and 5th rolls to receive the finishing touch. It is thus crushed four times.

1032.



The kettle is shown in Fig. 1033, which represents one capable of heating sufficient seed to keep 4 16-plate presses occupied, or to make 6 tons of cake per 11 hours. It is steam-jacketed and furnished inside with a damping-apparatus. The inside diameter is 5 ft., and the depth 2 ft. 6 in. The seed introduced is kept in motion by the stirring-gear, and when sufficiently heated and damped, is withdrawn by the box A in quantities to form one cake, and transferred at once to the moulding-machine, attached or separate.

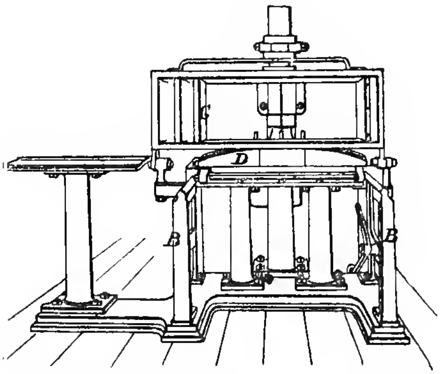
1033.



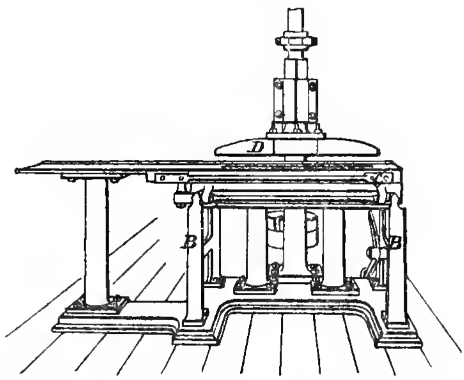
This machine is illustrated in Figs. 1034, 1035. Its purpose is to measure the quantity of seed required to make each cake, to shape it as required, and to press it so much, without extracting any oil, as will enable the greatest number of cakes to be put into the press. The measure of seed is placed on a strip of woollen cloth, spread upon a thin iron tray, sliding on the guides B; the bottomless hinged mould C, having the exact shape of the intended cake, is closed upon it, and the measure A (Fig. 1033), which is also bottomless, is drawn over guides in the upper surface of the mould C, thus accurately distributing the seed. The mould is next thrown upon its hinge (Fig. 1034), and the ends of the strip of cloth are folded over the seed, the thickness of which is about $3\frac{1}{2}$ in. The thin iron tray, with the mould of seed upon it, is then pushed along the guides B, beneath the die D. This action gives motion to a cam, shown above in the illustrations, but which may be placed beneath if necessary. This cam brings down the die, and compresses the mould of seed to a thickness of 1¼ in.; its revolutions are so timed that the seed is under pressure long enough (about ⅓ minute) to let the workman have another cake ready.

When the die of the moulding-machine rises, the cake and tray are removed and placed in the press (Fig. 1036), the tray being withdrawn. The plates of the press are slightly thickened towards

1034.

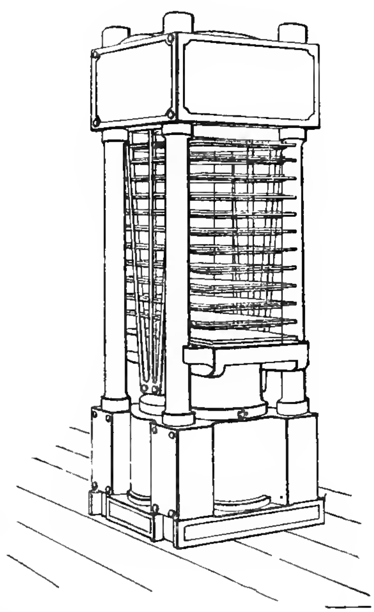


1035.



the edges, and bear the name of the manufacturer in reverse. The press is suitable for extracting oil from linseed, rape-seed, cotton-seed, hemp-seed, niger-seed, sunflower-seed, gingelly-seed, castor-seed, ground-nuts, coco-nuts, olives, &c. It is made in various sizes. The No. 1 double press (not shown) is furnished with 4 cake-boxes, suitable for making 4 tapered cakes at one pressing, each about 2 ft. 5 in. long, by 10½ in. wide at one end, and 7½ in. at the other, when using linseed, 48 lb. of Bombay seed being required to charge the press, and giving a cake weighing about 8 lb.; the maximum and minimum weights of its charges are 60 lb. and 40 lb., of the cakes, 13 lb. and 6½ lb. The charges vary from 3 to 6 an hour, being 4 for cotton-seed and 5 for linseed; most other seeds are worked the same as linseed, but rape and gingelly are worked twice. By using 2 presses for the first time and 3 for the second, 3 presses will crush as much seed as 5. These presses are made of a capacity to take 270–320 lb. seed at a charge, giving cakes of 9–15 lb., and requiring 30–45 minutes for the operation. In all these presses, the hair wrappers, weighing some 26 lb., used in the old process, are dispensed with.

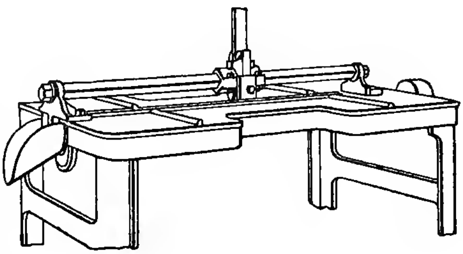
1036.



After being sufficiently pressed, the cakes are withdrawn, stripped of their cloths, and pared by the machine shown in Fig. 1037, which consists of 2 reciprocating knives moving above a table fitted with guides and gauges, and with a screw conveyer in the centre, for discharging the parings at one end. Two boys attending the machine can pare 12–13 tons a day. The parings are taken under a very small set of edge-runner mill-stones, which automatically discharge them, when sufficiently ground, into an elevator leading to the kettle, where they are worked up with fresh seed. Larger edge-runners are very commonly used for crushing Egyptian cotton-seed; a set weighing 404 cwt. crush about 6 tons per 11 hours.

The ordinary method of liberating the coco-nut from the shell is to break the latter into two or more pieces by blows from a hammer, and to leave these exposed to the sun's rays for a few days, when the kernel contracts, and leaves the shell. Some years since, Rose, Downs, & Thompson, of Hull, designed two machines for slicing and rasping the dried kernel, or copra, which, in general construction, resembled gigantic mincing-machines. The slicing-machine worked well, and turned out a large quantity, but it was found to be of little value in practice, on account of the frequency with which stones and similar foreign bodies got mixed among the copra, and injured the knives. The rasping-machine also suffered in a minor degree from the same cause. Moreover, there was no real gain in using the machines, as they did not reduce the material to a sufficiently fine degree. The first produced thin slices, and the second rendered these granular only, like coarse sawdust, so that it was still necessary to pass the material through an edge-runner mill, and no perceptible difference was made in the amount of grinding required in this latter. Consequently, both machines have been abandoned, and the broken copra is thrown at once under edge-runners, and then pressed and dealt with much in the same manner as an ordinary oleaginous seed. The firm named estimate the average cost of the machinery adapted to a small mill capable of treating about 40 cwt. of copra daily, and making 24–25 cwt. of oil, and 15–16 cwt. of cake, as follows:—Engine, boiler, edge-runners, presses, pumps, gauges, "hairs," cisterns, pipes, nuts, bags, bagging, and all fittings complete, at about 1000*l.* The same motive power will drive also the machinery for preparing the fibre from the husk, costing about 150*l.* additional.

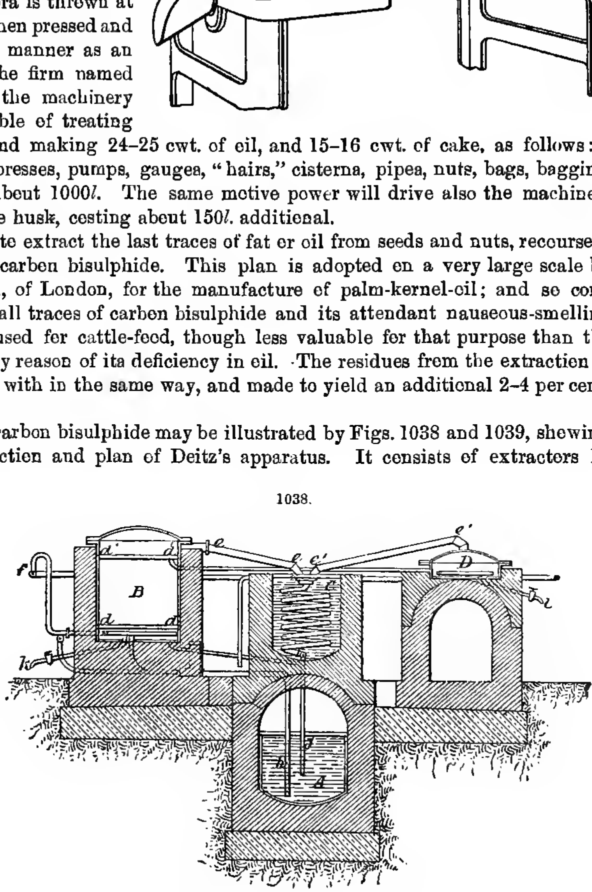
1037.



Not unfrequently, in order to extract the last traces of fat or oil from seeds and nuts, recourse is had to the solvent action of carbon bisulphide. This plan is adopted on a very large scale by Heyl, of Berlin, and by Sevin, of London, for the manufacture of palm-kernel-oil; and so completely is the meal freed from all traces of carbon bisulphide and its attendant nauseous-smelling compounds, that it is much used for cattle-food, though less valuable for that purpose than the meal from simple expression, by reason of its deficiency in oil. The residues from the extraction of olive-oil in S. Europe are dealt with in the same way, and made to yield an additional 2–4 per cent. of the so-called "pyrene" oil.

The method of employing carbon bisulphide may be illustrated by Figs. 1038 and 1039, showing respectively a longitudinal section and plan of Deitz's apparatus. It consists of extractors B, which are usually worked in couples alternately, and in connection with a still D, containing a steam-coil, and communicating with a cooler C by means of a pipe *e'*. The pipe *j* leads from the cooler-worm to a receptacle A for storing the bisulphide. The extractor B is also connected with the cooler C by the pipe *e*, and provided with suitable openings for the introduction and withdrawal of the fatty matters. These latter are put into B between two perforated plates *d d'*; bisulphide is pumped from A by the pipe *h* in at the bottom of B. The bisulphide passes up through the mass, absorbs the fat present, and escapes finally by the pipe *f* to the still D. The admission of bisulphide is continued till a sample drawn off at *k* is free from fat. The bisulphide is then shut off, and steam is injected into the extractor through a perforated coil lying between the bottom and the perforated plate. The remaining bisulphide is thus carried by the pipe *f* into the receptacle A. The fat-saturated bisulphide is distilled in D, by means of a steam-coil. The evaporated bisulphide liquefies in the cooler C, and runs back into A for further use. Steam is occasionally passed through the fat, to completely free it from bisulphide; and the clean fat is finally let out by the pipe *i*.

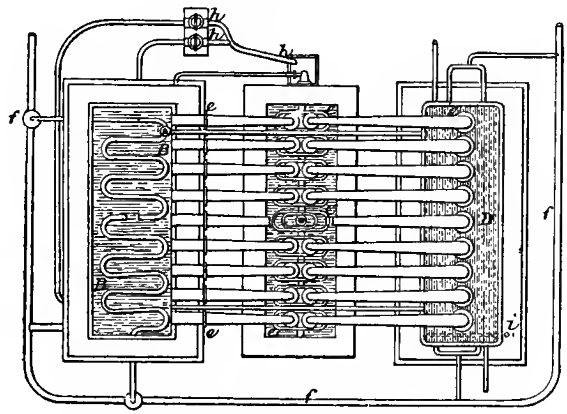
1038.



In America, preference is given to petroleum-spirit of low boiling-point, as being cheaper and less dangerous, though less rapid in its action. The materials there principally dealt with are the residues from the rendering of animal fats (as tallow and lard), containing 12–15 per cent. of extractable grease. The patents relating to this industry in America are very numerous, but those taken out by Adamson seem to be most largely adopted. The process lasts 24–36 hours, and the products are used mainly as lubricants, being unfit for making good soap. "Pomace" or castor-cake, and greasy cotton-waste, are similarly treated.

A very great disadvantage of petroleum-spirit, however, is that whereas the high sp. gr. of carbon bisulphide enables it to be kept covered with water (and even collected from the mouths of the condenser-worms under water), and thus protected from all risk of explosion by contact of its vapour with air and flame, petroleum-spirit, which is, bulk for bulk, about half as heavy as the bisulphide, cannot be so protected from accident and loss by evaporation. Its vapour-density also is much less.

1039.



Recovery of Waste Grease.—A description of the means suited to the recovery of grease from fabrics and liquids which have served their purpose may fitly be introduced here.

In the recovery of oil from oily cloths, the latter are first soaked with water and soda crystals in a tub, and steam is thrown in; the mixture of alkaline water and oil thus obtained (the latter saponifies to a slight extent), is run off into an open tank; this operation is repeated as often as appears necessary. The cloths are then squeezed nearly dry between rollers; the liquor is received in a tank, where it accumulates, and separates on standing, the oil collecting on the surface, while the dirty water remains below. The oil is ladled out into casks, and used for making blacking, or refined for other purposes. The cloths are finally dried by suspension in a chamber heated by coke fires in braziers. Offensive odours are generated, and the whole arrangement should be enclosed, and provided with means for conveying the vapours into a tall chimney.

The recovery of grease from the waste shoddy of woollen-mills, from cotton waste used for wiping oily machinery, from scrapings from fat-melting establishments, and in short from almost any mixed mass of grease and other matters, is now effected on a large scale by means of carbon bisulphide. The method of applying this solvent now generally adopted is to introduce the greasy matter very lightly and loosely into an airtight iron cylinder provided with a false bottom, taking care to ensure the porosity of the mass, and its freedom from more than a very small percentage of water. The bisulphide, pumped in from below, because it diminishes in sp. gr. as it dissolves the fatty matters, rises through the cylinder, dissolves out the grease, and flows away at the top into a still. It is then distilled off by steam, and condensed, running with the condensed steam into an underground reservoir, where it lies covered with water till required again. The greasy matters are left in the still, whence they can be drawn off. When all the grease has been extracted from the material, the bisulphide retained by the latter is drained off; the injection of free steam then drives off the last traces of bisulphide into a condensing-worm, and thence to the underground reservoir. The loss of solvent in each operation is trifling, but the most stringent precautions are necessary to prevent leakage. An arrangement of this character has been described and illustrated under Carbon Bisulphide (see pp. 605–6, Fig. 473).

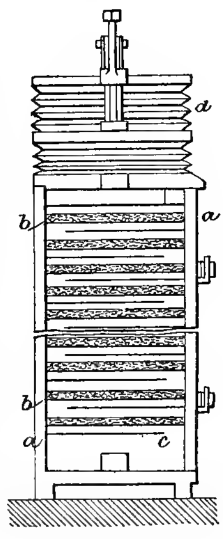
Soap-suds contain a large quantity of fat combined with alkali as a soap. The recovery of this fat is now largely accomplished, especially in the woollen-manufacturing districts of England, from the suds leaving woollen-mills, which contain, in addition to the soap employed in washing or fulling the wool, a large quantity of fat derived from the wool itself. These are first carefully strained and then settled to remove extraneous matters. From the settling-tank, the liquid flows into several large tanks, where, in succession, the "breaking" or decomposition of the soap is effected. Steam is first injected to raise the temperature to about 49° (120° F.), and sulphuric acid is then added, in such proportion as to leave the (broken) liquor feebly sour to the taste. This preliminary heating is not adopted in all cases, as the same end (the facilitation of the breaking) is attained by keeping the suds for 3–4 days. But this is a most objectionable proceeding, on account of the offensive putrefactive odours emitted; it also requires the provision of much additional storage room. In the breaking, the acid combines with the soda, and liberates the grease, which partially floats, and partially settles to the bottom of the tank with earthy and other impurities. Time is allowed for the complete separation of the grease; the liquid is then run off through drains, and the scum or "magma" is put into canvas filters on wooden frames. From these, the liquid portion escapes into the drains, and a blackish-grey greasy mass remains upon the filters. This mass is wrapped up in cloths, and first subjected to cold expression to free it completely from water. To recover the grease, the packages, as they leave the cold press, are transferred to a hot press, where steam is introduced at ordinary pressure. The grease is thus melted out, and, with condensed water and some dirt, escapes at the bottom into a sunken tank, about 2 ft. long, 1½ ft. wide, and 3 ft. deep. Here the oil separates from the dirty condensed water, floats, and is ladled out while still liquid. The dirty water is let out at intervals into a large underground tank, where more grease separates. The oil ladled out is transferred to a lead-lined vessel, and treated with strong sulphuric acid to remove any water that may be in it, after which, it is barrelled for sale. The residue in the hot press, called "sud-cake," is treated with carbon bisulphide to extract any remaining traces of grease, and is then used for manure-making. The waste liquor, neutralized with lime, or made slightly alkaline, may be beneficially used for irrigating pasture.

Essential Oils.—The extraction and recovery of vegetable essential oils is performed by the following processes.

Enfleurage.—The simplest and most important of the processes adopted for recovering the perfumes of plants for industrial purposes is known as absorption or *enfleurage*. The earliest and most primitive method of performing this consists in allowing the flowers to lie between glass plates covered on both sides with grease, and superposed in piles in a frame, the flowers being renewed every day during the season, which may last for 8 days or 3 months. In absorbing by means of oil, instead of solid grease, the glass plates are replaced by frames of wire-gauze, covered with pieces of linen soaked in olive-oil, between which the flowers are spread and renewed as in the other case. The oil is squeezed out by the gentle action of a screw press. These primitive plans are still in wide use, despite their cost for labour, their slowness, and the risk of the absorbent grease becoming rancid.

A great improvement is the pneumatic method introduced by Piver, and illustrated in Fig. 1040. The apparatus consists of a box *a*, about 10 ft. high and 6 ft. wide, containing wire-gauze trays *b* for holding the flowers; between them, sheets of glass or silvered copper *c*, fixed at one side, but free on the three edges, receive the grease, not only in a flat layer, but divided into extremely fine drops, by being forced through a plate penetrated with minute holes. Two bellows *d*, arranged so that one falls while the other rises, maintain a current of air throughout the apparatus, by which the grease is rapidly impregnated without the flowers coming into actual contact with it, thus avoiding the destruction of the perfume and staining of the grease, often arising from fermentation of the flowers in the presence of animal matters.

1040.



More recent improvements in the conduct of the absorption-process have been in the direction of replacing the grease by some neutral substance, such as paraffin, glycerine, and vaseline. In order to remove all traces of the paraffin from extracts obtained by its agency, it is recommended to subject them to a freezing-mixture, in order that all the stearoptene of the flowers may be deposited. Glycerine, concentrated and inodorous, has been proposed by Rimmel as superior to paraffin, on account of its fluid condition. Vaseline or cosmoline, extracted from petroleum residues, presents a great analogy to paraffin, except in having a cousistence nearer that of glycerine. Vaseline has several advantages, and has been largely used; it very readily absorbs the odours of those flowers which can be treated by heat. But there are many flowers which cannot be so treated, and it has been found that the alcoholic extracts made from impregnated vaseline rapidly lose their odour, even at the end of a month. On the whole, it is probable that the application of vaseline to *enfleurage* will be far less wide than was at first supposed.

Solvents.—The extraction of essential oils by means of solvents consists of three successive operations;—(1) Solution of the oil by passing the solvent over the flowers placed in a percolator; (2) distillation at a low temperature of the liquid obtained, to remove the wax mixed with the odoriferous body; (3) evaporation of the last traces of the solvent in a water-bath. The solvent may be ether, chloroform, carbon bisulphide, petroleum-spirit, &c. Prof. Vincent, in combination with a perfumer named Massignon, has adopted chloride of methyl as a solvent for extracting essential oils, the chloride being previously treated in the gaseous state with concentrated sulphuric acid, to remove malodorous impurities. The oil-yielding body (flowers, &c.) is repeatedly digested for 2 minutes with charges of liquid chloride in a close vessel, the impregnated chloride passing into a receiver; finally all traces are pumped from the digester into a vessel where the chloride is liquefied by cold compression; a jet of steam is passed through the exhausted mass of flowers to drive out the chloride retained by the traces of water in the flowers. The liquefied saturated chloride is evaporated *in vacuo*, leaving the essential oil in the waxy and fatty residues. The essential oil is removed from the mass by treatment with cold alcohol. Apparatus capable of dealing with 1 ton of flowers daily has been erected on this principle at Cannes, S. France.

In America, Prof. Seeley's method of applying gasoline as a solvent of essential oils has been largely used for extracting the valuable principle of hops.

Expression and Scarification.—Such processes as are described in this section are adapted only to materials yielding a large proportion of essential oil, such as the fruits of the *Citrus* genus. The simplest form is the so-called "sponge-process." The peel is first cut off the fruit in 3 thick longitudinal slices, leaving the central pulp of triangular shape, with a little peel at either end; the central pulp is cut transversely in the middle, and thrown on one side, while the peel is collected on the other. The latter is left till next day, then treated thus—A seated workman holds in the palm of his left hand a flattish piece of sponge, lapped round his fore-finger. With the other hand, he places a slice of peel upon the sponge, the outer surface downwards, and presses the uppermost (zeste-) side, so as to give it a convex instead of concave surface. The oil vesicles are thus ruptured, and the oil which issues from them is absorbed by the sponge with which they are in contact. Each slice receives 4–5 squeezes, and is then thrown aside. The workman carefully avoids pressing the small bit of pulp attached to each slice. As the sponge becomes saturated, it is forcibly wrung out into a coarse earthenware bowl, provided with a spout, and of a size to hold at least 3 pints; here the oil separates from the watery liquid accompanying it, and is decanted. Despite its apparent rudeness and wastefulness, this process is capable of affording an excellent article; it is employed chiefly for treating lemons.

Another implement adopted with both lemon and bergamot is known as the *écuelle à piques*. It is a stout pewter saucer, about 8½ in. wide, with a lip on one side for convenience of pouring. The bottom is covered with stout, sharp, brass pins, standing up about ½ in., the centre being deepened into a tube about ½ in. in diameter and 5 in. long, closed at the lower end. The whole resembles a shallow funnel, with the tube stopped up at the end. The peel is held in the hand, and rubbed over the pins, by which the oil-vessels of the entire surface are punctured; the liberated oil flows down into the tube, which is emptied at intervals into another vessel, where the oil may separate from the turbid watery liquid accompanying it.

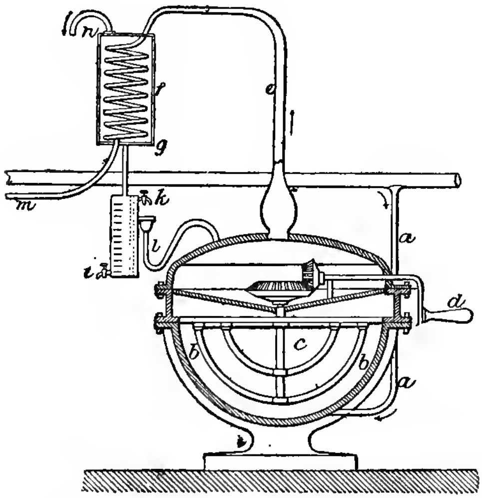
A modified form of the *écuelle*, for extracting bergamot-oil from the full-grown, but unripe, entire fruits, is constructed as follows. The fruits are placed in a strong metallic dish, about 10 in. wide, having a raised central opening, forming with the outer edge a broad groove or channel, and covered with a lid of similar form. The inner surfaces of both dish and lid are provided with a number of narrow, radiating, metallic ridge-blades, about ¼ in. high, and resembling knife-backs. The dish is also perforated to permit the outflow of the oil, and both dish and lid are arranged in a metallic cylinder, placed over a vessel to receive the oil. By a simple set of cog-wheels, a handle causes the cover, which is very heavy, to revolve rapidly over the dish; the fruit lying between the two is carried round, and simultaneously subjected to the action of the sharp ridges, which, rupturing the oil-vessels, set free the oil to flow out by the small holes in the bottom of the dish. Some 6–8 or more fruits are dealt with at once, and are kept under operation for about ½ minute; about 7000 fruits can thus be treated in one such machine per diem.

Distillation.—The oleiferous material is placed in an iron, copper, or glass still, of 1–1000 gal. capacity, and is covered with water; superposed is a dome-shaped lid, terminating in a coil of pipe, placed in a vessel of cold water, and protruding therefrom with a tap at the end. On boiling the contents of the still, the essential oil passes over with the steam, and is condensed with it in the receiver; the oil and water separate on standing. A great improvement, introduced by Drew, Heywood, and Barron, is the use of a steam-jacketed still, as shown in Fig. 1041. Steam is supplied from a boiler by the pipe *a* into the jacket *b*; within the head of the still, is fixed a "rouser" *c*, a double-branched stirrer curved to the form of the pan, and having a chain attached and made to drag over the bottom, the whole being set in motion by means of the handle *d*. The still is charged, and nearly filled with water; the head is then bolted on, steam is admitted into the jacket, the contents are well stirred, and soon the oil and steam are carried up the pipe *e*, condensed in the refrigerator *f*, and let out at *g* into the receiver *h*. Here the oil and water separate, and escape by different taps. In the illustration, it is supposed that the oil obtained is heavier than water; it will then sink, and be drawn out by the lower tap *i*, and, as soon as the water reaches the level of the upper tap *k*, it will flow into the syphon-funnel *l*, and thence into the still. Thus the same water is repeatedly used in the still. The pipe *m* conveys cold water into the refrigerator *f*; the water escapes as it becomes hot by the pipe *n*. When the oil distilled is lighter than water, the taps *i k* exchange duties. Before commencing operations, the siphon *l* is filled with water to prevent the escape of vapour.

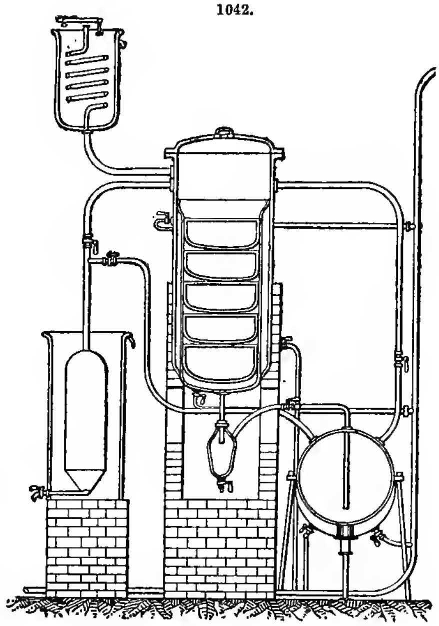
An apparatus recently constructed by Rigaud and Dussart is arranged so that dry steam enters directly among the matters to be distilled, and the temperature is always maintained at a high point. This is shown in Fig. 1042. It is claimed to yield a larger and superior product, and to prevent all chance of creating an empyreumatic odour, such as sometimes happens with other forms.

Distillation as a means of obtaining essential oils is worthy of every consideration. Generally it should be effected by steam; but there are cases (bitter almonds, &c.) where contact with water is

1041.

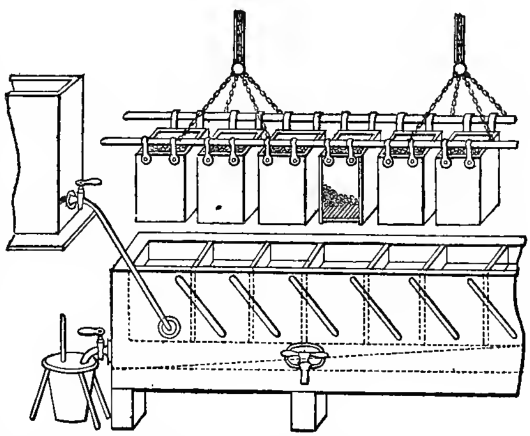


1042.



necessary for the production of the oil, while in others, open fire and steam are equally applicable, though the latter is superior. The water employed must be perfectly pure and neutral, though in some cases (sassafras, cloves, cinnamon, &c.), common salt is added to raise the boiling-point. The receiver is always some form (there are many) of "Florentine receiver." In some instances (anise, &c.) where the distillation-products are solidifiable at a low temperature, the condenser-worm needs to be warmed instead of cooled.

1043.

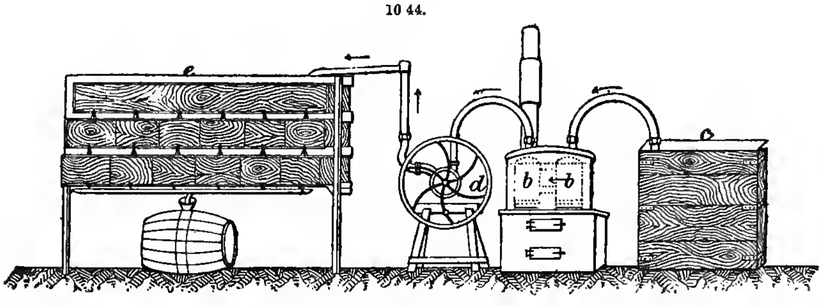


Maceration.—Some of the most delicately perfumed essential oils are spoilt by distillation; these are extracted by maceration in previously clarified solid fats or fixed oils. The grease to be perfumed is melted in a water-bath, and the flowers are thrown in, and allowed to remain for 24–48 hours, when they are withdrawn, freed from grease, and replaced by others, the operation lasting perhaps 15 days, and the product being numbered 6, 12, 18, 24, according to the amount of fragrance it has absorbed. Difficulties encountered in the conduct of the operation are the possible extraction of the colouring and other principles from the flowers, and the decomposition of the perfume and rancidification of the grease, by the repeated alternation of heat and cold. To obviate these drawbacks, Piver has introduced the saturator shown in Fig. 1043. This enables some 2100 lb. of grease, contained in 7 compartments, to be saturated in one day; the grease overflows by a spout leading from one compartment to another at the bottom, being kept in a liquid state by a water-bath meanwhile. Boxes of wire gauze carry the flowers, and advance in a contrary direction to the grease, each entering No. 7 and finally leaving No. 1 quite exhausted. This opposite passage brings the virgin oil into contact with the flowers which are nearly exhausted, while the already partially impregnated grease readily absorbs some of the excess of essential oil from the fresh flowers.

Refining, Clarifying, and Bleaching.—The various processes under this head may at first be broadly divided into "mechanical" and "chemical," although each, especially the latter, is capable of many subdivisions. They have for their object, firstly, the removal of all extraneous matters from the oil (using this term to include melted fats, as well as oils fluid at the ordinary temperature, since almost all these operations are conducted upon fluids), such as animal or vegetable fibre and tissue incidental to the modes of preparation (as in olive- and other seed-oils, badly-rendered tallow, &c.); secondly, of resinous substances dissolved in the oil, of which the refining of cotton-seed-oil is a notable example; thirdly, the removal of fraudulent admixtures, such as lime, glue, &c.; fourthly, the correction of rancidity; and fifthly, where the preceding operations do not sufficiently improve the colour of the oil, its bleaching by chemical processes. These will now be considered under their various heads, and it is obvious that much care and judgment are required in the selection of the particular method or combination of methods suitable to the refining of any given oil.

The first and most important method, to be employed either alone, or as a sequel to others, is that of simple but prolonged subsidence, on a large scale. Where necessary, the tanks employed may be heated by steam-coils or steam-jackets. These must be used with caution, however, since convection currents are set up, which interfere materially with the deposition of impurities. An obvious modification of this method is filtration, which may be effected in a very great variety of ways, either with or without the assistance of artificial pressure derived from (*a*) a "head" of the liquor to be filtered, (*b*) one of the many forms of filter-press in use, or (*c*) atmospheric pressure, by the production of a vacuum *under* the filter-bed (see p. 307). For example, olive-oil is mostly subjected to no process of purification, beyond what is attained by allowing it to deposit impurities, and repeatedly decanting. But for the best qualities, further purification is necessary, not only to secure limpidity, but a capacity for lengthened preservation, by eliminating the water, mucilage, and parenchymatous matters. Various devices are employed in different localities, one and all being filters. In France, the oil to be purified is received into perforated boxes carpeted with carded cotton (wadding); elsewhere, cotton tissue interposed between beds of granular and washed animal charcoal form the filter; also a bed of dry moss, on the 'Grouvelle et Jaunez' system; also layers of sand, gypsum and coke; also alternate beds of sand and vegetable charcoal, according to Denis de Montfort's plan; also carbonized schist and peat, by Cossus' method; also clay heated to 200° (? F.), as proposed by Wright; also by introducing China-clay and allowing to stand at a moderate temperature, then filtering through cotton, as adopted by A. Bizzarri. Perhaps the best mode is that of Pietro Isnardi, of Livornia, Tuscany, which received an award at the Vienna Exhibition. This apparatus, Fig. 1044, consists of a boiler full of water, serving as a water-bath for two turned-iron cylinders *b*,

1044.



receiving the oil from the reservoir *c*, a suction- and force-pump *d*, and a filter *e*, containing perforated trays whose holes are filled with wadding. This apparatus enables the oil to be filtered without coming into contact with the air, and at an elevated temperature which can be regularly maintained. Coco-nut-oil is another example of purification by simple subsidence and filtration.

Where filtration fails to remove impurities, recourse may be had to the action of acids or alkalies upon them. There are several methods of applying mineral acids to the purification of oils. Thénard's process consists in gradually adding 1–2 per cent. of sulphuric acid to oil previously heated to 38° (100° F.), and mixing by constant agitation. When the action of the acid is complete, the oil, after 24 hours' rest, appears as a clear liquid, holding flocculent matter in suspension; a quantity of water heated to 60° (140° F.) equal to about $\frac{2}{3}$ of the oil is added, and the mixture is well agitated until it acquires a milky appearance. It is then allowed to settle for a few days, when the clarified oil rises to the surface, while the flocculent matter falls to the bottom with the acid liquid. The oil is then drawn off, and washed in another vessel by agitation with half its bulk of warm water; but it requires to be filtered to make it perfectly clear. This process is largely used for refining linseed-oil.

Cogan operates upon about 100 gal. of oil with about 10 lb. of sulphuric acid, previously diluted with an equal bulk of water. This mixture is added to the oil in three portions, the oil being well stirred for about an hour after each addition. It is then stirred for 2–3 hours to ensure perfect mixture. After being allowed to stand for 12 hours, it is transferred to a copper boiler with a perforated bottom, through which, steam enters and passes in a finely divided state through the oil, raising it to the temperature of 100° (212° F.). This is continued for 6–7 hours, and the oil is transferred to a cooler, shaped like an inverted cone, terminating in a short pipe, and provided with a stop-cock at the side, a little distance from the bottom. After standing till the liquids are separated, generally about 12 hours, the acid liquor is drawn off through the pipe at the bottom, and the clear oil by the stop-cock in the side of the cooler; all below this tap is generally turbid, and is clarified by subsidence, or mixed with the next portion of oil.

These acid processes are efficient when well conducted, but too much or too little acid may spoil the product, because, as most of them depend for their action upon the fact that strong sulphuric acid chars organic substances by the removal from them of the elements of water, it chars the fibre in the oil first, but if more acid than necessary for this be present, it attacks the oil itself, and oil thus stained by charring cannot be completely decolorized again.

On this account, perhaps, more general preference seems to be accorded to alkaline processes. Evrard's, which is chiefly applied to colza- and rape-oils, is as follows. The oil, drawn cold, or at very slight heat, is well crutched up with a weak lye of soda or potash, and allowed to settle. Two layers soon form—a neutral oil floating on an alkaline liquid, a mixed emulsion intervening. The alkaline liquid is drawn off, and replaced by slightly alkaline water, and the whole is left to settle. This is repeated a few times with clear water, till the liquid at the bottom of the settlers is only slightly milky. The oil is drawn off and filtered, and is superior to oil purified by sulphuric acid, being much less corrosive to metal. The turbid residual waters are treated with acid, and give a greasy product fit for soap-making. A much simpler alkaline method adopted in Italy for olive-oil is to add 400 *grm.* of ammonia, diluted with 800 *grm.* of water, to every 100 *kilo.* of oil, agitating thoroughly, allowing to stand for 3 days, and then decanting and filtering.

One of the most remarkable impurities in fats, arising from methods of preparation merely, is that of lime in bone-fat. This fat has the power of dissolving considerable quantities of lime-salts, especially phosphate and carbonate. No amount of subsidence or filtration will remove them, and their presence in a soap-copper is most objectionable. It is greatly to be desired, therefore, that English makers of this fat would follow the example of their American confrères, and boil their bone-grease, after removal from the extractors (p. 1449), with a weak solution of sulphuric acid, in lead-lined wooden tanks. This removes all the lime, in the form of sulphate, which deposits on the floor of the tank after due subsidence; it also removes the gelatine and extraneous water entangled in the bone-fat, which cause the crude grease to froth greatly when heated.

A good example of the removal of resinous substances from oils is afforded by the process adopted for refining and bleaching cotton-seed-oil, an industry which has enormously developed both in England and the United States, within the last 15 years. When freshly expressed from new seed, this oil is of a light-claret colour, which darkens by long keeping, in which case also, the oil becomes more viscid, probably from oxidation of some of its constituents. The colouring matter is almost entirely resin, which may be removed by agitation at about 60° (140° F.) with solution of carbonate of soda. It is found in practice, however, that a much better result is obtained by the use of a caustic alkali—solution of soda, potash, or, in some rare cases, milk of lime. The amount of alkali thus employed depends entirely upon the quality of the crude oil, and is best determined by a preliminary experiment upon a small scale. A solution of caustic soda at about 1·10 sp. gr. is a suitable strength. Agitation must be thorough, and may be effected by any convenient mechanical means. The process is a rapid one; if the saponaceous liquid does not readily separate from the oil, the addition of a little brine will cause it to do so. The operation is often divided into two or three stages, and occasionally the refined oil is bleached by one of the oxidation processes, such as by chloride of lime. After all the refining, it should be washed with warm water, allowed to settle, and decanted, or filtered at as low a temperature as possible, especially if an oil be desired that will remain fluid at a low temperature. This process will answer well for any resin-containing oil. The imperfect soap, after removal, is treated with enough mineral acid to remove all the soda, and the resulting mixture of resin, fatty acids, and neutral oil is distilled with superheated steam (see Candles) for the manufacture of fatty acids, the resin being left in the still as pitch. The chief seat of this industry in England is at Hull. In the United States, the quantity of resin is so small, that the "foots" from the cotton-seed-oil refineries are made into a curd soap (see Soap).

For the removal of fraudulent admixtures from commercial oils, no general rule can be given; but subsidence, filtration, and boiling with weak sulphuric acid, will generally effect the desired result. Special methods are best sought under the head of Detection and Analysis, pp. 1462–77.

Methods for correcting rancidity in oil are as follows:—(*a*) Agitation with 5 parts of good vinegar, repeating the operation several times. (*b*) Agitation (5–6 times) of 50 parts of oil with 80 parts of water at 30° (86° F.) holding 12 parts of common salt in solution. (*c*) To 100 *litres* of oil, are added 2 *kilo.* of calcined magnesia; the mixture is agitated 4 times daily for ¼ hour each time for 6 days; the oil is then filtered; it must be quickly used, or it will become rancid again. (*d*) Agitation with a weak solution of caustic alkali, or a moderately strong one of an alkaline carbonate. (*e*) Prolonged agitation with water.

Most of the processes for refining and bleaching oils also deodorize them to a certain extent. As many of the odorant principles are more volatile than the oils, they may occasionally be removed by merely heating the oil in a closed vessel provided with an exit-pipe. For destroying the disagreeable smell of coco-nut-oil for soap-making, it is recommended to boil it in a wooden vessel by free steam on water containing 6 lb. sulphuric and 12 lb. hydrochloric acid to each ton of oil. Prolonged steaming will sometimes remove the unpleasant odour characteristic of oily distilled products.

Many plans of decolorizing oils are in vogue:—(*a*) Exposure to sunlight in large white glass bottles; the oil soon becomes colourless, but acquires an almost rancid flavour. (*b*) Agitation with 2 per cent. of a solution of permanganate of potash; bleaches effectually, but also leaves a bad flavour. (*c*) The oil is first agitated with water containing gum, and to the emulsion thus formed, is added coarsely crushed wood-charcoal; the whole is then slowly warmed to a degree not reaching 100° (212° F.), and when cold, the oil is dissolved out by ether or petroleum-spirit, and the latter is recovered by distillation; the result is good. (*d*) A process much recommended is to pass nitrous acid gas through the oil. (*e*) The oil (500 parts) is clarified by addition of 50 parts of China-clay and 50 of water. (*f*) In some cases, it is found advisable to use the coagulation of albumen in clarifying oils. The oil to be treated is mixed by agitation at the ordinary air-temperature with a weak solution of albumen in water. The whole is then gradually heated, most conveniently by steam, and when hot enough to coagulate the albumen, this latter collects in clots, enclosing particles of impurity; after the lapse of sufficient time, these clots subside, and the clarified oil is removed by decantation. The process is analogous to that of the refining of syrups by serum of blood.

Many oils are partially or completely decolorized by filtration through, or agitation with, freshly-burnt animal-charcoal or bone-black. The apparatus for filtering is similar to that employed in sugar-refineries (see Sugar), and consists essentially of tall wrought-iron cylinders filled with bone-black, and provided with a steam-jacket to control their temperature. When the charcoal ceases to decolorize, it should be treated with some solvent (bisulphide of carbon, or petroleum-spirit) to remove the oil, before it is revivified by calcination.

Most processes for the bleaching of oils depend upon the oxidization of the colouring matter by some suitable reagent, chiefly evolving nascent oxygen in some form. There are, however, instances known in which the colour is destroyed by a reducing agent, such as sulphurous acid, in an aqueous solution, as gas, or arising from the decomposition of an alkaline hyposulphite (e. g. that of soda) by a strong mineral acid. It may be laid down as a general rule that oils which have been burnt or charred by any previous process cannot be satisfactorily bleached. Experiment alone can determine the particular process best suited to any given oil, having regard to the purpose for which it is to be used. The utmost care is required in using any oxidation process for fats intended to be converted into soap, since if the fat be oxidized in any perceptible degree, as well as the colouring matter, (i. e. if too much of the bleaching reagent be used), the resulting soap will often be worse in colour than if the fat had not been bleached at all.

Palm-oil and tallow are the two chief fats bleached by the soap-maker. Both may be bleached by pumping air into them in finely divided streams, while they are kept at about 82°–93° (180°–200° F.). The colour of tallow may also be removed by boiling upon a solution of chloride of lime, or of chlorate of potash, to which a strong mineral acid has been added. No more potassic chlorate than 0·1 per cent. on the tallow should be employed.

Experiment has shown that the colour of palm-oil may be quite destroyed by heat. To effect this, the oil may be kept for some hours at about 127° (260° F.), or it may be put into a closed, horizontal, iron cylinder, and heated by a fire beneath up to about 240° (464° F.), at which temperature the colour is destroyed. This process gives rise to most offensive vapours, especially acrolein, and necessitates the conduct of operations in a closed vessel, with suitable means of condensing the vapours and rendering them innocuous, such as have been already alluded to under Floor-cloth (p. 1004), and elsewhere (pp. 1272–6, 1449).

Palm-oil may also be very suitably bleached by bichromate of potash and hydrochloric acid. The oil is made as free as possible from impurities, and, at about 49°–54° (120°–130° F.), is agitated with a strong solution of bichromate of potash, containing about 1 lb. of the salt to every 100 lb. of oil. To this, is added enough hydrochloric acid to form sesquichloride of chromium with all the chromium in the bichromate of potash, the quantity of liquid acid necessary of course varying with the amount of real acid contained in it. A slight excess of acid is rather an advantage than otherwise. The process occupies about an hour, after which, subsidence removes most of the chemicals, while subsequent agitation with hot water renders the oil quite pure enough for the soap-copper.

Detection and Analysis.—The ordinary solid fats and fixed oils (with the exception of butter and a few others) may be looked upon as mixed glycerides of oleic, stearic, and palmitic acids, in various proportions, the first preponderating in the oils, and the two last (especially stearine) in the fats. For ordinary purposes, there are therefore the following constituents to deal with:—(1) Moisture, especially in butter and palm-oil; (2) organic suspended matter, such as curd in butter; (3) mineral matters, such as salt in butter; (4) total fatty acids, in any ordinary oil or fat; (5) oleic, stearic, and palmitic acids, in any ordinary oil or fat; (6) soluble and insoluble fatty acids, only necessary in butter, and the few exceptional fats similarly constituted; (7) glycerine, from which to calculate the glyceryl in the fat; (8) possible presence of paraffin-wax and mineral oils.

A. Ordinary Examination of Fats. (1) *Estimation of Moisture in Fats.*—25 *grm.* of the fat are weighed into a carefully tared porcelain dish, which is then placed over a low gas-flame, and stirred with a thermometer, taking care that the temperature is maintained above 100° (212° F.), but not exceeding 110° (230° F.). This is continued until no more bubbles of vapour escape, indicating that all the moisture has been expelled; the whole is then allowed to cool. When cold, the thermometer is carefully drawn out, and any fat remaining attached to it is scraped off and returned. If, however, an instrument with a long narrow bulb be used, and it be carefully loosened by gently turning it round, usually no fat will adhere on withdrawing it. The dish plus the fat is then weighed, and the tare being deducted, the remainder is the dry fat in the 25 *grm.* taken, which, multiplied by 4, gives percentage of pure fat, and the difference between that and 100 represents the percentage of moisture.

(2) and (3) *Estimation of Organic and Mineral matters present as Impurities in Fats.*—This applies to the estimation of curd and salt in butter, and of fibrous and mineral impurities in oils and fats, and is thus conducted. The contents of the dish already used for moisture are melted, and the melted fat is poured off as far as possible without disturbing the sediment. Some petroleum-spirit, rectified at a temperature not exceeding 87° (188½° F.), is poured into the dish, and the whole is well stirred, and transferred to a previously weighed filter. By means of successive portions of petroleum, the whole of the contents of the dish are washed on to the filter, and all traces of fat are completely washed away from the other matters, which remain on the paper. The filter is then dried at 100° (212° F.), weighed, and the tare having been deducted, the remainder is organic matter plus mineral matter (or, in a butter, curd plus salt).

The filter and contents are then transferred to a previously weighed platinum crucible, and heated for some time to dull redness, till the ash becomes greyish-white. The crucible and ash are weighed, and the weight of the former being deducted, the difference is mineral matter (or, in a butter, salt). The mineral matter thus found is deducted from the former result, and the difference is the organic matter, and each multiplied by 4 gives the respective percentages.

(4) *Estimation of the total Fatty Acids in any ordinary Fat or Fixed Oil not containing Glycerides of Soluble Acids.*—This process, which is also applicable to the estimation of the total insoluble acids in a fat containing glycerides of soluble acids, divides itself into two heads, as follows:—

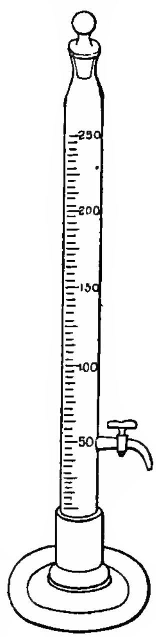
(α) Preparation of the sample.—If the sample be a perfectly clear and dry oil, it is at once ready for use; but if it be at all turbid, or if a solid fat, a portion must be placed in a tube, and kept in the water-oven below 100° (212° F.), until any moisture and heavy suspended impurities have settled to the bottom. A well-dried filter-paper is then placed in a funnel over a dry beaker, also in the water-oven, and the nearly clear upper portion of the melted fat is filtered, until a sufficient quantity is thus obtained fit for analysis.

(β) Process of analysis.—A perfectly clean and dry 5-oz. flask is accurately tared on the balance, and 5 *grm.* of the melted fat are carefully weighed into it. (It is not important exactly to a fraction, but as nearly 5 *grm.* as possible should be taken, and, in any case, the weight must be noted with great care.) To this, are then added about 30 *c.c.* of methylated spirit 60 o.p., and a fragment of caustic potash weighing about 2 *grm.*, and the flask is then placed in a basin of boiling water, until the whole of both fat and potash have dissolved, and the addition of a little water produces no permanent turbidity, which will be attained within 10 minutes, as a rule. The contents of the flask are then poured into a basin, and the flask is washed out with repeated quantities of boiling distilled water, until the contents of the basin measure about 250 *c.c.*, and no trace of soap remains in the flask. The basin is then placed over a low gas-flame, and evaporated till it ceases to give off spirituous vapours, a little boiling distilled water being added, if necessary, to prevent too great a loss by evaporation. The contents of the basin are then transferred to a 600-*c.c.* flask (1 pint size), the basin is washed with boiling water, and the washings are added to the flask. A slight excess of hydrochloric acid is then added, the whole is boiled, and shaken with a circular motion until a perfectly clear layer of fatty acids separates on the surface, and is set to cool. If the acids solidify on cooling to a good solid cake, well and good; but if not, a carefully weighed quantity of pure white wax must be added, and melted with the layer of fatty acids, so that, on cooling, they solidify firmly. This is always necessary in the case of oils, but not usually with solid fats. The mouth of the flask is then covered with a piece of ordinary cambric, held *in situ* by an indiarubber ring under the lip, so as to form a filter, and, the cake having been detached from the flask by a gentle motion, the watery liquid is poured off. Some boiling distilled water (about 200 *c.c.*) is then poured into the flask, and the whole is again boiled, well shaken, and cooled. The liquid below the cake is passed through the cambric as before, and this washing is repeated until the fluid collecting below the cake ceases to give a cloud with argentic nitrate. Care having been taken that, at the last pouring off, the cake has not been at all broken, the flask is inverted, and left to drain for the night with the cambric still attached. In the morning, the flask is placed in the water-oven till the cake has thoroughly melted, the cambric is removed, and the fat is then carefully poured into a dry and accurately tared platinum capsule, dried in the water-oven at 100° (212° F.), and weighed. The cambric is put into the flask, and the fat still adhering to both is washed out with small successive quantities of petroleum-spirit into a previously weighed small beaker. The petroleum is then evaporated off on the water-bath, the residual fat is weighed, and its weight is added to that of the main quantity already weighed in the capsule. The united weight then represents the total fatty acids in the quantity of fat taken, and is calculated to percentage by multiplying by 100, and dividing by the weight taken for analysis. It sometimes happens that an obstinate little globule of water forms below the melted acids in the weighing-capsule, and refuses to dry up; but this is easily removed by adding a little absolute alcohol, and again drying in the water-oven. The alcohol thus used carries off with it in volatilizing the little trace of moisture remaining.

(5) *Estimation of the Oleic, Stearic, and Palmitic Acids.*—To do this, advantage is taken of the solubility of oleate of lead in ether, so enabling its separation from the stearate or palmitate of the same metal. As formerly conducted, this was a tedious and not over accurate process; but by the apparatus and process devised by Dr. Muter, the estimation is rendered simple. Three cases present themselves, as follows:—

(*a*) For the Oleic Acid in non-drying Oils and Fats.—A small quantity (not more than 1·5 *grm.*) of the purified fat is saponified by alcoholic potash in a flask, washed into a basin with boiling distilled water, and the alcohol is removed by evaporation, all as described before in the estimation of the total fatty acids. The solution is kept boiling, and treated with acetic acid, drop by drop, until a decided *permanent* turbidity is produced; dilute solution of caustic potash is then added by drops, with *constant stirring*, until the liquid *just clears again.* The clear solution is then precipitated by plumbic acetate in slight excess, and stirred until the precipitated soap settles thoroughly. The supernatant liquor is poured off, and the soap is at once washed by boiling with a large volume of distilled water, and decanting. By this process, are obtained the perfectly neutral lead salts, containing:—Plumbic oleate ($Pb2C_{18}H_{33}O_2$), plumbic palmitate ($Pb2C_{16}H_{31}O_2$), and plumbic stearate ($Pb2C_{18}H_{35}O_2$). The first is readily soluble in ether; the two last are quite insoluble. The soap is scraped from the basin with a platinum spatula, and transferred to a flask of 100 *c.c.* capacity. The basin is rinsed into the flask with absolute ether, and then the flask is filled up with the same solvent, corked, shaken at intervals for some hours, and finally set to subside. The whole is then filtered through white blotting-paper, and the precipitate is washed with ether, till the washings cease to blacken with ammonium hydrosulphide. The filtrate and washings (which should not exceed 200 *c.c.*) contain the plumbic oleate, while the palmitate and stearate remain on the filter. Having thus got a solution of pure neutral oleate of lead in ether, it is transferred to a long tube of 250 *c.c.*, graduated from the bottom upwards, furnished with a well-ground stopper, and having a stopcock placed at 50 *c.c.* from the bottom (Fig. 1045). About 20 *c.c.* of a mixture of one part hydrochloric acid and two parts water are then added; the tube is stoppered, well shaken, and set to subside, when a clear solution of oleic acid remains, the plumbic chloride sinking to the bottom. When sufficiently settled, a fixed portion of the ethereous solution is run off through the stopcock into a tared platinum dish, evaporated at a gentle heat, then dried at 100° (212° F.), and the oleic acid is weighed and calculated to the whole bulk. To make sure, it is well to run off two different quantities, and weigh them, so checking one by the other.

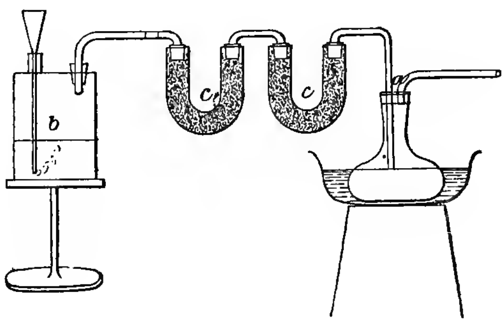
1045.



1046.

(β) For the Oleic Acid in drying Oils.—The process is conducted in a precisely similar manner up to the point where the whole has settled in the tube. A definite portion of the ethereous liquid is then run into a perfectly dry wide-mouthed flask of about 6 oz. capacity, carefully tared on the balance. The flask (Fig. 1047) is then fitted with a cork *a*, through which pass two tubes, one going down nearly to the surface of the liquid, and the other just passing through the cork. To the long tube, are attached two U-tubes *c*, filled with freshly-ignited chloride of calcium; to that again, is joined a gas-bottle *b*, in which a steady stream of hydrogen is generated from zinc and dilute sulphuric acid. When the air has been expelled from the flask by the stream of dry hydrogen, a basin is placed under it, and warm water is poured into the basin, so as to cause the ether to evaporate. When the ether is nearly gone, the water in the basin is kept boiling till the ether is entirely evaporated (i. e., till no more smell of ether is observable at the mouth of the exit-tube). The basin is then removed, and the flask is allowed to cool (still keeping up the stream of hydrogen); when cold, it is detached and weighed, and, the tare being deducted, the weight of oleic acid is calculated to percentage.

1047.



(γ) For the Stearic and Palmitic Acids.—The residue left on the filter, after extraction with ether, is carefully scraped off, and heated for some time (with constant stirring), which will liberate the acids, so that they will, on cooling, form a cake; this is washed, dried, and weighed, as described in section (4). The filter-paper is also to be burned in a weighed porcelain crucible, and the ash treated with a drop or two of sulphuric acid, and again ignited. After cooling, the crucible is weighed, and, the tare being deducted, leaves the equation—as 303 : 568 : : the weight of the residue; the answer, added to the weight of the cake already found, gives the total solid fatty acids (stearic and palmitic), which is then calculated to percentage. If it be desired to find the approximate proportion of each of these acids, the process is as follows. Several glass tubes are drawn out at one end to a long thin point, as in Fig. 1046 (natural size). The cake of mixed acids is then melted, and a little is sucked up into a pair of such tubes, until the drawn-out parts are entirely filled, and both are allowed to cool. They are then suspended side by side with a delicate thermometer, in a small beaker filled with water, taking care that the thermometer has a long narrow bulb placed exactly between the two tubes. Heat is now applied to the beaker, and at the moment that the fat in the thin tubes becomes transparent, the degree of heat is read off. The whole is allowed to cool gradually, and the temperature is again read at the moment of resolidification. By referring to the following tables, an approximate result is obtained.

Table of the Melting- and Solidifying-points of Mixtures of Stearic and Palmitic Acids.

Stearic Acid, proportion by weight.	Palmitic Acid, proportion by weight.	Mixture melts at	Mixture resolidifies at
90	10	67·2° (153° F.)	62·5° (144½° F.)
80	20	65·3° (149½° F.)	60·3° (140½° F.)
70	30	62·9° (145¼° F.)	59·3° (138¾° F.)
60	40	60·3° (140½° F.)	56·5° (133¾° F.)
50	50	56·6° (133¾° F.)	55·0° (131° F.)
40	60	56·3° (133¼° F.)	54·5° (130° F.)
35	65	55·6° (130¼° F.)	54·3° (129¾° F.)
30	70	55·1° (131° F.)	54·0° (129¼° F.)

It should be mentioned that this table is by no means certain when the mixtures are in some other proportions. Thus, a mixture of 10 stearic and 90 palmitic will show a melting-point of 60·1° (140¼° F.), but its cooling-point will be about 54·5° (130° F.), instead of 56·5° (133¾° F.), so that even to get fair approximation, both the melting- and the resolidifying-points must be taken. Pure stearic acid melts at 69·2° (156½° F.).

(6) *Analysis of Fats containing Glycerides of both Soluble and Insoluble Fatty Acids.*—The most generally interesting fat in this series is butter, which has to be distinguished from the artificial butter manufactured from solid beef-suet, and known in commerce as "oleo-margarine" or "butterine"

(see p. 1362). Remarks will therefore be specially directed to this subject, merely pointing out that the same process would be available for coco-nut and palm-nut-oils, or any of the few other fats containing soluble acids. Suet, and the artificial butter manufactured from it, will yield on melting, settling, and filtering, a fat containing about 95·5 per cent. of insoluble fatty acids; but the fat of butter will be found to possess on an average very nearly the following composition:—Insoluble fatty acids (chiefly oleic and margaric), 88; soluble fatty acid (calculated as butyric), 6; total, 94. From an estimate of both the soluble and insoluble acids, it follows that deficiency of the former and excess of the latter gives a good basis for detecting adulteration. This may be done in two ways, viz., by specific gravity, and by analysis.

(α) Examination of Butter by "actual density."—The term "actual density" was applied by Dr. Muter to this method as meaning the weight of any given volume of butter at 37·8° (100° F.), divided by that of the same volume of distilled water at the same temperature, to distinguish it from ordinary sp. gr. compared with water at 15½° (60° F.). The actual density of pure butter ranges from 0·912 to 0·914, while that of butterine is 0·903–0·906. Consequently there is a difference on the lowest estimate of 0·006, and an approximate judgment can be made as follows:—All butter, 0·912 or over; ⅔ butter, 0·910; ½ butter, 0·909; ⅓ butter, 0·908; all butterine, 0·906 or under. It is, however, customary to pass as "good," butter having an actual density of anything over 0·911, because, by keeping, the density increases; but, to cause a fall below this point, it would require a degree of rancidity so great as to produce complete unfitness for either alimentary or analytical purposes. The process is carried out as follows:—The butter is first kept melted till all the impurities settle down, and the clear fat is filtered, as already directed in the estimation of "total fatty acids." A special sp. gr.-bottle is procured, of a pear shape, and having a thermometer fused through the stopper. The thermometer has a long narrow bulb, running right through the centre of the bottle, and its scale, which is from 15½ to 48·9° (60°–120° F.), is entirely above the stopper. This bottle is exactly counterpoised, and is then filled with recently boiled distilled water at 35° (95° F.). The stopper is inserted, and the whole is at once plunged up to the neck into a 12-oz. squat beaker, partially filled with distilled water at 39½° (103° F.), in which is placed a thermometer. As the temperature rises in the bottle, the water leaks out at the stopper, and in a few minutes (if the quantity of water in the beaker be properly regulated), a time arrives at which the two thermometers equalize themselves at 37·8° (100° F.). The joint between the stopper and the bottle is instantly wiped by a small piece of blotting-paper to absorb loose water, and the bottle is lifted out, wiped thoroughly dry, and weighed. This process having been repeated three times, the average weight is scratched on the bottle with a diamond, and it is then ready for use. The pure butter-fat, prepared as already described, is melted in the water-oven, and cooled to 35° (95° F.). It is then poured into the bottle till full, the stopper is inserted, and the whole is plunged into the beaker of water at 39½° (103° F.). The same operations are gone through as just directed for the water, and the weight so obtained is divided by that marked on the bottle. The contrivance of having a *rising* fat heated by a *falling* water until the two equalize is the perfection of accuracy, and moreover gives *an appreciable rest in the variation of temperature*, sufficient to enable the excess of fat which has leaked out to be removed exactly at the required point.

(β) Chemical analysis for the amounts of soluble and insoluble acids.—For this purpose, the following reagents are necessary:—

a. Semi-normal volumetric sulphuric acid, containing 49 *grm.* H_2SO_4 per *litre*. This is made by weighing out 50·6199 *grm.* pure oil of vitriol, sp. gr. 1·843, and diluting with distilled water to 1 *litre*. Each *c.c.* of this acid will represent 0·088 *grm.* of soluble butter-acids, calculated as butyric acid, or 0·09 of soluble butter-acids on the basis that they are 90 per cent. butyric and the rest chiefly caproic.

b. Volumetric normal solution of sodium hydrate, containing 40 *grm.* real NaHO per *litre*, and made by dissolving say 45 *grm.* of ordinary caustic soda in a *litre* of distilled water, then filling a burette with this solution, and running it into 100 *c.c.* of the volumetric sulphuric acid placed in a beaker, to which a few drops of alcoholic solution of phenol-phthallein have been added, until it produces a pink colour. The number of *c.c.* of the soda solution used having been noted, ten times that quantity is placed in a test mixer, and made up to 1 *litre* with distilled water. Each *c.c.* of this alkali will now represent 1 *c.c.* of the acid.

c. Volumetric normal solution of potassium hydrate in methylated spirit, made by dissolving 60 *grm.* of ordinary caustic potash in 1 *litre* of methylated spirit, checked, and made up with spirit, exactly as directed for the sodium hydrate solution. It is to be preserved in a well-stoppered bottle, and always checked again before use.

d. An ordinary solution of barium chloride.

The process is performed as follows:—5 *grm.* of melted and purified butter-fat (as directed under "total fatty acids") are weighed into a 5-oz. flask, 50 *c.c.* of the alcoholic potash (*c.*) are carefully added from a burette, and the whole is boiled on a water-bath for about 15 minutes, or until the addition of a little water produces no turbidity. This solution is washed into a long, narrow, graduated measure with successive quantities of distilled water, till the whole measures 300 *c.c.*, and it is then divided into two parts of 150 *c.c.* each. In part A, the insoluble acids are estimated; in part B, the soluble.

Part A is treated with solution of barium chloride, until no more precipitate forms; the precipitate is collected on a filter, and well washed with warm water. It is then transferred to a "Muter's oleine tube" (see Fig. 1045) having a wide mouth, by washing it in with distilled water, and allowed to settle. As much as possible of the water is drawn off by inclining the tube forward and running off the clear water at the stopcock; 20 *c.c.* of diluted hydrochloric acid (1 acid to 2 water) are added, together with 100 *c.c.* of pure ether; the stopper is introduced, the tube is well shaken, and then allowed to settle till the ethereous solution separates. The amount of the ethereous solution is noted, and a definite quantity (say one-half) is drawn off into a tared platinum capsule; the ether having been evaporated off, the residual acids are weighed, all as already directed for the estimation of oleic acid in non-drying oils. The weight, first doubled (if half the ethereous liquid has been used), and then multiplied by 40, gives the percentage of the insoluble acids in the butter-fat. The amount of adulteration is best calculated on this result by the following formula, in which, P is the weight per cent. of insoluble acids found, and x the percentage of adulteration.

$$\frac{(P - 88) \times 100}{7 \cdot 5} = x.$$

Looking, however, to the fact that the insoluble acids in butter increase by age and rancidity, no article should be positively condemned which shows less than 90 per cent. of insoluble fatty acids. Once tho adulteration is thus rendered certain, its percentage should be calculated, as above, on the ordinary standard of good butter.

If preferred, the insoluble acids in butter may be estimated by the process already detailed for total fatty acids in ordinary oils and fats, in section (4).

Part B is diluted with another 100 *c.c.* of water, placed in a flask, brought under a burette containing the volumetric sulphuric acid (*a*), and 50 *c.c.* are run in. The flask is then attached to an upright condenser, boiled until the insoluble acids separate in a clear oily layer, and then allowed to cool. The cake is detached, and the fluid is run off through a filter, made as directed in section (4), by fixing a piece of cambric over the mouth of the flask. Another 100 *c.c.* of boiling water is then added to the cake, and the whole is again boiled under the upright condenser; when cooled, the liquid is passed through the same filter. This operation is repeated, and the united filtrates are brought under a burette containing the volumetric sodium hydrate (*b*), and, a few drops of alcoholic solution of phenol-phthallein having been added, the solution is run in. When a pink colour has been produced, the number of *c.c.* used is noted, and this number, multiplied firstly by 0·09 and secondly by 40, gives the percentage of soluble fatty acids in the butter-fat.

(7) *Estimation of the Glycerine formed by Saponification.*—This is not generally necessary, except for scientific purposes, and it is customary to deduct the percentage of total fatty acids found from 100, and consider the difference as glyceryl. Up till the beginning of this year (1881), no ready process for the estimation of glycerine had been proposed; but since then, Dr. Muter has published the preliminary notice of a process which is likely to give good results. The author takes advantage of the power of glycerine in arresting the precipitation of cupric hydrate from cupric sulphate by potassium hydrate. He takes a definite quantity of the solution of glycerine in one of the oleine tubes already described (Fig. 1045), and to it, he adds an excess of potassium hydrate, and drops in a solution of cupric sulphate with constant shaking, until a permanent precipitate is produced. The whole is then made up to a definite bulk, and, when settled, a portion of the blue liquid is run off through the stopcock; the amount of dissolved copper is estimated by neutralizing with nitric acid, then adding excess of ammonium hydrate, and running in a volumetric solution of potassium cyanide till decolorized. By doing this on a solution of glycerine of known strength, the value of the cyanide in glycerine is ascertained. Those interested will find details in the *Analyst* for March 1881.

(8) *Testing a Solid Fat for Paraffin-wax and Mineral Oils.*—The mixture of fats with solid mineral hydrocarbons has become of late years quite an acknowledged custom. Therefore, any fat should always be submitted to the "actual density" process described for butter, on p. 1465. Ordinary fats have an "actual density" at 38° (100° F.) rarely below 0·9032, while solid paraffin-wax treated in the same way shows nothing above 0·8810. If, therefore, an apparent fat shows less than the latter figure, it is probably all mineral; but if somewhere between the two, it is most likely a mixture, and must be treated in the same manner as hereinafter described for the detection and estimation of heavy mineral oil in ordinary fatty oils. The test for paraffin-wax in oils is, as hereafter shown, so simple, that it is advisable always to apply it, unless the fat shows a density so high as to positively preclude its presence.

B. Identification of Oils in Mixtures.—The next subject claiming attention is the identification and testing of oils, especially when mixed, a point of the greatest difficulty, and one which eminently requires experience. It does not, like the subject just finished, rest on a definite chemical basis; and although many processes have been from time to time advocated, none has really stood the test of repetition by other hands. The peculiarity of oils is that one analyst may have methods which may and do give fair results in his own hands, but which, repeated by others without his special experience, become not only inaccurate, but positively misleading. It would be quite possible to make an apparently valuable *résumé* of the subject, by giving all the processes above referred to, and still to leave the reader really no nearer his desired object than at the commencement. The aim of the present article, however, is to avoid this beaten track, and to omit everything but the few definite points which, intelligently followed up and backed by practice, may lead to the fairest deduction possible in the present state of science. The first essential in setting about the study of oils is the possession of a set of really genuine standard samples; this is very difficult to procure, as the oil-trade is so permeated by the principle of admixture, that the refiners have too often good reason to shun any attempts to render its detection more easy. To test the real state of matters in this respect, the writer once applied to seven leading houses to assist him with standards; only one came forward in response. Nothing, however, can be done without standards of, at least, the following kinds:—

Marine Animal Oils.	Terrestrial Animal Oils.	Mineral Oils.
Fish (cod)	Lard	Ordinary paraffin
Whale	Neats'-foot	Heavy lubricating.
Seal	Horse-bone	
Sperm	Tallow (oleic acid).	
Cod-liver.		

Drying Vegetable Oils.	Partially Drying Vegetable Oils.	Non-drying Vegetable Oils.
Linseed	Cotton	Olive
Hempseed	Castor.	Almond
Nut.		Rape
	Manufactured Oil.	Colza (refined rape)
	Rosin.	Ground-nut
		Coco-nut.

Many other oils exist, but the foregoing represent such as are commonly met with in commerce. If, however, the reactions of others should be desired in any special case, it will be easy to follow out the methods hereinafter given, and fix one's own reactions, if not found in the present article, which must necessarily be limited.

The following reagents and special articles are required:—(1) Pure carbon bisulphide; (2) petroleum-spirit, rectified under 88° (190° F.); (3) alcoholic caustic soda, made by dissolving 115 *grm.* of sodium hydrate in 1 *litre* of redistilled methylated spirit; (4) sodium bicarbonate, pure; (5) silver sand, well washed, dried, and ignited; (6) barium polysulphide, made by dissolving barium oxide in boiling distilled water, cooling, pouring off the mother-liquor from the crystals, boiling it with excess of sulphur, and filtering; (7) syrupy zinc chloride, made by saturating hydrochloric acid with pure zinc oxide, and evaporating till the liquid assumes the consistence of golden syrup; (8) sulphuric acid, sp. gr. 1·843, which has been shaken up with a little mercury occasionally during some hours; (9) stannic chloride, the fuming perchloride of tin of commerce; (10) syrupy phosphoric acid, ordinary phosphoric acid evaporated to a sp. gr. of 1·72; (11) mercuric nitrate, made by dissolving mercury to saturation in cold nitric acid, and then boiling for ten minutes with as much more nitric acid; (12) absolute sulphuric acid, the strongest acid, which has been recently heated for some time to 316° (600° F.), then boiled, and quickly secured in an air-tight vessel; (13) amylic alcohol, sp. gr. 0·818; (14) a sp. gr.-bottle, fitted with a thermometer stopper from 60° to 120° F.; (15) a long delicate thermometer, graduated in single degrees from 0° to 149° (32°–300° F.); (16) some long test-glasses of $1\frac{1}{2}$ in. diameter, capable of holding 150 *c.c.*, and made to stand heat; (17) some dropping-tubes, delivering slowly drops of water weighing $\frac{8}{10}$ gr.; (18) some white porcelain capsules, semicircular in form, and 2 in. diameter, without spouts; (19) some small glass rods, 3 in. long.

(1) *Examination for Mineral and Rosin Oils.*—

(*a*) Warm the oil, and smell it. If it gives off the odour of paraffin, it contains ordinary illuminating mineral oil. In this case, carefully counterpoise a watch-glass, and having weighed on to it about 1 *grm.* of the oil, keep it in an air bath heated to 110° (230° F.) until the weight is constant; note the loss of weight, and calculate to percentage of paraffin-oil.

(*b*) Place 10 *grm.* of the oil in a basin with 20 *c.c.* of the alcoholic caustic soda (No. 3 reagent), heat to boiling on a water-bath, and evaporate nearly to dryness. Then add 75 *c.c.* of distilled water, and boil for half-an-hour. Observe the nature of the resulting mass or liquid, and note one or other of the following cases.

Case 1. An emulsion only is formed. Probably there is only mineral or rosin oil. Add water, and warm, when, if a clear oil separates, mineral oil is present, but if brown, then rosin-oil may be present. Now draw off the aqueous liquid from beneath, and make it acid with sulphuric acid. If no precipitate forms, the oil was all mineral; but if a precipitate be produced, collecting on warming in brown viscous drops, then the presence of rosin-oil is confirmed.

Case 2. A semi-pasty mass is obtained. Probably it is an ordinary fatty oil mixed with mineral or rosin-oil. Add water, and warm, when the mineral oil, if present, will float to the surface. Now draw off the aqueous liquid, and shake it up with amylic alcohol; if the alcohol separates in a brown layer, rosin-oil was present. Once more draw off the aqueous liquid, acidulate with hydrochloric acid, and warm, when the separation of oleic acid, with its characteristic odour of fat, will show the presence of the fatty oil. This would also apply in the case of testing a solid fat for paraffin-wax.

Case 3. A perfectly pasty soap is formed, which dissolves in warm water without any separation of oil. The sample is an ordinary fatty oil, containing possibly (though not likely) a little rosin-oil. Shake up with amylic alcohol, when, if no brown colour be produced in the alcohol, no rosin-oil is present. Once more draw off the aqueous liquid, add an excess of sodium chloride (which will precipitate the fatty soap) and filter. If the oil be a pure fatty one, the warmed filtrate will only give a slight turbidity on acidulating with hydrochloric acid, and will smell of fat; but if the solution give a copious precipitate, and, when heated, has a resinous odour, the oil contains rosin. If, on setting free the fatty acids from the soap with hydrochloric acid, and cooling to 15½° (60° F.), they partly solidify, animal oil, such as lard or neats'-foot, may be suspected, although certain vegetable oils (such as cotton-seed), especially when crude, give tolerably solid acids. (The fatty acids of coco-nut-oil, and palm-nut-oil, when liberated and heated, smell of volatile fatty acids, just like butter, and the insoluble portion is very low).

Having thus got a fair preliminary idea of the constitution of the sample, it may be confirmed by taking the "actual density" at 38° (100° F.), as already directed for butter (p. 1465). If the "actual density" of the article be under 0·900, it is all mineral oil; if between 0·900 and 0·960, it may be either all fatty oil, or a complex mixture; while if over 0·960, it is all rosin-oil.

(2) *Estimation of a Mixture of heavy Lubricating Mineral Oil and Rosin-oil.*—There is no known method of chemically separating these, and so an approximation must be made from the "actual density." Mineral oils for lubricating have an "actual density" not exceeding 0·880, while rosin-oil is generally about 1·000; therefore the following table may be taken as approximate, which, however, is only good in the ensured absence of fatty oils.

All mineral	0·880	60 per cent. rosin	0·952
10 per cent. rosin	0·892	70 " "	0·964
20 " "	0·904	80 " "	0·976
30 " "	0·916	90 " "	0·988
40 " "	0·928	All rosin	1·000
50 " "	0·940		

The reader is warned that this is only approximate, as there are samples of rosin-oil as low in "actual density" as 0·9800.

(3) *Estimation of Mineral Oil in Fatty Oils.*—20 *grm.* of the sample are saponified with 35 *c.c.* of the alcoholic caustic soda (reagent No. 3) in a deep basin on the water-bath; 20 c.c. of redistilled methylated spirit, or sufficient to perfectly dissolve the soap, are added. The whole being still kept boiling on the bath, 9 *grm.* of sodium bicarbonate are added little by little, well stirring after each addition, so that all the excess of alkali may become carbonate; 50 *grm.* of sand (No. 5 reagent) are stirred in so as to thoroughly mix the whole, and the evaporation is continued until a perfectly dry residue is obtained. This residue is now packed into a stoppered percolator, and covered with petroleum-spirit (No. 2 reagent), and the whole is allowed to macerate for an hour; the stopper is then opened, and percolation is commenced into a 40-oz. flask, until the spirit has run off. More petroleum is then added, and percolation is continued until a few drops of the liquid evaporated on a watch-glass cease to leave any residue. This takes in all a considerable quantity of petroleum, so that sometimes the whole percolate measures nearly 1 *litre.* The flask containing the petroleum is then attached to a condenser, and the bulk of the petroleum is reduced by distillation to something under 100 *c.c.* The residue is transferred to an "olein tube" (see p. 1463), and the flask is rinsed with warm petroleum, so that the contents of the tube measure, say 150 c.c. A platinum capsule is carefully tared, and a measured small aliquot part of the fluid in the tube is run into it, from the stopcock, and evaporated to dryness at

a temperature not exceeding 104⅓° (220° F.). The residue is weighed, and calculated to the whole bulk of the fluid; that result, multiplied by 5, gives the percentage of mineral oil. As a rule, the tendency of the process is to come out about 0·5 per cent. too high, so that any fraction of a per cent. under or over 0·5 may be disregarded, i.e., if 20·4 per cent., to simply call it 20 per cent., but if 20·8 per cent, then report 20·5 per cent. To check the weighing, it is desirable to run off more than one small aliquot part, and evaporate and weigh. This process is equally applicable to the detection of paraffin-wax in solid fats.

(4) *Estimation of Rosin in Fatty Oils.*—To perform this with anything like accuracy, requires a tedious separation, in which the oil is saponified with alcoholic caustic soda, and the soap is dissolved in water. Dilute sulphuric acid is dropped in until the liquid becomes permanently turbid, and then dilute sodium hydrate is added drop by drop till it just clears again. The whole is then mixed with sand, and evaporated to perfect dryness, to ensure which it is necessary to moisten the apparently dry residue with absolute alcohol, and again dry. The residue is packed into a stoppered percolator, and extracted with a mixture of 5 parts by volume of absolute ether and 1 of absolute alcohol. The solvent is distilled off, and the residue is dissolved in water, and warmed with a slight excess of sulphuric acid, when the rosin separates in viscous drops, which are collected and weighed. These drops still contain a little oleic acid, and, if perfect accuracy be desired, must be dissolved in alcohol, and the solution polarized, which, however, is a process requiring special training and appliances, and is therefore beyond the scope of the present article. Indeed the estimation of a very small percentage of rosin in boiled linseed-oil, for example, is a problem requiring the highest skill and practice, and if under 2 per cent., it is, in the present state of science, practically impossible.

(5) *Estimation of Tallow-oil (free Oleic Acid) in an Ordinary Oil.*—This point is an important one because oils containing free oleic acid are unsuitable for lubricants. 50 *grm.* of the oil and 100 *c.c.* of alcohol are placed in a flask with a few drops of tincture of turmeric, or an alcoholic solution of phenol-phthallein, and well shaken.

A normal volumetric solution of sodium hydrate (40 *grm.* per *litre*, each *c.c.* of which represents 0·282 oleic acid) is dropped in until a red colour is produced, and the whole is again shaken. This is repeated until the red is permanent; the number of *c.c.* of sodium hydrate used are read off, and multiplied by 0·282, and then by 2, which gives the percentage of free oleic acid.

Before this process is undertaken, a little of the oil should be shaken up with alcohol of 60 o.p., and the alcoholic solution, when clear, mixed with a few drops of alcoholic solution of acetate of lead. If no precipitate be produced, no free fatty acid is present.

(6) *Mutual Detection of the various Fatty Oils.*—Having discussed all the cases of mixtures with other oils, we now come to the actual identification of the various fatty oils themselves.

The first step is to train the nose to distinguish between certain main groups. To do this, take some oil in a small flat porcelain basin, warm it up to about 142° (300° F.), and observe the smell. Then, as soon as sufficiently cool, rub some into the palm of the hand, and again smell. A little practice will thus permit the easy detection and distinction between (1) marine animal oil, (2) terrestrial animal oil, (3) vegetable oil. The odours of these three classes are entirely *sui generis*, and it is safe to pronounce on the main question by this test. The marine oils have all the repulsive fishy odour in various degree, the sperm requiring most practice; the other animal oils have all the peculiar sourish smell of cooking animal fat, soon learned by experience; the vegetable oils, on the other hand, have a more or less sweetish odour, and practice will even enable most of them to be named.

Case 1. The oil is evidently a marine animal oil. Take the "actual density" at 38° (100° F.) (see p. 1465), and compare with the following table:—

	Highest extreme.	Lowest extreme.	As commonly met with.
Cod (fish)	0·9220	0·9114	0·9176
Cod (liver)	0·9180	0·9173	0·9179
Seal	0·9195	0·9136	0·9150
Whale	0·9066	0·9056	0·9060
Sperm	0·8963	0·8672	0·8724

To confirm this, take 10 drops of the oil in a porcelain capsule (No. 18, p. 1467), add (from a dropping-tube) 5 drops of barium polysulphide (reagent No. 6), and stir rapidly with a small rod, when sperm-oil will become golden-yellow, and remain so, while the others will be very pale after a few strokes of the rod and setting aside for 5 minutes. Now take a similar quantity of oil, add 5 drops of zinc chloride (reagent No. 7), and stir, when whale and cod-liver will not change, or will only become pale-violet, while seal and cod-fish will be yellow or orange, the former exhibiting brown spots, the latter not. Next, to another similar portion of oil, add 5 drops of sulphuric acid (reagent No. 8), when cod-liver will alone give a violet, the others going brown at once. Then, to another similar portion of oil, add 5 drops stannic chloride (reagent No. 9), when whale-oil will only turn orange-yellow, seal and fish becoming red-brown, and cod-liver violet and then red. Lastly, to another similar portion of oil, add 5 drops mercuric nitrate (reagent No. 11), and after stirring, add a drop or two of sulphuric acid, when seal-oil will effervesce, and give off red fumes.

Case 2. The oil is apparently of terrestrial animal origin. Take, as before, the "actual density," when a pure oil of this class will never vary more than from 0·9050 to 0·9082. Tallow-oil (free oleic acid) is put out of the question in the preliminary examination by alcoholic acetate of lead, and so there can be only:—

	Highest extreme.	Lowest extreme.	As commonly met with.
Lard	0·9082	0·9076	0·9078
Neats'-foot	0·9079	0·9052	0·9070

All the members of this division bleach to a very pale-yellow with barium polysulphide, while lard-oil becomes perfectly white, and gives off a slight smell of sulphuretted hydrogen. They give scarcely any colour with zinc chloride, and become dark reddish-brown with sulphuric acid. A persistent yellow with the polysulphide, a green or brown with zinc chloride, and a greenish tint or too light a brown with sulphuric acid, would indicate impurities of vegetable oil. The only ones which, however, could be mixed without raising the density would be rape, nut, and olive, while sperm would lower the density. Characters of special varieties of neats'-foot-oil will be found in the general tables (pp. 1472–5).

Case 3. The oil is apparently vegetable in origin. Take, as before, the "actual density":—

	Highest extreme.	Lowest extreme.	As ordinarily met with.
Olive	0·9079	0·9052	0·9070
Rape	0·9077	0·9060	0·9067
Almond	0·9109	0·8980	0·9056
Refined rape (colza)	0·9065	0·9053	0·9067
Ground-nut	0·9092	0·9073	0·9085
Nut	0·9090	0·9080	0·9084
Refined cotton (salad)	0·9140	0·9130	0·9136
Poppy	0·9155	0·9150	0·9154
Coco-nut	very variable, from 0·9103 to 0·9152		
Cotton (brown)	0·9197 (an exceptional sample)	0·9170	0·9176
Hempseed	0·9195	0·9190	0·9193
Linseed	0·9300	0·9232 (an exceptional sample)	0·9252
Boiled linseed	0·9440	0.9320	0·9380
Castor	0·9576	0·9550	0·9558

Now proceed to use the reagents in the capsules, putting 5 drops of the reagent (from the dropping-tubes) into 10 drops of oil, and stirring; note the following effects:—

1. Barium polysulphide goes very pale-yellow only with inferior olive, ground-nut, and castor; and greenish with hempseed and very bad olive. The density throws out castor and hempseed, and only ground-nut and inferior olive are left. Try zinc chloride, when olive gives a green, and ground-nut a yellow. Confirm ground-nut by saponifying, and throwing up the fatty acids with hydrochloric acid. Then dry them, and dissolve in 4 parts of alcohol of 85°. To this, add an excess of rectified spirit, when, if ground-nut-oil be present, white flakes of arachidic acid will deposit; these may be collected, dried, and weighed. By treating pure ground-nut-oil side by side, the percentage of it in a mixture may be deduced.

2. Zinc chloride gives a green or greenish-yellow with olive, rape, colza, almond, linseed, and cotton. Olive and colza are green, linseed yellow or greenish-yellow, rape yellow, cotton (when heated) brownish, while almond is milky with a greenish tinge. The density excludes definitely linseed and cotton; it remains to distinguish between the others. Try stannic chloride, when, if a

green be produced, it is rape or colza; olive and almond respectively give faint-yellow or no colour. If it be not rape or colza try phosphoric acid, which will decolorize almond-oil, and turn olive-oil green. To distinguish between linseed and cotton, if required, try sulphuric acid; linseed goes orange-yellow, while cotton goes deep reddish-brown.

3. Sulphuric acid. There only now remain to be considered poppy- and nut-oils. The former becomes dark-brownish by agitation with sulphuric acid, while the latter only goes orange-yellow.

Having thus ascertained, by the density and reactions, the purity of the oil, and named it, the next case is that of a mixed vegetable oil; it is here that the experience comes into play. The most valuable help [in addition to the "actual density," and the full tables of reactions of all the oils hereafter appended (see pp. 1472–5), as devised by Chateau, and somewhat modified by the present writer, who uses by preference a different reagent for the first group], consists in the following process, originally proposed by Maumené. 50 *grm.* of the oil are carefully weighed into a tube, the temperature is taken with the long delicate thermometer (No. 15), 10 *c.c.* of absolute sulphuric acid (reagent No. 12) are added from a pipette, and the whole is rapidly stirred with the thermometer until it ceases to rise, and the number of degrees through which it has gone up are registered. According to the originator, we should get the following results, in about 2 minutes, the results being constant if the acid be used of the same strength, and the surrounding temperature be kept equable:—

Olive gives a rise of	108° F.	Gingelly gives a rise of ..	154° F.
Castor „	116° F.	Poppy „ ..	187·5° F.
Neats'-foot „	122·7° F.	Hemp „ ..	208° F.
Bitter almond „	125° F.	Nut „ ..	214° F.
Sweet almond „	126·5° F.	Train (ray liver) „ ..	215·5° F.
Rape „	134° F.	„ (cod) „ ..	215·5° F.
Beech-nut „	149° F.	Linseed „ ..	217° F.
Ground-nut „	152° F.		

The phenomenon is easily defined and observed, and gives distinctions much more characteristic than those yielded by any of the former methods. The phenomena remain the same if two oils are mixed together. Thus two measures of olive-oil and one of poppy-oil should show:—

2 vol. olive-oil	= 2 × 108	= 216
1 vol. poppy-oil	= 1 × 187·5	= 187·5
3 vols. mixture,		403·5° F.
Or 1 vol.		= 134·5° F.

and the experiment really gives this result, as has been ascertained by repeated trials with this and other mixtures.

In practice, the present writer did not succeed well with this process, for although he occasionally came up to these figures, yet the use of so hygroscopic an article as absolute sulphuric acid is always uncertain; he is, therefore, now in the habit of using the following process:—

Preserve some pure sulphuric acid, of sp. gr. 1·845, in a well-stoppered and capped bottle, never leaving the stopper out for more than the moment required to extract some of the contents. Get a tin vessel about 5 in. deep and capable of holding at least 2 qt. of water. Have some glass tubes on feet, capable of standing heat, about 1½ in. in diameter, and holding about 7 oz. of liquid. Have the acid in a bottle 6 in. high, with a thermometer inside. Counterbalance the tube, and weigh in accurately 50 *grm.* of the oil. Raise the water in the tin vessel to 28° (82° F.), immerse both the sulphuric acid bottle and the tube in the water, and place the long thermometer inside the latter. As soon as both the acid and the oil are at a temperature of 27° (80° F.), draw out 10 *c.c.* of the former with a pipette, and let it flow gradually (at the rate of 1 *c.c.* every 5 seconds) into the latter without touching the sides, stirring all the time with the thermometer. After all the acid is in, continue to stir rapidly for exactly ½ minute, keeping the tube in the water with one hand and stirring with the other, and then move the thermometer more slowly, noting the exact degree at which it ceases to rise. From that, deduct 80, and the difference is the amount of rise. Treated in this way, and using a definite hydrated acid, the rise of temperature is not quite so great, but it is (at least in the writer's hands) much more constant. With him, olive-oil gives a rise of 106° F., rape-oil of 131° F., and so on, very nearly in proportion to the original figures. It cannot, however, be too strongly impressed that every one using this process must fix his own standards *according to his own method of working*, and that a pure standard oil should always be done *in precisely the same manner* immediately before the suspected article. For this reason, the writer prefers not to give his own tables of results, as no two persons, unless actually working side by side, will ever get absolutely identical figures.

GENERAL TABLES OF THE FULL REACTIONS OF ALL THE USUAL OILS, ACCORDING TO CHATEAU, BUT SOMEWHAT MODIFIED BY THE WRITER.

GROUP I.—To 10 drops of the oil in a white porcelain capsule, add 5 drops of barium polysulphide (reagent No. 6), stir with a glass rod, and note whether the golden-yellow colour remains after 20 strokes of the rod, or whether it bleaches, and becomes very pale-yellow or white, as under:—

CASE I.—The Golden Colour remains with:—		CASE 2.—The Colour fades to Canary-yellow, or alters with:—	
Vegetable.	Animal.	Vegetable.	Animal.
Linseed. Poppy. Nut. Almond. Olive. Rape. Colza. Cotton. *Gingelly.* *Gold of pleasure.*	Sperm. *Neats'-foot (very rarely).*	Castor. *Poppy (Indian).* Hempseed (G. to G. Y.). Olive (*inferior*). Ground-nut. *Beech-nut.* Coco-nut.	Neats'-foot. Horse-bone. Lard (bleaches with slight H_2S). Fish. Cod-liver. Seal (B. Y.). Whale. Tallow (much H_2S).

NOTES.—G., green; G. Y., greenish-yellow; B. Y., bright-yellow; H_2S, gives off sulphuretted hydrogen. Unusual oils in italics.

GROUP II.—To 10 drops of the oil in a porcelain capsule, add 5 drops zinc chloride (reagent No. 7), stir, and observe whether the oil is scarcely affected, or develops distinct colour:—

White, or scarcely affected.		Distinct Yellow to Brown.		Green or Blue Shades.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Poppy. Nut. Almond (*hot-pressed*). *Gingelly.* Coco-nut.	Neats'-foot. Lard. Horse-bone. Sperm. Whale (*sometimes pale-violet tinge*). Cod-liver (cold).	Linseed. *English* (Y.) Rape (Y.) Ground-nut (Y.) Castor (R. Y.) Beech (F. R.) Cotton (B.)	Whale (Y. B.) Fish (O. Y.) Seal (R. B.)	Linseed (*foreign* B. G.) Olive (G.) Colza (G.) *Gold of pleasure* (G. pale). Almond (milky with G. tinge).	Cod-liver (*hot* G.)

NOTES.—Y., yellow; R. Y., rose-yellow; F. R., flesh-rose; O. Y., orange-yellow; B., brown; Y. B., yellow-brown; R. B. red-brown; G., green; B., G., bluish-green.

GROUP III.—To 10 drops of the oil in a capsule, add 5 drops sulphuric acid (reagent No. 8), and observe firstly without agitation and secondly with; 3 cases occur: (1) some shade of brown, (2) some shade of yellow, and (3) a greenish tint:—

Some Shade of Brown.		Some Shade of Yellow.		Greenish or Green Veins.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Linseed *foreign* (R. B.). Nut (R. B.). Ground-nut (R. B.). Beech *agitated* (B. R.). Cotton (B. R.). Coco-nut (R. B.).	Lard (R. B.). Neats'-foot (*agitated* R. B. with Gy. S.). Horse-bone *agitated* (R. B.). Fish (S. B.). Seal (R. B.). Sperm (R. B.). Whale (R. B.). Cod-liver (V. to D. B.).	Poppy (D. Y.). Castor (D. Y.). Olive (R. Y. to B.). *Gingelly.* Almond (P. Y., O. Y. and G. Y.).	Neats'-foot (rarely) (O. Y. with Gy. S.).	Hempseed (G. to R. B.). Linseed (G. B.). *English.* Colza (G. S.). Rape (B. G.). *Gold of pleasure.*	None.

NOTES—R. B., red-brown; B. R., brownish-red; Gy. S., grey spots; S. B., Sienna-brown; D. Y., dark-yellow; O. Y., orange-yellow; G., green; G. B., greenish-brown; G. S., green spots; V., violet.

GROUP IV.—To 10 drops of the oil in a capsule, add 5 drops stannic chloride (reagent No. 9), stir, and observe firstly the immediate colour, and secondly the colour of the thickened or solidified mass :—

CASE 1.—The coloration takes place instantaneously.

Yellow, Faint Yellow (F. Y.), Golden Yellow, no colour.		Brownish Red, Distinct Brown (D. B.), Reddish Yellow (R. Y.), Brownish Yellow (B. Y.).		Green, Greenish-bluish, Green, Greenish Blue.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Poppy (French). Castor. Olive. *Gingelly.* (F. Y.). Sweet almond (no colour).	Neats'-foot (Paris). Lard (O. Y.).	Linseed all qualities (B. Y.). White Poppy (India) (R. Y.). Nut (R. Y.). Olive (huile d'enfer). (R. Y.). Pea-nut (distinct B.). *Gold of pleasure.* Beech (R. Y.). Cotton-seed O. Y. (?) Coco-nut (D.B.)	Neats'-foot (R. Y.). Lard (R. Y.). Horse-bone (R. Y.). Whale (O. Y.). Sperm (purplish R. B.). Seal. Fish (deep R. B.).	Linseed (English) green veins. Ditto (N. Europe) (bluish G.). Ditto (Bayonne) (bluish G.). Ditto (India) bluish G.). Hempseed. Rape-seed. Colza.	Cod-liver, passing from violet-blue to dragon's-blood. Ray, same.

CASE 2.—The colour of the thickened or solidified mass.

Yellow, Faint Yellow (F. Y.), Bright Yellow (B. Y.), Straw Yellow.		Brown, Distinct Brownish Red (D. B. R.), Orange Yellow, (O. Y.), Reddish Yellow (R. Y.).		Green, Greenish, Dirty Green, Dark Green.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Poppy (French). White do. (India). Castor (faint). Olive (refined). B. Y. *Gingelly.* Sweet Almond (Canary Y.). *Gold of pleasure* (Faint Y.).	Sheep-foot (Faint Rosy Y.).	Linseed (D. B. R.). Olive (Ordinary) (O. Y.). Colza. Pea-nut (B. R.). Beech (distinct R. Y.). Cotton (Y B.).	Neats'-foot (O. Y.). Horse-bone O. Y.). Whale (clear mahogany). Sperm (O. Y.).	Hempseed (Dark green). Olive, *inferior* (dirty-green). Rape-seed (dirty green).	None.

GROUP V.—To 10 drops of the oil on a capsule, add 5 drops phosphoric acid (reagent No. 10), stir and observe ; then heat, and again observe :—

CASE 1.—Colours when cold.

Very little Effect.		Yellow to Orange.		Greenish to Bluish.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Poppy. Nut. Castor. Almond. Rape (?). *Gold of pleasure* (?). Coco-nut.	Neats'-foot. Lard.	Linseed, *Foreign* (S. Y.). Ground-nut (S. Y.). Cotton (G. Y.). *Gingelly* (O.V.).	Horse-bone (O. Y.). Whale (O. Y.). Sperm (S. Y.). Seal (B. R.). Fish (R. Y.). Cod-liver (R. Y.).	Linseed, *English.* Hempseed (D. G.). Olive. Colza. Rape. *Gold of pleasure.*	None.

CASE 2.—Colours on heating.

Colourless.		Yellow to Brownish-yellow.		Colour of the Froth on the Surface.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable	Animal.
Poppy. Olive (sometimes). Coco-nut (sometimes faint yellow).	Lard (sometimes very faint yellow.	Linseed (B. Y.). Poppy (B. Y.). Hempseed (R. Y.). Nut (B. Y.). Castor (B. Y.). Olive (R. Y.). Almond (B. Y). Rape (B. Y.). Colza (B. Y.). Beech (B. Y.). Cotton (B. Y.). *Gingelly* (B.Y.). *Gold of pleasure* (B. Y.). Ground-nut (G. Y.).	Neats'-foot (B. Y.). Horse-bone (G. Y.) Sperm (B. Y.).	Gingelly (greenish). Hempseed (greenish). Olive .. .. } Grey. Ground-nut } Grey. *Gold of pleasure* .. } Grey. Cotton .. } Grey. Linseed .. } Blackish. Castor .. } Blackish. Rape .. .. } Blackish. Colza .. .. } Blackish. Beech .. } Blackish.	Whale (greenish). Cod-liver (greenish). Sperm (grey). Neats'-foot (blackish). Seal (blackish). Fish (blackish).

Deep Browns.	
Vegetable.	Animal.
	Seal. Fish. Whale. Cod-liver.

GROUP VI.—To 10 drops of the oil on a capsule, add 5 drops mercuric nitrate (reagent No. 11), and observe the effect. Then add 2 or 3 drops of sulphuric acid, and observe the colour of the liquid which covers the precipitate:—

CASE 1.—Colours given by the Salt alone.

White or Grey Emulsion, or No Coloration.		Yellow, Faint Yellow, Gold Yellow (G. Y.), Canary Yellow, Orange Yellow (O. Y.), Straw Yellow (S. Y.).		Greens—Greenish, Sea Green (S. G.), Bluish Green.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Poppy, French. White (slightly yellowish). White Poppy (ditto). Nut (no coloration). Castor (white). Sweet Almond (greyish white). *Gingelly* (white). Beech (no coloration.) Coco-nut (flesh-colour).	Neats'-foot, Paris. Lard. Sperm (no colour).	Linseed (S. Y.). Olive, refuse (G. Y.). Rape (S. Y.). Pea-nut (faint Y.). *Gold of pleasure* (S. Y.) Gingelly (O.Y.). Cotton (faint Y.).	Neats'-foot (R. Y.). Horse-bone (O. Y.). Whale (faint Y.). Seal (reddish Y.). Fish (G. Y.). Cod (S. Y.). Ray (faint Y.).	Linseed, English. Hempseed (greenish after agitation). Olive (greenish Y.). Colza. Rape (S. G.). Gold of pleasure (faint G.).	None.

Case 2.—Colours given by Sulphuric Acid added after the action of the Salt of Mercury. Appearance of the Liquor covering the Precipitate.

Greys—Fleshy Grey, Brownish Grey (B. G.), Rose, Greenish Grey (G. G.).		Yellows—Reddish Yellow (R. Y.), Orange Yellow.		Browns—Raw Sienna (R. S.), Reddish Brown (R. B.), Bright and Dark Chocolate.		Disengagement of Vapours of Nitrogen Compounds. Sudden Effervescence.	
Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.	Vegetable.	Animal.
Hempseed (G. G. by agitation). Colza (dirty flesh colour then fleshy grey). Rape (B. G.).		Linseed, N. Europe (dirty Y. finally). Ditto, Bayonne (R. Y.). Ditto, India (dirty Y.). Ditto, English (deep Y.). White Poppy (R. Y.). Castor (canary Y. and Gold Y. at first). Olive, ordinary (R. Y.). *Gingelly* (green veins, then O. Y.)	Neats'-foot, Buenos Ayres (R. Y. at first). Horse-bones (dirty B. Y. at first).	Linseed, N. Europe (sepia R. B., then dirty Y.). Ditto, Bayonne (ditto). Ditto, India (R. B.). Poppy, French (dark B.). Nut (light B., dark B., blackish B.). Castor (dark B.). Hempseed (dark R. B. without agitation). Coco-nut (almost black). Olive, superfine (R. S. greyish). Olive, inferior (R. B.). Sweet Almond (light chocolate). Colza (brownish rose then light B.). Pea-nut (chocolate). *Gold of pleasure* (R. B. then chocolate). Beech (light R. B.). Cotton (light chocolate).	Neats'-foot, Paris (chocolate B.). Lard (ditto). Ditto, Buenos Ayres (R. B. and chocolate). Horse-bone (B. R. and chocolate). Tallow (light chocolate B.). Whale (dark chocolate B.). Sperm (light B. and black). Seal (br. bl.). Fish (ditto). Cod-liver (dark B.). Ray-liver (sepia).	Linseed, N. Ditto, Bayonne. Nut. Castor. The other drying oils do not effervesce like the above.	Tallow. Seal.

In entering upon the subject, it was stated to be essentially one requiring experience; as a fitting conclusion, and a practical illustration of how experience is to be applied, three examples may be given of analyses of mixtures which have recently come before the present writer.

I. *A Sample of Lubricating-oil.*—Very pale-yellow in colour, and smelling of paraffin-oil; 0·5 *grm.* heated at 110° (230° F.) till constant lost 0·1 *grm.* = volatile paraffin 20 per cent. A larger portion heated till it ceased to lose weight, then saponified, and tested, gave no separation of mineral oil. The colour proved that there was no rosin-oil, and the liquid when acidulated threw up fatty acids which, on cooling, partly solidified: *ergo* suspected lard or neats'-foot. The remainder on the watch-glass, after volatilizing the paraffin, had, while hot, the faint odour of lard-oil, and, treated with barium polysulphide, became almost colourless, and smelt slightly of sulphuretted hydrogen. A large quantity of the oil heated in a flat dish at 110° (230° F.) for some hours, and cooled to 38° (100° F.), had an "actual density" of 0·9077. Zinc chloride showed absence of olive-oil, therefore the report was:—Paraffin-oil, 20 per cent.; lard-oil, 80 per cent.

II. *A Sample intended to be sold as Salad-oil.*—Colour yellow with a faint greenish tint. Heated, it smelt of fine olive-oil, but slightly more rancid. Tests proved no mineral oil, and colour forbade rosin-oil. Actual density, 0·9092. Barium polysulphide, colour remained golden. Zinc chloride, green at first, but developed a decided pale-brown. Sulphuric acid, no green tinge, but a pale reddish-brown. The tests show that it is not colza; and some saponified, and the fatty acids dissolved in 4 parts alcohol, give no precipitate on diluting, therefore no ground-nut. The brown tinge with the zinc chloride could not have been produced by poppy, so that it is probably olive mixed with refined cotton. By density it would show about:—Olive-oil, 66 per cent.; cotton-oil, 33 per cent., if this conclusion be right. Next tried a standard sample of olive, and one of refined cotton, by the sulphuric acid method, and then tried the sample, when the comparative elevations in temperature showed 35 per cent. of cotton. Taking, therefore, a common-sense view of the matter, the oil was considered to be $\frac{2}{3}$ olive and $\frac{1}{3}$ cotton.

III. *A Sample of "American Marrow."*—Too fluid for genuine marrow, and of a decidedly yellow tinge. Heated, smelt distinctly of dripping, but also had a slight smell of salad-oil. Tried barium polysulphide, when the colour paled, but still remained a little. Tried zinc chloride; no green, therefore not olive or refined rape, but became slightly tinged with brown. Saponified a portion, and proved absence of ground-nut and coco-nut (the latter by getting off no volatile fatty acids). Sulphuric acid gave deep red-brown. "Actual density," 0·9093. Tried a mixture of half refined cotton-oil and half beef-marrow: "actual density," 0·9095, and gave similar appearances with reagents. Took insoluble fatty acids of original, and found 94·9; all marrow gave 95·5; refined cotton gave 94·2. Therefore concluded it to be a mixture of genuine dripping or marrow with refined cotton-oil in equal proportions. J. M.

Additional Tests.—Another, and entirely different, method of recognising the purity of the fatty oils, but which is not applicable to mineral oils, depends upon observations of the melting-points of their fatty acids. By comparison with standard samples, and mixtures of known composition, this method will often give very reliable results, especially in conjunction with some of the tests previously described. It is also frequently very desirable to determine the "actual density" of the fatty acid, since so many fatty oils occur in commerce in a state of partial rancidity, that the density of the oil itself is not unfrequently affected thereby. If, however, the whole be converted into fatty acids, more constant and reliable results are obtained.

As an example of the application of the melting-point test, the familiar case of mixtures of olive-oil and cotton-seed-oil may be taken. The fatty-acids of refined cotton-seed-oil melt at 36° (97° F.), while those of pure olive-oil are about 30° F. lower, varying between 15½° and 21° (60°–70° F.), according to whether the oil comes from the first or last portions expressed. The inference from this is obvious.

In applying this test, it is of the *utmost* importance to ensure complete saponification of the oil, and it is very desirable to precipitate the soap from its solution in water by the addition of sodium chloride, and to dissolve the soap so precipitated in a fresh portion of water before decomposing it with mineral acid. Since there are so many ways of determining melting-points, which give different results, it is undesirable to quote actual figures here, or to do more than point out the method, and the importance of each operator keeping to one mode of working, and one system of recording his observations. Dalican's method, described on p. 1477, is the one usually adopted for determining melting- and solidifying- points.

A test for the presence of coco-nut- or palm-kernel- oils, in presence of any other vegetable or animal fatty oils, depends upon the quantity of salt required to separate or precipitate their soaps from solution in a given quantity of water. It may be thus applied:—To 10 *grm.* of the pure fatty acid, is added aqueous solution of caustic soda equal to 1·25 *grm.* soda (100%), in a beaker of 100–150 *c.c.* capacity, previously tared. The whole is then boiled, and water is added until the contents of the beaker weigh 50 *grm.* at 100° (212° F.). At this point, a saturated solution of sodium chloride is run into the beaker from a burette, and the whole is stirred and boiled over a gas-flame. It will be found that while only about 8–10 *c.c.* of the solution are required with ordinary oils, coco-nut-oil will require more than 50 *c.c.*, and mixtures of the two will take proportionate amounts to separate the soap. By keeping the solution just boiling, constantly stirring, and adding the sodium chloride gradually, the exact moment of precipitation of the soap may easily be observed.

For the detection and estimation of rosin in admixture with fats and fatty oils, the determination of the sp. gr. of the fatty acids will be found a very valuable guide. The greater the proportion of rosin, the higher is the sp. gr. Since, however, some of these fatty-acid mixtures are solid at 38° (100° F.), it is desirable to adopt a higher temperature, say 60° (140° F.), as a standard at which to perform the operation. As in every other case, unknown samples presented for examination must be compared with samples of known composition.

Another process, applicable to this same problem, as well as to similar ones, consists in making an "ultimate organic analysis" of the mixture, and determining by direct combustion the proportions of carbon and hydrogen in the sample, and of oxygen by "difference." Such an operation, however, can only be conducted by a skilled chemist, and cannot be described here.

It cannot be too clearly impressed upon the would-be acquirer of information on this subject, that, in the present state of chemical knowledge, there are no decided and definite tests for each kind of oil, as there are for each kind of mineral substance, and that, in arriving at a conclusion as to the composition of any oil or mixture of oils, the analyst can only be guided by what may not inaptly be described as "circumstantial evidence," several tests indicating a balance of probabilities in one direction.

In Dalican's work, quoted in the Bibliography of this article, minute instructions are given for testing the value of tallow, oils, &c., for candle-making and soap-boiling. It is stated that this method has been adopted as a standard by the tallow-melters, brokers, and candle-manufacturers of Paris, and it is claimed for it that it gives absolutely concordant and reliable results. The following is a summary of the process.

In an enamelled basin of at least 1 *litre* capacity, 50 *grm.* of the tallow (or oil) is heated till it begins to give off vapour [about 200° (392° F.)]. While this is heating, a mixture is made of 40 *c.c.* of pure caustic soda solution at 36° B. (1·324 sp. gr.), and 30 *c.c.* of alcohol 40° Cartier or 95°–96° Gay-Lussac (sp. gr. 0·815). This mixture is added gradually to the hot tallow, the whole being well stirred, until a solid mass is formed; 1 *litre* water is added, and the whole is boiled for 45 minutes. The soap solution is then decomposed by the addition of 60 *c.c.* of sulphuric acid at 25° B. (sp. gr 1·205), and the whole is boiled until the fatty acids are perfectly limpid, and free from clots.

To perform the "titration," which consists in a very careful determination of the melting-point, a glass tube, 10–12 *c.* long and 1½–2 *c.* wide, is filled two-thirds full with the fatty acids melted at as low a temperature as possible, and the tube is suspended in a flask by a perforated cork. The bulb of a delicate thermometer, whose stem is divided into fifths of a degree C., is placed in the centre of the mass of fatty acids, the thermometer being suspended for convenience of manipulation and observation. When the fatty acids begin to crystallize, a rotary movement thrice to the right and thrice to the left, is given to the thermometer. During this operation, the thermometer falls slightly and then *rises again to a point at which it remains stationary for at least two minutes.* This is the degree which is accepted as the "titre" of the tallow, and is sometimes called the melting-point, but is really the point of solidification, of the fatty acids.

From the titration so obtained, the per-centages of stearic and oleic acid in the original tallow may be deduced from the following table, constructed synthetically by Dalican, from commercially pure stearic acid, and oleic acid perfectly freed from stearic, margaric, and other hard fatty acids. In the table, 1 per cent. is allowed for loss by water and impurities, and 4 per cent. for loss by glycerine, contained in the original tallow.

Degrees C.	Percentage of		Degrees C.	Percentage of	
	Stearic acid.	Oleic acid.		Stearic acid.	Oleic acid.
40·0°	35·15	59·85	45·5°	52·25	42·75
40·5°	36·10	58·90	46·0°	53·20	41·80
41·0°	38·00	57·00	46·5°	55·10	39·90
41·5°	38·95	56·05	47·0°	57·95	37·05
42·0°	39·90	54·10	47·5°	58·90	36·10
42·5°	42·75	52·25	48·0°	61·75	33·25
43·0°	43·70	51·30	48·5°	66·50	28·50
43·5°	44·65	50·35	49·0°	71·25	23·75
44·0°	47·50	47·50	49·5°	72·20	22·80
44·5°	49·40	45·60	50·0°	75·05	19·95
45·0°	51·30	43·70			

N.B.—The range of this table is between 104° and 122° F.

It is scarcely necessary to add that, if the origiual fat be accurately weighed, the operations carefully conducted, and the fatty acids [freed from water by exposure to at least 120° (248° F.)] be then weighed, it will be seen at once whether the original tallow contained any undue impurity or fraudulent admixture. 50 *grm.* pure tallow should give 47·5 *grm.* fatty acids.

For various other commercial tests, Dalican's book may be consulted with advantage.

A special test for linseed-oil has been described under Floorcloth (pp. 1002–3). The reader may also consult the article on Soap.

Illuminating Values.—Attempts to employ mineral oils for the production of illuminating-gas have resulted in many practical methods being devised, and beyond the application of an atmosphere of one of the petroleum-products in some forms of electric lamp, the lighter oil or "spirit" (see Paraffin) is largely used for carburetting air both in "sponge" lamps for domestic purposes, and on a more extensive scale in petroleum-producing centres, such as Pennsylvania, Rangoon, and Honolulu. Fatty oils are devoted to illuminating purposes by burning them in their liquid state in lamps provided with wicks.

The results of numerous experiments made on the illuminating-qualities of fatty oils in France are recorded in the annexed table:—

(See also Photometry.)

Name of Oil.	Locality of Production.	Duration of Combustion in a		Mean intensity for a consumption of 40 grm. and 8 hours' duration, in a lamp with	
		Night-lamp.	Lamp with 1 wick.	1 wick of 0·021 m. dia.	2 wicks of 0·039 m. dia.
Colza	N. France	36 hours	29 hours	1·04 burner	1·14 burner
Colza (fine) ..	India	40 "	26 "	0·95 "	1·06 "
Colza (trade) ..	"	4 "	11 "	0·39 "	0·83 "
Ground-nut ..	Senegal	39 "	35 "	1·05 "	1·04 "
Olive	Port Maurice ..	40 "	23 "	1·07 "	0·89 "
Sperm	N. America	27 "	29 "	1·05 "	0·01 "
Gold of pleasure	French Flanders ..	38 "	20 "	0·77 "	0·94 "
Wild rape	Black Sea	28 "	23 "	0·82 "	0·84 "
Linseed	Brittany	18 "	14 "	0·87 "	...
Whale	N. America	15 "	18 "	0·86 "	1·05 "
Gingelly	Syria	14 "	26 "	0·73 "	0·85 "
Coco-nut	Cochin China ..	55 "	41 "	1·06 "	1·18 "

Other points which have to be taken into consideration are the density, the co-efficient of expansion, and the congealing- and liquefying-temperatures of the oils. On the whole, the most suitable fatty oils for illuminating, stated in their order of merit, are colza, coco-nut, ground-nut, olive, sperm, and whale.

Petroleum and shale-oils, as compared with fatty oils, possess three advantages—cheapness, greater light for the same consumption, and lower flame and less useless divergence in small apparatus; but they are more liable to smoke when the supply of air is not properly regulated, and their manipulation requires greater care. They give an intensity of about one carcel burner for 30 grm. consumed per hour.

The comparative cost of a single light, and intensity of the luminary produced at the focus of the optical apparatus, by colza-oil and mineral oil, is thus estimated by J. N. Douglass, in his experience of lighthouse illumination, on the Trinity House System :—

	First cost.	Labour.	Annual Maintenance.	Total light per annum.	Cost of light per hour.	Cost of light per candle.
					d.	*d.*
Colza-oil	£7400	2 men	£793 15 0	1,782,504 candles	43·2	0·107
Mineral oil	£7400	2 men	£693 6 6	1,782,504 "	37·7	0·093

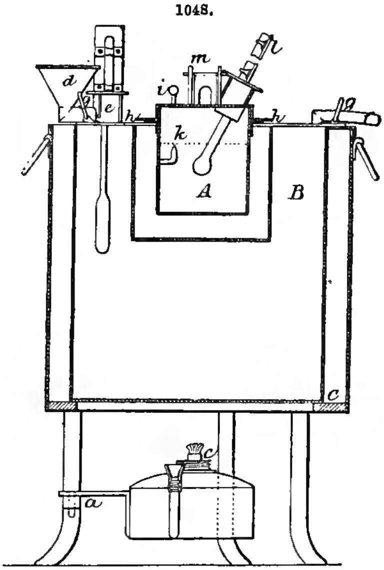
Heating Values.—Reference has been made to the utilization of creosote-oils (obtained by the distillation of coal tar) as fuel, in the article on Coal-tar Products (see p. 649). The application of bone-oil to heating purposes is described on p. 1450. All other oils, except mineral oils, possess too great a value in other ways to be economically used as fuel on anything like a commercial scale.

Of late years, great strides have been made in the direction of utilizing mineral oils, especially petroleum, as a source of heat for the generation of steam. Owen Ross deduces from a great number of analyses of petroleums that the calorific power in the lighter oils amounts to 27,000–28,000 heat units, and that 1 lb. of such fuel will suffice, when the gases are completely utilized, to evaporate 27–28 lb. of water, or nearly 4 times the effect ordinarily obtained from coal. The complete utilization of the gases is essential to secure this result, which necessitates the supply of air being slightly in excess of what is actually required for complete theoretical combustion of the hydrocarbon. It is estimated that the vapour from 1 gal. of petroleum-spirit of 0·655 sp. gr., and represented by the formula $C_{11}H_{26}$ (or 1607 lb. of carbon and 633 lb. of hydrogen in 1 ton of the spirit), will saturate nearly 263 cub. ft. of air; but it is considered inadvisable in practice to exceed such a proportion as will produce a gas burning without any deposition of carbon, so that 1 gal. of petroleum-spirit may be employed to carburet 700 cub. ft. of air. The result arrived at is the burning of all the carbon contained in the fuel to the state of carbonic acid, and all the hydrogen to water, avoiding smoke, soot, and other effects of incomplete combustion, and realizing almost the whole calorific power of the fuel. In the case of very high temperatures, petroleum fuel has a still greater advantage. It has been shown that in ordinary high-temperature furnaces using coal, the loss of heat amounts to $\frac{18}{20}$ of the total generated; this is largely due to the high temperature at which the combustion-products enter the chimney, but also to the great quantity of the products of combustion over which the caloric derived from the coal has to be distributed. This latter is reduced to little more than half in the case of petroleum-spirit. An additional advantage of great importance in most industries is the absence of sulphur from the fuel. It also permits the fire to be regulated with facility, and is especially useful when the pressure of steam is only required occasionally. The advantages of petroleum as a fuel are somewhat detracted from by the inconstant volatility of its constituents, and the danger of storing large quantities. Its range of utility will probably be confined to the neighbourhoods of its production; in England, it can hardly compete with coal in price, though much superior to it for very many purposes.

As to the best means of burning petroleum vapour, or, in other words, how best to effect the carburetting of the air and the combustion of the carburetted air, there is some difference of opinion; probably various plans will be found to suit various ends. Siemens' regenerative furnace and Eames' (American) furnace are well spoken of for employing the fuel in smelting operations. For steam purposes, perfect success has attended the adoption of the simple plan of conveying petroleum (or petroleum residues) by one pipe and steam by another to the mouth of the furnace, and blowing the petroleum into the furnace in a spray by means of the jet of steam.

Lubricating Values.—An efficient lubricator must exhibit the following characteristics:—(1) Sufficient "body" to keep the surfaces between which it is interposed from coming into contact; (2) the greatest fluidity consistent with (1); (3) a minimum co-efficient of friction; (4) a maximum capacity for receiving and distributing heat; (5) freedom from tendency to "gum" or oxidize; (6) absence of acid and other properties injurious to the materials in contact with it; (7) high vaporization- and decomposition-temperatures, and low solidification-temperature; (8) special adaptation to the conditions of use; (9) freedom from all foreign matters. The modern methods of testing the lubricating qualities of oils are directed to a discovery of the following points:—(1) Their identification and adulteration; (2) density; (3) viscosity; (4) "gumming"; (5) decomposition-, vaporization-, and ignition-temperatures; (6) acidity; (7) co-efficient of friction. The 1st and 2nd stages are described under Detection and Analysis, p. 1462. The viscosity and gumming tendency may be simultaneously detected by noting the time required by a drop to traverse a known distance on an inclined plane. A nine days' trial gave the following result:—Common sperm-oil, 5 ft. 8 in. on the 9th day; olive-oil, 1 ft. 9½ in. on the 9th day; rape-oil, 1 ft. 7¾ in. on the 8th day; best sperm-oil, 4 ft. 6⅓ in. on the 7th day; linseed-oil, 1 ft. 6¼ in. on the 7th day; lard-oil, 11¾ in. on the 5th day. The day given is in each case that on which the oil ceased to travel. There are several ways of applying the plane test. A very simple and general test of fluidity is to dip blotting-paper in the oil, and hold it up to drain: symmetrical drops indicate good fluidity; a spreading tendency, viscosity. Retention of the oil on the paper for some hours at 93⅓° (200° F.), or for some days at ordinary temperatures, will show the rate of gumming.

1048.



Fire-testing is specially applicable to mineral oils. There are several forms of tester, as Tagliabue's, Millspaugh's, Abel's, Saybolt's, Parrish's, Salleron-Urbain's, Sintenis', Bernstein's, and Bailey's. The apparatus consists essentially of a receptacle for the oil to be tested, a water-bath surrounding the receptacle, a lamp for heating the water-bath, a thermometer to indicate the temperatures, an outlet for the vapour generated from the oil, and a means of reaching the oil itself.

The form of tester recognized in this country under the Petroleum Act, 1879, is shown in Fig. 1048. The oil-cup A consists of a cylindrical vessel of 2 in. diameter and $2\frac{2}{10}$ in. internal height, with an outward projecting rim *h* $\frac{6}{10}$ in. wide, ⅜ in. from the top, and 1⅞ in. from the bottom of the cup. It is made of gun-metal or brass tinned inside. A bracket *k*, consisting of a short stout piece of wire bent upwards and terminating in a point, is fixed to the inside of the cup to serve as a gauge. The distance of the point from the bottom of the cup is 1½ in. The cup is provided with a close-fitting overlapping cover made of brass, which carries the thermometer *l* and test-lamp *m*. The latter is suspended from two supports at the side by means of trunnions on which it oscillates, and is provided with a spout, whose mouth is $\frac{1}{10}$ in. in diameter. The socket to hold the thermometer is fixed at such an angle, and its length is so adjusted, that the bulb of the thermometer when inserted to its full depth shall be 1½ in. below the centre of the lid.

The cover is provided with three square holes, one in the centre, $\frac{8}{10}$ in. by $\frac{4}{10}$ in., and two smaller ones, $\frac{3}{10}$ in. by $\frac{2}{10}$ in., close to the sides and opposite each other. These three holes may be closed and uncovered by means of a slide moving in grooves, and having perforations corresponding to those on the lid. In moving the slide so as to uncover the holes, the oscillating lamp is caught by a pin fixed in the slide, and tilted in such a way as to bring the end of the spout just below the surface of the lid. Upon the slide being pushed back so as to cover the holes, the lamp returns to its original position. Upon the cover, in front of and in line with the mouth of the lamp, is fixed a white bead *i*, the dimensions of which represent the size of the test-flame to be used.

The bath or heated vessel B consists of two flat-bottomed copper cylinders, an inner one of 3 in. diameter and $2\frac{1}{2}$ in. height, and an outer one of $5\frac{1}{2}$ in. diameter and $5\frac{3}{4}$ in. height; they are soldered to a circular copper plate C, perforated in the centre, which forms the top of the bath, in such a manner as to enclose the space between the two cylinders, but leaving access to the inner cylinder. The top of the bath projects both outwards and inwards about $\frac{3}{8}$ in.; that is, its diameter is about $\frac{3}{8}$ in. greater than that of the body of the bath, while the diameter of the circular opening in the centre is about the same amount less than that of the inner copper cylinder. To the inner projection of the top, is fastened, by six small screws, a flat ring of ebonite, the screws being sunk below the surface of the ebonite, to avoid metallic contact between the bath and the oil-cup. The exact distance between the sides and bottom of the bath and of the oil-lamp is $\frac{1}{2}$ in. A split socket similar to that on the cover of the oil-cup, but set at a right angle, allows a thermometer *e* to be inserted into the space between the two cylinders. The bath is further provided with a funnel *d*, an overflow pipe *f*, and two loop handles *g*.

The bath rests upon a cast-iron tripod stand, to the ring of which, is attached a copper cylinder or jacket, flanged at the top, and of such dimensions that the bath, while firmly resting on the iron ring, just touches with its projecting top the inward-turned flange. The diameter of this outer jacket is $6\frac{1}{2}$ in. One of the three legs of the stand serves as support for the spirit-lamp attached to it by means of a small swing-bracket *a*. The distance of the wick-holder *c* from the bottom of the bath is 1 in.

Two thermometers go with the apparatus, one for ascertaining the temperature of the bath, the other for determining the flashing-point. The former has a long bulb and a space at the top. Its range is from about 32° to 88° (90°–190° F.) It is furnished with a metallic collar, fitting the socket, and the part of the tube below the scale should have a length of about $3\frac{1}{2}$ in. measured from the lower end of the scale to the end of the bulb. The thermometer for ascertaining the temperature of the oil is similarly fitted with collar and ivory scale; it has a round bulb, a space at the top, and ranges from about 13° to 66° (55°–150° F.); it measures from end of ivory back to bulb $2\frac{1}{4}$ in.

The test is applied in the following manner:—The apparatus is placed where it is not exposed to draughts. The water-bath is filled by pouring water into the funnel *d* until it begins to flow out at the spout of the vessel. The temperature of the water at the commencement of the test is to be $54\frac{1}{2}$° (130° F.), attained in the first instance either by mixing hot and cold water in the bath, or in a vessel from which the bath is filled, until the thermometer which is provided for testing the temperature of the water gives the proper indication; or by heating the water with the spirit-lamp (which is attached to the stand of the apparatus) until the required temperature is indicated.

When a test has been completed, this water-bath is again raised to 130° F. by placing the lamp underneath, and is readily achieved while the petroleum-cup is being emptied, cooled, and refilled with a fresh sample to be tested. The lamp is then turned on its swivel from under the apparatus, and the next test is proceeded with.

The test-lamp is prepared for use by fitting it with a piece of flat plaited candle-wick, and filling it with colza- or rape-oil up to the lower edge of the opening of the wick-tube. The lamp is trimmed so that, when lighted, it gives a flame of about 0·15 in. diameter, and this size of flame, which is represented by the projecting white bead *i* on the cover of the oil-cup, is readily maintained by simple manipulation from time to time with a small wire trimmer.

When gas is available, it may be conveniently used in place of the little oil-lamp, and for this purpose, a test-flame arrangement for use with gas may be substituted for the lamp.

The bath having been raised to the proper temperature, the oil to be tested is introduced into the petroleum-cup, being poured in slowly until the level of the liquid just reaches the point of the gauge which is fixed in the cup. In warm weather, the temperature of the room in which the samples to be tested have been kept should be observed in the first instance, and if it exceeds 65° F., the samples should be cooled down to about 60° F., by immersing the bottles containing them in cold water, or by any other convenient method. The lid of the cup, with the slide closed, is then put on, and the cup is placed in the bath. The thermometer in the lid of the cup has been adjusted so as to have its bulb just immersed in the liquid, and its position is not under any circumstances to be altered. When the cup has been placed in the proper position, the scale of the thermometer faces the operator.

The test-lamp is then placed in position upon the lid of the cup, the lead-line or pendulum, which has been fixed in a convenient position in front of the operator, is set in motion, and the rise of the thermometer in the petroleum-cup is watched. When the temperature has reached about 66° F., the operation of testing is to be commenced, the test-flame being applied once for every rise of one degree, in the following manner:—The slide is slowly drawn open while the pendulum performs three oscillations, and is closed during the fourth oscillation.

If it is desired to employ the test apparatus to determine the flashing-points of oils of very low volatility, the mode of proceeding is to be modified as follows:—The air chamber which surrounds the cup is filled with cold water, to a depth of 1½ in., and the water-bath is filled as usual, but also with cold water. The lamp is then placed under the apparatus, and kept there during the entire operation. If a very heavy oil is being dealt with, the operation may be commenced with water previously heated to 120° F., instead of with cold water.

The Schedule omits to state that the length of the pendulum to be used shall be 2 ft. from the point of suspension to the centre of gravity of the weight.

The "flashing-point" of an oil is understood to mean the temperature at which the escaping vapour will momentarily ignite; the "burning-point" is that at which the oil takes fire and burns. Lubricating-oils should always flash above 120° (250° F.), and take fire at a considerably higher temperature. Animal and vegetable oils do not vapourize, but decompose at high temperatures, beyond the range of a water-bath. A comparison of petroleum, sperm-oil, and lard-oil showed the following respective figures:—Flashing-point: 118° (245° F.), 219° (425° F.), 246° (475° F.); igniting-point: 143° (290° F.), 252° (485° F.), 274° (525° F.); burning-point: 149° (300° F.), 260° (500° F.), 274° (525° F.) The standard animal and vegetable lubricating-oils, and all mineral oils of good body and high sp. gr., decompose or vapourize only at temperatures exceeding that of steam in ordinary engines, the former usually and latter sometimes bearing steam at locomotive pressure. As to congealing-points, these have been mostly given in the case of each oil in the preceding pages. Under Ice, pp. 1134–5, will be found a number of freezing-mixtures useful for testing such points. The precise value of any lubricating material is best ascertained by one of the many forms of apparatus devised for this purpose, such as McNaught's, Napier's, Ingham and Stapper's, Bailey's, Ashcroft's, Crossley's, Van Cleve's, Hodgson's, &c., fully described and figured in Thurston's work quoted at the end of this article.

The suitability of a lubricating medium depends upon the character of the work being done, and is not constant. In order to procure the nearest possible approach to what is required for special purposes, many compounds are now in the market, being mainly mixtures of mineral and animal or vegetable oils in proportions calculated to develop the particular characteristics required. The general experience gained of various oils used for lubricating tends to the following results:—(1) A mineral oil flashing below 149° (300° F.) is unsafe, on account of causing fire; (2) a mineral oil evaporating more than 5 per cent. in 10 hours at 60° (140° F.) is inadmissible, as the evaporation creates a viscous residue, or leaves the bearing dry; (3) the most fluid oil that will remain in its place, fulfilling other conditions, is the best for all light bearings at high speeds; (4) the best oil is that which has the greatest adhesion to metallic surfaces, and the least cohesion in its own particles: in this respect, fine mineral oils are 1st, sperm-oil 2nd, neatsfoot-oil 3rd, lard-oil 4th; (5) consequently the finest mineral oils are best for light bearings and high velocities; (6) the best animal oil to give body to fine mineral oils is sperm-oil; (7) lard- and neatsfoot-oils may replace sperm-oil when greater tenacity is required; (8) the best mineral oil for cylinders is one having sp. gr. 0·893 at 15½° (60° F.), evaporating-point 288° (550° F.), and flashing-point 360° (680° F.); (9) the best mineral oil for heavy machinery has sp. gr. 0·880 at 15½° (60° F.), evaporating-point 229° (443° F.), and flashing-point 269° (518° F.); (10) the best mineral oil for light bearings and high velocities has sp. gr. 0·871 at 15½° (60° F.), evaporating-point 218° (424° F.), and flashing-point 262° (505° F.); (11) mineral oils alone are not suited for the heaviest machinery, on account of want of body, and higher degree of inflammability; (12) well purified animal oils are applicable to very heavy machinery; (13) olive-oil is foremost among vegetable oils, as it can be purified without the aid of mineral acids; (14) the other vegetable oils admissible, but far inferior, stated in their order of merit, are gingelly-, ground-nut-, colza-, and cotton-seed-oils; (15) no oil is admissible which has been purified by means of mineral acids.

The results of W. H. Watson's experiments upon the corrosive action of various oils on copper and iron surfaces are worthy of reproduction here. After 10 days' exposure of copper to the action of the several oils named below, the effects were evidenced by the following quantities of copper held by them:—Linseed-oil, 0·3000 gr.; olive-oil, 0·2200 gr.; neats'-foot-oil, 0·1100 gr.; almond-oil, 0·1030 gr.; seal-oil, 0·0485 gr.; colza-oil, 0·0170 gr.; sperm-oil, 0·0030 gr.; paraffin, 0·0015 gr. Iron subjected to similar treatment for 24 days was affected to the following extent:—Neats'-foot-oil, 0·0875 gr.; colza-oil, 0·0800 gr.; sperm-oil, 0·0460 gr.; lard-oil, 0·0250 gr.; olive-oil, 0·0062 gr.; linseed-oil, 0·0050 gr.; seal-oil, 0·0050 gr.; castor-oil, 0·0048 gr.; paraffin, 0·0045 gr.; almond-oil, 0·0040 gr.; special lubricating-oil, 0·0018 gr. These results show that the extent of the action of any oil on one metal is no guide to the degree in which it will affect another metal.

Boiling, Oxidizing, and Vulcanizing.—Certain oils (as shown by the table on p. 1467), possess a much greater "drying" tendency than others, that is to say, on exposure to the air, they absorb oxygen, lose their greasiness, and ultimately become dry and hard. This property is availed of in the manufacture of linoleum (see p. 1001), of printing-ink (see p. 1170), of paints (see Paint), of oil-varnishes (see Varnish), &c. The oxidizing tendency is much increased by three separate processes:—(1) By exposure to the air in very thin layers, as detailed under Floorcloth, p. 1002; (2) by heating, or, as it is improperly termed, "boiling," which has been noticed under Ink, p. 1171, and will receive further attention here; and (3) by the addition of "driers" while hot.

The "boiling" process described on p. 1171, is still widely adhered to by printing-ink makers, and is declared to be indispensable for the manufacture of lithographic ink. A great improvement consists in the substitution of a steam-jacket for an open fire, and the blowing-in of air. The pan is best of copper, circular in shape, with an equal depth and diameter, and a rounded bottom. It is surrounded with an iron steam-jacket for about half its depth. Both pan and jacket are made to withstand a pressure of 40 lb. a sq. in. The top of the pan is closed by a dome rivetted to it, provided with a man-hole and a stuffing-box, the latter for admitting the shafts of a couple of fans, made to rotate in opposite directions, and intersecting each other. From a cupola on the dome, issues a 3-in. pipe for conveying away the vapours, to be treated as described under Floorcloth, p. 1004. The lower part of the pan is fitted with a 1-in. pipe, for introducing air under pressure through the jacket and into the pan. The oil (linseed) is run from a tank holding one batch for boiling (about 2 tons), when it has settled during 4–5 hours. The waste steam from the jacket passes through a coil of 1½-in. iron pipe in this tank, thus warming the oil somewhat, and tending to cause a separation of impurities. The oil runs at a temperature of about 35° (95° F.) into the pan, when steam is admitted to the jacket, and the fans are started. When the steam in the jacket reaches a pressure of 35 lb. a sq. in., the air-blast may be admitted. The heat and blast are maintained for about 4 hours; the pressure of steam in the jacket must never be allowed to descend below 30–35 lb. a sq. in., while the admission of air is not gauged, but is kept up as long as the oil does not froth over into the condenser. The oil is run out by a 2-in. tap in the centre of the bottom, joined to pipes connected by running joints, the same tap being used for the admission of the air, and a second tap being provided beyond.

When driers are used, as they almost always are, the oil drawn from the pan is allowed to rest for some time, so that the major part of the driers may settle out, and may be available for re-use. The action of the driers is various. Sulphate of zinc simply facilitates the separation of the vegetable albumen and mucilage present in the oil, and which impair its drying; other substances, such as peroxide of manganese, peroxide of iron (umber), protoxide of lead (litharge), and other lead salts, either impart oxygen to the oil, or, dissolving in the oil, and being themselves oxidizable in combination, operate catalytically in increasing its oxygen-absorbing power. The recipes for the composition of the driers are kept secret; but when using the steam process, the admixture of catalytic substances and litharge may be varied to produce any desired degree of colour, without affecting the drying, the shade deepening with the increase of the lead salt. The driers used must be of exceeding fineness, such as is only obtainable by running them with water through a series of settling-tanks.

It has been stated by C. W. Vincent, before the Society of Arts, that the air does nothing towards making the oil "drying." Linseed-oil heated for 3 days consecutively at a high temperature, in presence of the air, but without driers, required the same time to dry as the raw oil from which it was prepared, but the "body" was much increased. Heating alone for the same time with only surface exposure to air, produced no such increase of body; the oil became more greasy, less penetrative, and less drying.

In sending boiled oil on long journies, it is advisable always to add a proportion of raw oil, to avoid the risk of its becoming "fatty," and not free enough in working; for a 3-months' journey, and boiled oil less than 1 month old, the proportion of raw oil may be 25 per cent.

Dr. Domingos Freire has recently stated that the oxidation of oils is not due alone to the action of oxygen, but also to a fungus, which he names *Microclados olecrum*, a microphyte which cannot develop in oils containing phenol (carbolic acid), arsenious acid, or copper sulphate.

Some remarks on the vulcanizing of oils will be found under the heading of Indiarubber Manufactures, pp. 1161–2. A substance possessing many of the characteristics of indiarubber is made by mixing flowers of sulphur with hot linseed-oil. The oil is said to be heated in an iron pot over a fire to about 232° (450° F.) and is then removed, and placed under a hood for conveying vapours to the chimney. When the oil has cooled to about 176½° (350° F.), the sulphur is thrown in. The odours emitted are most offensive, and need every precaution for their rendering innocuous. The product is used as an adulterant of or substitute for indiarubber.

Imports of Oils.—The imports of the various oils into the United Kingdom in 1879 were as follows:—

Train-oil or blubber: from British N. America, 10,059 tuns, value 268,068*l.*; United States, 3244 tuns, 75,350*l.*; N. whale fisheries, 1717 tuns, 40,746*l.*; Norway, 1303 tuns, 36,025*l.*; Spain, 449 tuns, 11,552*l.*; other countries, 1177 tuns, 30,073*l.*; total, 17,949 tuns, 461,814*l.*

Spermaceti or head-matter: from the United States, 1527 tuns, 85,793*l.*; Australia, 351 tuns, 20,341*l.*; Chili, 96 tuns, 5816*l.*; other countries, 273 tuns, 15,540*l.*; total, 2247 tuns, 127,490*l.*

Animal oils: from the United States, 94,449 cwt., 166,492*l.*; France, 4919 cwt., 10,479*l.*; other countries, 7781 cwt., 11,134*l.*; total, 107,149 cwt., 188,105*l.*

Palm-oil: (foreign) from W. coast Africa not particularly designated, 657,142 cwt., 996,294*l.*; Fernando Po, 6460 cwt., 10,310*l.*; Portuguese possessions, 3544 cwt., 5475*l.*; Gold Coast, 202,151 cwt., 310,301*l.*; British W. Africa, 5835 cwt., 8894*l.*; other countries, 6197 cwt., 13,514*l.*; total, 881,329 cwt., 1,344,788*l.*

Castor-oil: from the British E. Indies, 105,854 cwt., 204,845*l.*; other countries, 2392 cwt., 5363*l.*; total, 108,246 cwt., 210,208*l.*

Coco-nut-oil: from Ceylon, 111,318 cwt., 216,358*l.*; Madras, 59,479 cwt., 122,460*l.*; Mauritius, 12,252 cwt., 23,323*l.*; Bombay, 9134 cwt., 20,342*l.*; other countries (including "Sydney" and "Cochin"), 7808 cwt., 15,582*l.*; total, 199,991 cwt., 398,065*l.*

Olive-oil; from Italy, 16,474 tuns, 763,450*l.*; Turkey, 4681 tuns, 198,253*l.*; Greece, 3376 tuns, 141,484*l.*; Spain, 411 tuns, 18,559*l.*; France, 331 tuns, 17,127*l.*; Egypt, 302 tuns, 12,782*l.*; other countries, 623 tuns, 27,366*l.*; total, 26,198 tuns, 1,179,021*l.*

Seed-oils of all kinds: from Germany, 10,641 tuns, 334,909*l.*; France, 1892 tuns, 71,079*l.*; United States, 1257 tuns, 35,194*l.*; Holland, 1071 tuns, 35,749*l.*; Belgium, 626 tuns, 19,000*l.*; other countries, 378 tuns, 13,044*l.*; total, 15,865 tuns, 508,975*l.*

Chemical, essential, or perfumed oils: from Italy, 203,881 lb., 62,536*l.*; France, 108,399 lb., 35,522*l.*; United States, 82,544 lb., 37,522*l.*; China, 62,711 lb., 16,534*l.*; British E. Indies, 59,207 lb., 13,782*l.*; Germany, 27,667 lb., 11,788*l.*; Turkey, 1366 lb., 9842*l.*; other countries, 17,028 lb., 7014*l.*; total, 562,803 lb., 194,540*l.*

Unenumerated oils: from France, 21,481*l.*; United States, 18,976*l.*; Australia, 16,350*l.*; Belgium, 12,021*l.*; other countries, 15,162*l.*; total, 83,990*l.*

Petroleum—unrefined: from the United States, 1765 tuns, 13,101*l.*; other countries, 128 tuns, 440*l.*; total, 1893 tuns, 13,541*l.* Refined: from the United States, 42,478,427 gal., 1,349,616*l.*; other countries, 324,828 gal., 19,377*l.*; total, 42,803,255 gal., 1,368,993*l.*

Prices of Oils.—The approximate London market values of the principal oils and fats of commerce are as follows:—Tallow: St. Petersburg Y.C., new, 37–45*s.* a cwt., old, 35–43*s.*; Australian beef, 35*s.* 6*d.*–37*s.*; sheep, 38*s.*–39*s.* 6*d.*; South American sheep, 36–42*s.*, beef, 39*s.* 6*d.*–42*s.*; North American, 35–40*s.*; British rough fat, 1*s.* 6*d.*–1*s.* 7*d.* a stone, town fat, 38*s.* 3*d.* a cwt., melted stuff, 27*s.* 6*d.* a cwt., rough melted stuff, 14*s.* a cwt. Spermaceti: refined, 1*s.* 3*d.*–1*s.* 4*d.* a lb.; American 1*s.*–1*s.* 2*d.* Seed-oil: pale, 29–30*l.* a tun; yellow to tinged, 25*l.*–29*l.* 10*s.*; brown, 24–26*l.* Sperm-oil: 60–68*l.* a tun. Cod-oil, 27*l.* 10*s.*–29*l.* a tun. Whale-oil: pale, 26–29*l.* a tun; yellow, 25–28*l.*; brown, 20–26*l.* Cod-liver oil, 2*s.* 9*d.*–5*s.* a gal. Lard-oil, 38–44*l.* a tun. Tallow-oil, 31–35*l.* a tun. Castor-oil: E. Indian, 4½–5¼*d.* a lb.; inferior, 4¼–4⅝*d.* Olive: Gioja, 43*l.* a tun; Levant, 45–46*l.*; Spanish, 46–49*l.*; Sicily, 46*l.*-46*l.* 10*s.* Coco-nut-oil: Cochin, 39–50*l.* a tun; Ceylon, 36*l.* 15*s.*–47*l.*; Mauritius, 37*l.* 10*s.*–46*l.* Palm-oil: fine Lagos, 36*l.* 10*s.*–37*l.* a tun; palm-kernel oil, 36–38*l.* Linseed-oil, 24*l.* 2*s.* 6*d.*–28*l.* 10*s.* a tun. Rapeseed-oil: English pale, 31*l.* 15*s.*–32*l.* a tun; brown, 29*l.* 15*s.*–30*l.* Cotton-seed-oil: refined, 26–30*l.* a tun. Almond-oil: essential, 20-30*s.* a lb.; expressed, 1*s.* 10*d.*–2*s.* Aniseed-oil, essential, 9–11*s.* a lb. Cajuput-oil: essential, 3*s.* 6*d.*–4*s.* 6*d.* a bottle. Caraway-oil: essential, 2*s.* 6*d.*–6*s.* a lb. Cassia-oil: essential, 2*s.* 8*d.*–4*s.* 8*d.* a lb. Cinnamon-oil: essential, 2*s.* 2*d.*–5*s.* 6*d.* an oz.; leaf, 1½–1⅝*d.* Citronella-oil: essential, 3–5½*d.* an oz. Clove-oil: essential, 8*s.* 9*d.*-9*s.* a lb. Croton-oil, 2½-2¾*d.* an oz. Ginger-grass-oil: essential, 2½–3½*d.* an oz. Lavender-oil: essential, 7*s.* 6*d.* a lb. Lemon-oil: essential, 3*s.*–5*s.* 6*d.* a lb. Lemon-grass-oil: essential, 2¾–4½*d.* an oz. Mace-oil: expressed, 6–7*d.* an oz. Neroli-oil: essential, 6–9*s.* an oz. Nutmeg-oil: essential, 2¼–4*d.* an oz. Orange-oil: essential, 5–7*s.* a lb. Otto of rose, 15–35*s.* an oz. Patchouli, 1*s.* 6*d.*–3*s.* an oz. Peppermint-oil: essential, American fine, 10*s.*–15*s.* 6*d.* a lb.; English, 21–23*s.* Pimento: essential, 12*s.* 6*d.* a lb. Rosemary-oil: essential, 3*s.* 6*d.* a lb. Sassafras-oil: essential, 1*s.* 9*d.*–3*s.* 9*d.* Spearmint-oil: essential, 13*s.* 6*d.* a lb. Thyme-oil: essential, 5*s.* a lb.

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(See Bones; Candles; Coal-tar Products; Drugs; Floorcloth; Ink; Nuts; Paraffin; Perfumes; Photometry; Pigments and Paint; Resinous Substances; Soap; Varnish; Wax).

PAPER (Fr., *Papier*; Ger., *Papier*).

The manufacture of paper may be conveniently divided into two main sections:—(1) the materials which are or may be employed for the purpose; and (2) the methods by which those materials are converted into paper and finished for the market.

The Raw Materials.—In former days, paper was manufactured exclusively from rags, either linen or cotton; but the increased demand for it, for printing and other purposes, has made it absolutely necessary that some more abundant source should be found. Paper is composed chiefly of cellulose, in a more or less purified state, and as this forms the basis or groundwork of all vegetable life, it is obvious that the supply of raw materials is practically unlimited. But as cellulose in nature is found intimately associated with colouring and incrusting matters, the removal of which involves the use of comparatively expensive chemicals, the paper-manufacturer, in fixing his choice on a raw material, must take into consideration not only its first cost, but also the amount and character of such combined substances, and the comparative ease or difficulty with which they can be removed, in order to secure the cellulose in a pure state.

The following list contains the more important materials actually in use for manufacturing paper:—Rags, linen and cotton; flax; hemp; esparto or alfa; woods of various kinds; straw; old ropes; jute; old sacking; manilla hemp; canes and bamboo; and *Adansonia* fibre. To these, might be added an almost innumerable list of other substances which are used to a very limited extent. The production and commerce, and in many cases the structure, of the vegetable fibres, will be found described at length in the article on Fibrous Substances, pp. 909–1000. In this article, attention will be confined to the paper-making qualities of the chief materials.

Rags.—Though, strictly speaking, not raw material, the substance of the rags having undergone a purifying treatment before being manufactured, they may conveniently be classed as such here. Rags may be obtained in an almost endless variety, differing according to the locality in which they are gathered. They are generally sent to the paper-maker packed in bales, having been to a certain extent sorted. For trade purposes, rags are divided into a large number of classes or grades, distinguished by various letters. When rags are stored in large quantities, care should be taken that they are perfectly dry, as, if at all damp, they are liable to fire, from the heat developed by slow decomposition. Nearly all the incrusting and colouring matters having been removed from the cotton or flax from which the rags are made, in the textile manufacturing processes, it follows that they consist of tolerably pure cellulose, and therefore yield a large percentage of fibre. This, together with the fact that they are readily bleached to a very pure white, the resulting fibre being exceedingly strong, renders them a most valuable material. Alone, they are used for only the finest qualities of paper, but they are often mixed with inferior fibres to give strength.

Flax.—Raw flax being in great demand for textile purposes, cannot be economically manufactured directly into paper. Such portions, however, as are rejected by the spinner can thus be made use of. (See Fibrous Substances, pp. 964–978; Linen Manufactures, pp. 1246–1255).

Hemp.—Hemp is generally used only in the form of old ropes, &c. (See Fibrous Substances, pp. 934–8; Rope.)

Esparto.—This grass is perhaps, next to rags, the most important material used by paper-makers in this country. The consumption has steadily increased since it was first introduced by Routledge in 1856. Various qualities of esparto are known, the best of which is imported from Spain. Slightly inferior qualities are brought from various districts in N. Africa. (See Fibrous Substances, pp. 978–981.) The amount of fibre in esparto varies according to the locality in which it is grown, Spanish yielding more than any other kind. According to Dr. Hugo Müller, Spanish esparto contains 49·52–50·19 per cent. of cellulose, and African, 47·55–50·16 per cent. This, of course, does not represent the amount of fibre actually obtainable by the manufacturer, a considerable loss occurring during the various processes to which it is subjected. The yield of bleached fibre obtained in practice probably does not much exceed 40 per cent.

Wood.—Two varieties of pulp suitable for paper manufacture may be obtained from wood, viz. mechanically and chemically prepared pulps. Almost any kind of wood may be used, those being chosen which most readily yield a pulp by suitable treatment. Hitherto wood-pulp has not been very largely employed by paper-makers in this country, chiefly because there has been a plentiful supply of other material; but in America and on the Continent, large quantities are consumed every year. What is used here comes principally from Sweden and Norway, and may be obtained either bleached or unbleached. When properly prepared, wood-pulp is a very valuable material, and may be used either alone or mixed with other fibres in papers of good quality. The amount of cellulose differs in various woods, running from 39·47 (oak) to 56·99 (fir).

Straw.—As a material for mixing with other fibres, straw-pulp is in great demand. For this purpose, it is valuable; but if used alone, only very inferior paper can be made from it. Though straw does not yield a very large amount of fibre, yet the supply of it is in most districts pretty considerable and constant. The varieties generally used are oat, wheat, rye, and barley; of these, rye is considered the most suitable, on account of its yielding the largest amount of fibre; next in importance comes wheat. The amount of actual cellulose in straw is comparatively large (say 49·00), but probably not more than 35 per cent. is actually obtained as pulp, the reason being that a large portion of the cellulose is in the state of loosely aggregated cellular tissue, and that much of this is lost in the treatment.

Jute.—Fibre from jute possesses properties that would render it extremely valuable as a paper-making material, if means could be devised whereby it could be economically bleached to a good white, at the same time preserving the strength of the fibre. Hitherto, this has not been accomplished, hence jute has received only a limited application, having been used chiefly for papers in which a great degree of whiteness is not essential. Jute is usually obtained in the form of "butts" or "cuttings," these being the portions (root-ends, &c.) rejected by the textile manufacturer. (See Fibrous Substances, pp. 940–5; Jute Manufactures, pp. 1176–1186).

Bamboo and Cane.—Much attention has been given of late years to the bamboo (see Fibrous Substances, pp. 920–1) as a probable source of paper-making material. It has been made the subject of a series of very carefully-conducted experiments by Thos. Routledge, and is highly recommended by him. Before the subject was taken up by him, many attempts had been made to obtain pulp from the bamboo, but they were economically unsuccessful, as the large amount of silica present rendered it necessary to act upon it with very strong solutions of caustic soda, at high pressure (150–160 lb. a sq. in.). The difficulties of such a treatment are well-nigh insurmountable. In all these trials, it was the well-developed and matured plant that was used. If, instead of this, the young and succulent shoots are taken, before the plant has had time to develop much woody substance or silicious covering, the case is materially altered. These shoots are very easily reduced to a suitable paper-making material, by simple digestion in comparatively weak solutions of alkali, at the ordinary atmospheric pressure. Before this treatment, however, Routledge proposes to free the plant from a large quantity of sap and juice by crushing between fluted rollers: this considerably facilitates the subsequent boiling operation. Owing to the fact that the young green shoots contain about 75 per cent. of moisture, and that the remainder yields only 60 per cent. of fibre, it would be necessary to partially prepare the fibre at or near the spot where the bamboo is cultivated. The quality of the pulp produced is excellent. The bamboo grows with enormous rapidity, sometimes at the rate of even 1 ft. in a single night, and according to Routledge, if the cutting of the shoots be attended to carefully, the plant will continue year after year to throw out fresh ones. The variety to which attention has hitherto been directed is *Bambusa vulgaris*; there are, however, other members of the same family which would perhaps be equally suitable. There appears not the slightest doubt, that if Routledge's conclusions are correct, we have here an almost boundless and very valuable source of material. Unfortunately, the opinions of experienced men differ somewhat on the question; but notwithstanding this, the subject is one that deserves very careful attention, as it is becoming obvious that in the future, perhaps the near future, the supply of esparto, to which the paper-makers of this country now look for the largest proportion of their raw material, will be considerably smaller than at present, and may in fact ultimately cease altogether. That it is steadily diminishing, is evident, and this, together with the fact that it takes about 14 years to raise from seed, if indeed it could be conveniently done at all, renders it absolutely necessary that manufacturers should devote more attention to probable new sources of material.

In America, a considerable quantity of paper is annually made from pulp prepared from cane (*Arundinaria macrosperba*). It grows profusely in the lowlands of the Mississippi, and along the rivers of N. and S. Carolina, and, labour being cheap in those districts, it can be very economically gathered. The fibre, which is sold to the paper-maker in the form of half-stuff, is obtained by a very curious process. The cane, cut into pieces, is tightly packed into strong cast-iron cylinders, called "guns," about 22 ft. long and 1 ft. in diameter, fitted with strong ends, and provided with a very strong dome for containing steam. Steam is sent into these cylinders until a pressure of about 180 lb. a sq. in. is indicated; this is kept up for about 15 minutes; the end of the cylinder is then suddenly opened, and the whole mass of cane is forced violently out against a target provided in case of accident. While in the gun, the pores of the cane are filled with the highly compressed steam, which, on reaching the outer air, expands rapidly, with a loud report, like that of a cannon, with the effect of thoroughly disintegrating the cane, and reducing it to a fibrous state. It appears that the effect is due partly to chemical and partly to mechanical action. The fibre thus produced is well washed, and beaten under revolving rolls fitted with knives, similar to those used in the beating-engines of paper-mills.

Waste paper.—A very important source of material is waste paper, large quantities of which are remanufactured. Any kind of old paper can thus be utilized, and as it has already undergone the necessary treatment, very little more is required to prepare it. It generally goes by the names of "broke" or "imperfections."

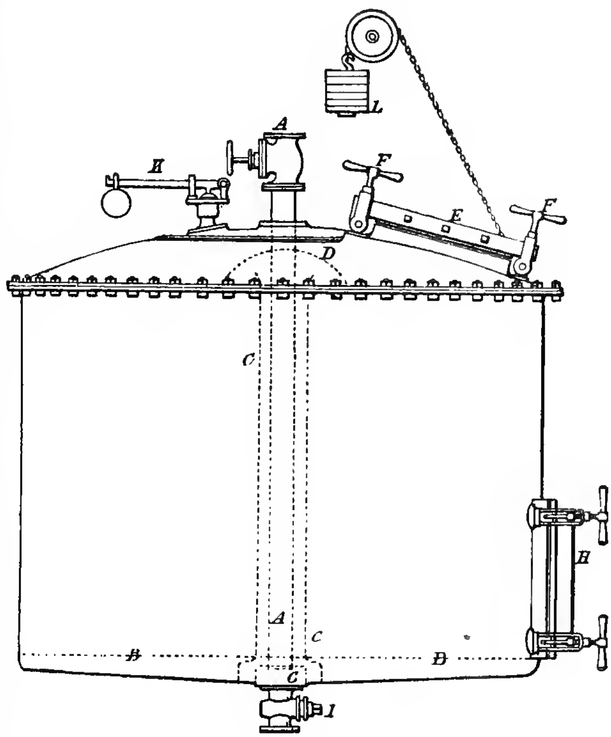
MANUFACTURE.—*Treatment of Esparto.*—As by far the largest proportion of the paper manufactured in Great Britain is made, if not entirely, at least largely, of esparto, and as the processes to which this fibre is subjected are typical of the treatment which other fibres undergo, with such exceptions as will be pointed out in their proper place, the methods in general use for the preparation of this important material will fitly occupy the foremost place.

The first process is the removal of accidental impurities, such as pieces of weed, root-ends, &c., which, from their nature, are with great difficulty boiled and bleached, and would not only therefore tend to deepen the colour of the bulk of fibre produced, but would be liable to appear subsequently in the finished paper as dark-coloured specks, technically known as "sheave." This treatment, which is called "dry-picking," in contradistinction to a subsequent process, known as "wet-picking," is generally performed by girls, who work at separate tables placed in a long row. A portion of the table set apart to each girl is covered with a very coarse iron-wire gauze, on which small bunches at a time of esparto are spread, to enable the worker more readily to see the imperfections, and through which small impurities, such as sand, pass away. It has been proposed to economize time and labour by using a machine for the purpose of dry-picking. One of the best machines of the kind is that made by Masson and Scott. In it, the grass is first put through a conical willow, where all the dust is removed by a blast, and carried away into a separate chamber. The grass so purified is brought forward on an endless travelling felt, at each side of which, girls are placed to remove the roots and other objectionable bodies. The grass so sorted is then taken to the boiler-house.

Boiling.—There are several sorts of boilers in use, but only two call for special notice. The one in ordinary use is shown in Fig. 1049. The grass is put in by the door E, which can be firmly fastened down by the screws F. The steam enters by the pipe A, which goes a little below the perforated bottom B. Surrounding the steam-pipe is a wider pipe C, open at the top, and made slightly trumpet-shaped, also open at the bottom, below the false bottom. It carries at its lower end a kind of shoulder, on which the false bottom rests. The enlarged part of this tube beyond the shoulder has two or more openings G, through which the liquor can freely pass. The action of the boiler is as follows:—The steam from the pipe A heats the liquor that has drained from the grass through the perforations in the false bottom B, and, forcing it up the wide pipe C, causes it to strike against the dome or bonnet D, and distribute itself again over the grass. This is technically called "vomiting." The boiler is emptied by the door H, and the liquor is run off by the tap I. The boilers are usually supplied with a safety-valve K. The weights L are for convenience in lifting the door E. While the boiler is being filled with grass, the vomit is usually kept going; this has the effect of softening the grass, and allowing it to be more closely packed.

This form of boiler is not suitable for use with very high-pressure steam. Under such circumstances, it is slightly modified. In Sinclair's patent high-pressure boiler, there are two false bottoms communicating with each other by means of short pipes. The vomit-pipe extends as far as the lower partition, and the steam enters at the bottom of the boiler. In Rœckner's, the compartment formed by the perforated bottom communicates with the top of the boiler by means of a pipe outside, which has a bend in it, forming a complete circle. This is with the object of keeping the pipe always full of liquor. The vomit is produced by steam entering the pipe at the bottom of the bend. In some mills, rotary boilers are employed for esparto, but their use is far from being general.

1049.



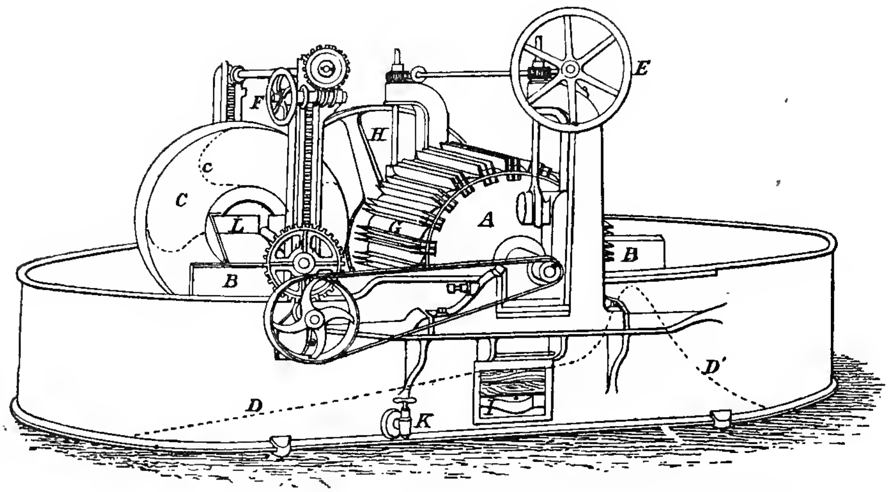
It is impossible to give anything like exact figures for the amount of caustic soda necessary to properly boil esparto, so much depending upon the quality of the grass, the style of boiler employed, and the class of paper proposed to be manufactured. The same effects may sometimes be produced by boiling with a small quantity of caustic soda for a long time, or at a high pressure; or for a shorter time, or at a lower pressure, with a larger proportion.

The proportion given by Routledge, to whom the development of the esparto process is due, is 10 per cent. of pure caustic soda. In respect to the boilers, it is said that Rœckner's form is the most economical, as, other things being equal, a smaller quantity of soda is sufficient. The time required is also subject to much variation, some mills boiling for four and others for eight hours.

Washing.—The boiling being completed, the steam is turned off, the lid is removed, and the almost black liquid, highly charged with matter (resin, silica, &c.) extracted from the grass, is run away to a large store-well. Water is now run in, the lid is fastened on, and steam is turned on again for a short time. The liquor from this washing is also run into the store-well. The grass is next removed by the bottom door H, and is carried away in trucks to the "wet-picking" house, where it is again overhauled, and any unboiled portions are removed. In some mills, where a great degree of purity is not required in the paper, this sorting process is dispensed with.

It is now taken to the breaking- or washing-engine, where it is reduced to pulp, and washed free from the liquor remaining after the partial washing in the boiler. The construction of the engine will be readily understood by reference to Fig. 1050. It consists essentially of a large rectangular vessel, with oval ends, in the centre of which is a partition B, technically called the "mid-feather." The roll A, carrying the knives G, and driven from the wheel H, revolves in one of the compartments formed by the mid-feather. In this compartment, the floor is inclined so as to bring the pulp well under the roll, as shown by the dotted line D. Immediately under the roll, is what is called the "bed-plate," the end of which is seen at I, extending up to the mid-feather, and fitted with knives, similar to those in the roll A. The distance between the roll and the bed-plate can be altered by means of the handle E. After passing between the roll and the bed-plate, the pulp flows down the peculiar elevation known as the "back-fall," shown by the dotted line D', and finds its way round to the other side of the mid-feather. On the inclined part of the floor, and just in front of the bed-plate I, is placed a grating for the purpose of catching small pieces of stone, and other heavy substances that may have found their way into the pulp. There is generally a similar grating, but with rather finer openings, on the other side of the mid-feather. The whole engine is usually made entirely of iron in one casting, though in some cases, the sides are of iron and the floor is of wood. The drum C serves to run off the wash-water. It is divided into four or five compartments by the

1050.



partitions shown by the dotted lines *c*. The centre of the drum is a conical tube, the narrow end of which is towards the mid-feather; this causes the water to flow into the spout L, and down the mid-feather, which is made hollow at this part for the purpose. Or the water, as in the older forms, may be conducted along a trough placed across the engine. The sides of the drum are commonly made of mahogany, as this is found to stand the action of the soda better than any other wood. The circumference is covered with fine copper gauze, backed with a very much coarser material. The drum can be raised or lowered by the small wheel F, and it is driven by a belt from the shaft that bears the roll. The pulp is discharged through a valve in the bottom. The tap K may be used for the purpose of cleaning the engine. The breaker is first half-filled with water, and then the charge of grass is put in. In about 20 minutes, it is sufficiently broken up, and the water is then run off by the washing-drum, fresh water at the same time running in, in order to ensure a thorough washing. At this stage of the manufacture, the pulp goes by the name of "half-stuff."

Bleaching.—The next step in the process is to bleach the pulp. For this purpose, it is run from the breaker into a "poacher," placed at a slightly lower level. The poacher very closely resembles the breaker, except that it is somewhat larger, and contains, instead of knives, a number of cast-iron paddles on the circumference of a hollow drum, with which to thoroughly stir the pulp. Bleaching-liquor, usually made in another part of the mill, by dissolving bleaching-powder in water, is now run in, and the whole is thoroughly mixed up by means of the paddles. It is the practice in some mills to assist the bleaching operation by the addition of a small quantity of an acid, either hydrochloric or sulphuric. Other manufacturers attain the same end by heating the mass with a jet of steam to about 32° (90° F.); others, again, put in a small quantity of bicarbonate of soda, a portion of the carbonic acid of which has the same effect as hydrochloric or sulphuric acids.

The quantity of bleaching-powder necessary is subject to considerable variation, depending greatly upon the quality of the grass, and the extent to which it is boiled; 12 lb. per cwt. of esparto may be considered a fair average quantity. After remaining in the poacher for about 2 hours, the almost perfectly white pulp is run off into large chests or drainers, and allowed to remain there for about 8 hours, or longer if convenient. The chests are supplied with perforated bottoms, through which a large proportion of the liquor drains away. It is said that the action of light assists the bleaching process, and for this reason, the chests are often placed in an exposed position. The drained pulp is next transferred to hydraulic presses, where most of the liquor left in is got rid of.

The preceding method of treating the grass is the one usually adopted, but, in some cases, other systems are in use. Thus, instead of breaking and bleaching in separate engines, some manufacturers perform the two operations in the breaker, which, in this case, is provided with two drums, one covered with coarse gauze for removing the liquor from the boiling operation, and the other for removing the excess of bleach, when the pulp is considered white enough, which usually happens in about 2½ hours. The gauze on the drum for removing the bleach is finer, because at the end of the operation the pulp is much finer, and would therefore pass in considerable quantity through a coarse one. In this modified system, the pulp is not pressed, but, after the excess of bleach has been washed away through the drum, is run off into the "beaters."

Beating.—Beating-engines differ but little in appearance from breaking-engines. The revolving roll, however, carries more knives, and is let down much nearer to the bed-plate, in order to complete the process only partially done in the breakers, of reducing the esparto to a sufficiently fine pulp. It is in the beaters that the final preparations of the pulp are made, and much care is necessary in their management. The bleached pulp from the hydraulic presses, or direct from the breakers, according to the system of bleaching employed, is placed in the beaters together with a quantity of water carefully filtered through a bag of woollen felt.

Immediately after furnishing the engine, a quantity of some loading or filling material is run in. The one usually employed, as being the most economical, is kaolin or China-clay (see pp. 635–9). The addition of China-clay in moderate quantity can hardly be looked upon as an adulteration, since it serves to close up the pores of the paper, and enables it to take a good surface. Of course, if added largely, it tends to weaken the paper. The clay is usually made into a fine milk with water, by being mixed in vessels provided with revolving agitators, placed above the level of the beaters. Before being run into the engine, it is carefully sieved through fine wire-cloth. Occasionally papers are made without any clay. Other filling materials have been proposed, and several others are in actual use, the chief of these being precipitated sulphate of lime, or "pearl-hardening;" this, however, is used only in the finest class of papers, it being too expensive for ordinary use. No rule can be given for the amount of loading material to be used, as papers are made with quantities varying from 5 to 15 per cent., and even more. When the clay or other substance exceeds 15 per cent., it certainly cannot be to the advantage of the user.

The quality of the water is a matter of the utmost importance in the manufacture of fine papers. Above all things, it should be free from suspended matter, and from dissolved iron. While much of the former can be removed by settling in large ponds, and by careful filtration, the latter cannot be economically eliminated, and is liable to be precipitated in the fibre, thus injuriously modifying the colour of the paper.

The subsequent treatment of the pulp depends on the kind of paper that is required. Papers may be roughly divided into two classes, viz., "tub-sized" and "engine-sized." As all papers, even tub-sized, excepting blotting- or water-leaf-paper, are more or less sized in the engine, this may form the next point for consideration.

Sizing.—The principle upon which engine-sizing depends is briefly this, viz. the precipitation and intimate mixture with the pulp of a substance which, when dry, will to some extent fill up the interstices between the fibres of the paper, and which possesses the property of being with difficulty wetted with water. Such a substance is the compound of common rosin with alumina. In order to obtain a thorough mixture of this body with the fibre, it is always formed in the engine by adding an aqueous solution of rosin-soap to the pulp, and when this is intimately mixed with it, running in a solution of alum. The rosin-soap is made in the following manner. Ordinary rosin, the quality depending on the quality of paper required, is boiled, preferably in a steam-jacketed boiler, with a solution of carbonate of soda (ordinary washing soda) until a sample of the soap formed is completely soluble in water. This takes place in about 2½ hours. The amount of carbonate of soda used differs widely, though why, it is difficult to see; usually about 1 part to 3 of rosin is considered necessary. Any excess above the quantity required to thoroughly dissolve the rosin is useless and wasteful, because, if left in the soap, it consumes an equivalent quantity of alum, and cannot possibly serve any good purpose. The boiling being completed, the charge is run off into iron tanks, and allowed to settle. The soap soon cools to a semi-solid mass, and a quantity of liquor, containing a considerable portion of the impurities, such as colouring matter, of the rosin, rises to the top, and can thus be removed. The soap so purified is next dissolved in water, with the addition of a small quantity of carbonate of soda, if necessitated by imperfect boiling in the previous operation, and is mixed with a quantity of starch-paste, made up in a separate vessel by dissolving farina in hot water. The mixture is then carefully sieved, and is ready for use. Some manufacturers prefer caustic soda for forming the soap, and others use soda ash; all are equally suitable. The proportion of starch to rosin differs in nearly every mill, and the quantity of size to be added to the beater varies according as the paper is required to be soft- or hard-sized. About 1½ parts of starch to 1 part of rosin is an average quantity; and about 3½ lb. of the mixture to 100 lb. of dry pulp is a fair proportion. In some mills, it is the practice to make up the starch with the China-clay, instead of mixing it with the rosin. (For Rosin, see Resinous Substances.)

It is better, but not absolutely necessary, to dissolve the size in water before putting into the engine. After allowing the rosin-soap and starch to get thoroughly mixed with the pulp, the alum solution may be run in. It is made up in a large leaden tank, furnished with steam-pipes for heating; it is necessary to use lead, as the alum in strong solution rapidly attacks iron vessels. The choice of a suitable alum is a matter of very great importance; care should be taken that it be free from excess of sulphuric acid, and from soluble iron. The sulphuric acid is deleterious on account of its action upon the colouring matter used subsequently, some colours being completely discharged by it, and because of its effect upon metal-work in contact with it, especially upon the brass wire-cloth on which the paper is made. As the sulphate of alumina is the only active agent in the alum, the sulphates of potash and ammonia being without any action on the rosin-soap, some paper-makers use a preparation called "aluminous cake," which consists entirely of sulphate of alumina. The only objection to this substance is that it not unfrequently contains an excess of free sulphuric acid and soluble iron. If it could be guaranteed free from these impurities, there is no reason why it should not supersede the more expensive alum. A considerable excess of alum over the quantity necessary for precipitating the rosin is employed, as it has the effect of brightening the colours added subsequently. Other materials have been suggested as substitutes for rosin in the sizing process, but none can compete with it in point of economy. Wax, dissolved in soda, and precipitated with alum, will answer the purpose, but it does not appear to have been used on a manufacturing scale. The addition to the rosin of a small proportion (about 2½ per cent.) of gum tragacanth is said to be very advantageous, giving the finished paper some of the characters of a tub-sized paper. (For Alumina, see Mordants, pp. 1295–6.)

It is necessary at some stage of the treatment of the pulp in the beaters, and before the addition of the colouring materials, to add some substance that will entirely get rid of any bleaching-liquor unavoidably remaining in the pulp. The substance usually employed is sulphite of soda, technically known as "antichlor." Its action depends upon the fact that it is converted into sulphate of soda by the active chlorine in the bleaching-liquor, the latter being at the same time changed into a chloride, in which state it is quite inert. If any free chlorine were allowed to remain, it would be very hurtful, as it would bleach the pink employed, and would at the same time act injuriously on the wire-cloth. Other substances have been used instead of the sulphite of soda, almost any reducing agent being suitable. A very cheap substitute is often prepared by boiling sulphur with milk of lime. It is the practice in some mills to wash out the excess of bleach with water, the beaters being supplied with drums for this purpose.

Colouring.—The colouring matters usually added for the production of white paper are ultramarine and pink, the latter being either a preparation of cochineal or a coal-tar colour. Sometimes a coal-tar blue is used instead of ultramarine. The addition of a small quantity of blue and pink is requisite to complement the slight yellow colour of the pulp, and so produce a white paper. The ultramarine has to be chosen with special reference to its tinctorial power, and chiefly to its capacity for resisting the action of alum, inferior qualities being discharged by the latter. Ultramarine, being a pigment, is only mechanically held by the pulp; aniline blue actually dyes the pulp, and is therefore more intimately combined with it.

Paper of any colour may be made either by adding some material of the colour required, or such substances as will produce it. It will not be necessary to enumerate here the different materials employed. The so-called "toned" paper is produced by adding to the pulp a solution of pernitrate of iron, from which a fine precipitate of oxide of iron deposits on the fibres, and thus the slightly brownish shade is obtained. The size, clay, and colouring materials having been added to the pulp, nothing now remains but to reduce it to a sufficiently fine state of division. In this part of the process, much care and attention are called for, as upon the proper conduct of the beating operation, the character of the paper greatly depends.

The object of the beaterman should be, by carefully adjusting the distance of the roll from the bed-plate, to thoroughly disintegrate the esparto, and to produce a pulp with as long a fibre as possible. If the roll be lowered too much at the commencement of the operation, the fibres, instead of being drawn out or beaten, will be cut by the knives, and the paper will be proportionately weakened.

If circumstances allow of it, the pulp should be worked in the beaters for a long time, and the disintegrating process should be conducted slowly; but the method of working depends considerably upon the character of the paper required. Thus, if a very thin paper is to be produced, it is absolutely necessary, in order to make a strong firm sheet, to beat the pulp slowly, and preserve the fibre, whereas this is not so necessary in the case of thick papers. In this, as in many other particulars, the manufacturer has to consider not only the production of a good strong sheet of paper, but, on the other hand, the expense involved on account of the extra time and power consumed.

Though the ordinary form of beater contains only one roll, some have been made containing two, and with a special appliance for sending the pulp under the rolls in two separate streams. Engines have been made containing even four rolls. In some American mills, beating-engines are employed of a totally different construction from the ordinary form. The most important of these are the Jordan and Kingsland beaters, so called from the names of their inventors. The former consists essentially of a conical-shaped roll, studded with knives, in the same way as the ordinary roll, revolving in an iron box of corresponding shape, and fitted with knives placed at slightly different angles in the direction of its length. The half-stuff enters at the narrow end, through a box provided with an arrangement for regulating the flow, and is discharged through two or more openings in the cover at the wide end. The Kingsland engine consists of a vertical, circular chamber, the sides of which are covered with knives, and between which a circular plate revolves; this is also covered on both sides with knives. The pulp enters through a pipe in the centre of one of the sides of the chamber, and flows out through an opening in the opposite side.

The latest form of beater is that invented by S. L. Gould. The essential difference between it and the Kingsland is that, instead of having a plate revolving vertically against two stationary ones, its plate, which is placed horizontally, is covered with knives on one side only, and revolves upon but one fixed plate, much in the same way as a pair of mill stones.

The pulp supplied to these forms of beater is generally broken much finer than is the case with the ordinary kind, because it is necessary to make it flow easily through them; this could not be done if the fibres were not sufficiently broken up. The chief advantages claimed for them is that they are more economical, both of time and power; also that the pulp is more regularly beaten.

Treatment of Rags.—The first step in the treatment of rags is to remove, before sorting, as much as possible of the dust and other impurities which invariably accompany them. This is not absolutely necessary, though advantageous, as it renders them less unpleasant for the workers to sort subsequently. This preliminary purification is generally done in a machine, technically called a "thrasher." It consists essentially of a square wooden box, the top of which is lined inside with steel spikes about 6–8 in. long. The box is divided into two portions, by means of a piece of coarse wire gauze. In the upper portion, a shaft revolves, bearing a number of teeth, similar to, and alternating in position with, the stationary teeth at the top of the box. The rags are supplied at one end of the box, and are discharged at the other, the dust having escaped through the wire gauze into the bottom division. It is objected by some that the thrasher causes a great waste of fibre, but, on the other hand, it may be said that a less violent subsequent treatment is necessary.

Cutting.—The next thing to be done is to sort and cut the rags into convenient pieces. This work is usually performed by women, who stand at tables, each with a broad knife firmly fixed into it, and inclined at a slight angle, with its back towards the worker. Before the women, are placed wooden boxes, the bottoms of which are covered with coarse wire gauze, the number of the boxes being determined by the number of different qualities of rags desired. Each mill has its own particular method of working, but, as a general rule, the rags are sorted with special reference to their colour, and the material of which they are composed. They are generally cut into pieces of 2–5 in. square. In some places, machines are used for cutting the rags, but though useful for some kinds of paper, they can never supersede hand-cutting for the finer qualities. One chief reason is that with hand-cutting, the rags can be much more efficiently sorted, and imperfect pieces rejected. It is said also that machine-cut rags suffer greater loss of fibre in the treatment that follows than do those cut by hand.

Dusting.—The cut rags are generally passed through a "duster," in order to complete the removal of dust and dirt. The rag-duster is usually a round or octagonal box of wire gauze, strengthened with stays and ribs, revolving inside a wooden box, one end being slightly raised to facilitate the motion of the rags, which enter at the higher and are discharged at the lower end. Occasionally the wire box is made conical. Various forms of duster are used, but they differ only slightly in principle from the one described. If necessary, rags are put through more than one duster, and, in some places, they are put into a "devil" as well, where they are subjected to a much more violent treatment. The "devil," which is of a somewhat similar construction to a thrasher, is used only when the rags are exceptionally dirty. Some manufacturers pass the dust from the ordinary rag-duster through another made of finer gauze, in order to save the fibre which becomes detached. The loss occasioned by dusting and cutting differs as much as the material the rags are made of; it varies from 6 to 15 per cent.

Boiling.—The next process is that of boiling, though some paper-makers prefer to give the rags a preliminary washing.

The boiling may be accomplished in various kinds of vessels, either stationary or revolving, but the latter are very generally preferred, owing to the fact that a more perfect circulation of the liquor is obtained with them than with the former.

The revolving boilers may be either cylindrical with round ends, or spherical; if cylindrical, they are usually made to revolve horizontally. Some cylindrical boilers, however, are placed in an inclined position, and are fitted inside with a spiral band of thick iron, to facilitate the agitation of the rags. All revolving boilers are fitted with hollow journals, through one of which, enters the steam for boiling. The "chemical" used may be lime, carbonate of soda, caustic soda, or a mixture of the two former, which is of course equivalent to the latter. The quantities used, as well as the pressure, and time of boiling, vary with the character of the rags; as a general rule, it may be stated that rags require much weaker solutions than esparto and most other materials, as the grease and colouring matter are comparatively readily removed.

The boiling having been completed, the rags must be washed. This is sometimes partially accomplished in the boiler. The rags are taken from the boiler to the washer. This is similar in construction to that described under esparto. The breaking and washing usually occupy 2–4 hours.

Bleaching.—The bleaching of the rags may be conducted in a similar manner to that of esparto. In addition, the method of bleaching with gas, and sour-bleaching, are sometimes resorted to. The former, on account of the great inconvenience due to the escape of chlorine, is but rarely used. It may be conducted in large chambers made of brick and cement or stone, and with a tight-fitting top, connected by a stoneware pipe with the apparatus for generating the gas. This may conveniently consist of stoneware retorts or small tanks of stone, fitted with some arrangement whereby they can be heated. The chlorine is obtained by heating black oxide of manganese with hydrochloric (muriatic) acid, or a mixture of the oxide of manganese and salt with sulphuric acid. Sour-bleaching consists in the alternate treatment of the rags with bleaching-liquor and a weak acid. It is usually done in large chests or drainers. In some mills, the half-stuff is first well soaked with the bleaching-liquor, and then weak sulphuric or muriatic acid is run in upon them; in others, the reverse takes place, the acid being allowed to saturate the pulp first, and then the bleach is run in. The most economical way would appear to be, first to bleach as much as possible with liquor alone, and then to add an acid when this is nearly exhausted. Whatever the method of bleaching employed, the excess of bleaching agent must be got rid of, and this can be accomplished by one or other of the methods before described. The subsequent treatment of the pulp calls for no special remarks; the time necessary for reducing rags to the proper degree of fineness is, however, generally longer than for esparto.

Treatment of Straw.—The preparation of paper-pulp from straw has been the subject of numerous patents, chiefly in France and America. They do not, however, differ from each other to any great extent in principle.

Cutting.—The first process to which straw is subjected is that of cutting. This is done principally for the purpose of rendering it more convenient to pack into the boilers; it also makes it more easily cleaned. The cutter is similar to that ordinarily used for cutting hay for stable uses. The cut straw has to be cleaned and freed from the dust and dirt that invariably accompany it. This operation may be performed in various ways. One very suitable method is to blow the straw by means of a violent blast of air along a wooden tube or shaft, into a chamber, whose sides are made of coarse wire gauze, through which the dirt escapes. The straw thus purified is taken to the boilers.

Boiling.—The boilers are usually rotary, and closely similar to those used for rags. The heat may be applied in several ways: directly; by means of a steam-jet opening into the boiler; or by means of a coil of steam-pipe. The direct method is but seldom used, as it sometimes entails damage to the pulp, through overheating due to imperfect circulation. This cannot happen with the two latter arrangements. The objection to heating by means of an open steam-pipe is that the liquors are unduly diluted by the condensed steam, and, for this reason, the last-mentioned plan is preferred by some. A solution of caustic soda is the agent invariably used, the strength necessary depending very largely on circumstances, such as the pressure, and time of boiling. A higher pressure than that required for esparto and rags is necessary, 60–80 lb. a sq. in. being usual. The time may vary from 6 to 12 hours, and the amount of caustic soda from 15 to 25 lb. a cwt. Some manufacturers recommend a preliminary boiling in water; this has the effect of removing a large quantity of matter from the straw, and of rendering the subsequent boiling process easier. The washing may be performed in large vats provided with perforated bottoms, or in an ordinary washing-engine, in which latter case, the roll should carry only blunt knives, as the fibres are generally sufficiently disintegrated by the boiling process. When properly washed, the pulp may be bleached by one of the ordinary methods. When this is accomplished, antichlor is put in to remove the excess of bleach, and the pulp, which is much too finely divided to allow of its being pressed, is made into a coarse thick web of paper; by this means, most of the lime and other substances from the bleach are got rid of. The machine on which this is done corresponds exactly to a paper-making machine proper, without the drying-cylinders and calenders. This method may also be adopted before bleaching, in order to get rid of the last traces of the liquor from the boiling operation, and free the pulp from knots, sand, &c., the machine being provided for this purpose with sand-tables. The pulp, in the form of rolls or webs of thick paper, is ready to be taken to the beaters, where its subsequent treatment is similar to that of other fibres. Owing to the fact just mentioned, that the straw is to a considerable extent disintegrated by the boiling process, very little working in the beaters is sufficient. In other establishments, the straw is drained in large stone chests, similarly to esparto and rags.

Treatment of Wood.—The manufacture of paper-pulp from wood is confined almost exclusively to Sweden and America. This appears to be due to the fact that, in these countries, abundance of suitable wood is found, and can be very cheaply obtained. Many attempts have been made in this country, but they have been nearly all abandoned. In America, poplar is the wood generally employed, on account of the ease with which it can be disintegrated.

The method of treating it is as follows. The wood is brought to the mills in cords of about 5 ft. long. The bark is removed, and the blocks are cut into thin slices across the grain, in a machine constructed somewhat on the principle of an ordinary chaff-cutter. The wood is passed slowly and steadily, by means of an advancing screw, along a trough, at the end of which it comes against very strong steel knives, firmly fixed on a rapidly-revolving cast-iron disc.

Boiling.—The slices of wood, which are about ½ in. thick, are then taken to the boilers. These are vertical cylinders, about 5 ft. in diameter and 16 ft. high, divided into compartments by means of perforated diaphragms. The boilers are heated either directly by means of furnaces underneath, or by steam circulating round an outer jacket. The boilers are partially filled with a solution of caustic soda at about 17° Tw., and the heat is kept up for 6 hours, the pressure being equal to about 70 lb. a sq. in. At the end of this time, the contents of the boiler are ejected with considerable violence into a large iron chamber placed underneath (see Bamboo and Cane, p. 1485). The pulp is then allowed to pass into large iron drainers, mounted on wheels for convenience of locomotion. In the centre of the tramway along which the drainers pass, are placed sewers to receive the liquor. When as much as possible of the liquor has drained away, hot water is poured upon the pulp. A small quantity only is used, so as to keep the liquor sufficiently concentrated to pay for evaporation. The pulp is then taken to washing-engines, similar in principle to those described under Esparto, p. 1487. The washed fibre is next freed from unboiled portions, sand, &c., by being passed over sand-tables and through screens (see Paper-machine, p. 1494), and is then passed over the wet end of a machine, as in the case of straw. It is bleached in the ordinary way, and is then made into a very thick coarse web on a cylinder paper-machine; in this form, it is sold to the paper-manufacturers. The subsequent treatment of it in the paper-mill calls for no special remarks. Wood-pulp so prepared may be used alone, or mixed with rags or other material, for almost all classes of paper.

The fibres prepared from poplar are very white, but are somewhat deficient in strength; those from other woods, such as members of the family of *Coniferæ* (pines), are much longer and stronger, but owing to the fact that, in the raw state, they usually contain a very large quantity of resinous matter, these woods are much more difficult to digest, requiring a stronger solution of caustic soda, and a considerably higher pressure. The process just described is that actually in use at a mill in America; at other places, a similar method of treatment is adopted, or if any material difference exists, the details are kept secret. Many other reagents have been suggested as substitutes for caustic soda. Among these, may be mentioned sulphide of sodium, chlorine, and a mixture of hydrochloric and nitric acids (aqua regia). But, as far as is known, they have all been abandoned, on account of the expense and extra trouble involved in their use. Many attempts have been made to utilize the fibre in sawdust, by treating it with one or other of the before-mentioned chemicals, but hitherto without much success. Works have also been erected in this country with a view of obtaining pulp from other waste forms of wood, such as small chips and shavings; but, principally owing to the nature of the material, and the consequently severe treatment necessary for their disintegration, they too have been given up.

The so-called "mechanical" wood-pulp is obtained by disintegrating the wood entirely by means of machinery, without the use of chemicals. As long as 100 years ago, it was proposed to utilize sawdust and shavings, by stamping them into a pulp; but owing to the want of suitable machinery, the attempt was unsuccessful. The next idea was to disintegrate blocks of wood, by grinding with rapidly-revolving cylinders of stone. This, after many years of labour, has been brought to a state in which it is a commercial success. The details of the process are as follows:—The wood is first cut up into blocks, the size of which is determined by the width of the stones used for grinding; any knots present are cut out with an axe. The stones are made of sandstone, and are covered over three quadrants with an iron casing, the remaining quadrant being exposed. The surfaces of the stones are made rough by the pressure of a steel roll studded with points, and which is pressed against it while revolving. In addition to this, channels, about ¼ in. deep are cut into the stone at distances of 2–3 in. They are made in two sets, crossing each other in the centre of the stone, and serve to carry off the pulp to the sides of the stone, in addition to giving increased grinding-surface. The pressure of the blocks of wood against the stones is steadily maintained by screws worked by suitable gearing; this is necessary in order to obtain a pulp of uniform character. A stream of water is kept constantly playing on the stone; by this means, the pulp as formed can be conveniently carried away. It is first passed through a rake, which retains small pieces of wood that have escaped grinding. The stream of pulp then passes through the sorters. These are cylinders about 3 ft. long and 2 ft. in diameter, covered with a coarse wire-cloth (No. 18). The fibres that are retained by this wire fall into the refiners, which consist of a couple of horizontal cylinders of sandstone, the upper one only of which revolves. Here they are further disintegrated, and are again passed through the wire-cloth; this is repeated until all the fibres have passed through. The pulp, after passing through the first sorter, may be conducted through a series of gradually increasing fineness, and, by this means, be separated into different qualities. Though pulp so prepared cannot compete with chemically-prepared stuff, as the fibres are extremely short, and have comparatively little felting-power, it may be used with advantage as a sort of filling-material. It is said to be used entirely for some low-quality newspapers.

Various modifications of the foregoing process have from time to time been proposed; among others, that of softening the wood by previous soaking in water, or steaming, seems to be valuable, as by so doing, it is highly probable that a longer fibre could be obtained, the soft wood being more readily torn away by the stones. Some inventors have proposed to replace the sandstone by an artificial stone containing a large quantity of emery.

Treatment of "Broke" Paper.—As "broke" paper has already passed through the manufacturing process, but little is necessary to be done to it. If quite clean, it only requires to be broken up again in an engine; but if dirty, or with much printing on it, some sort of boiling is necessary. Generally speaking, a rather dilute solution of soda is sufficient. Sometimes it is necessary to thrash and dust the waste paper much in the same way as rags.

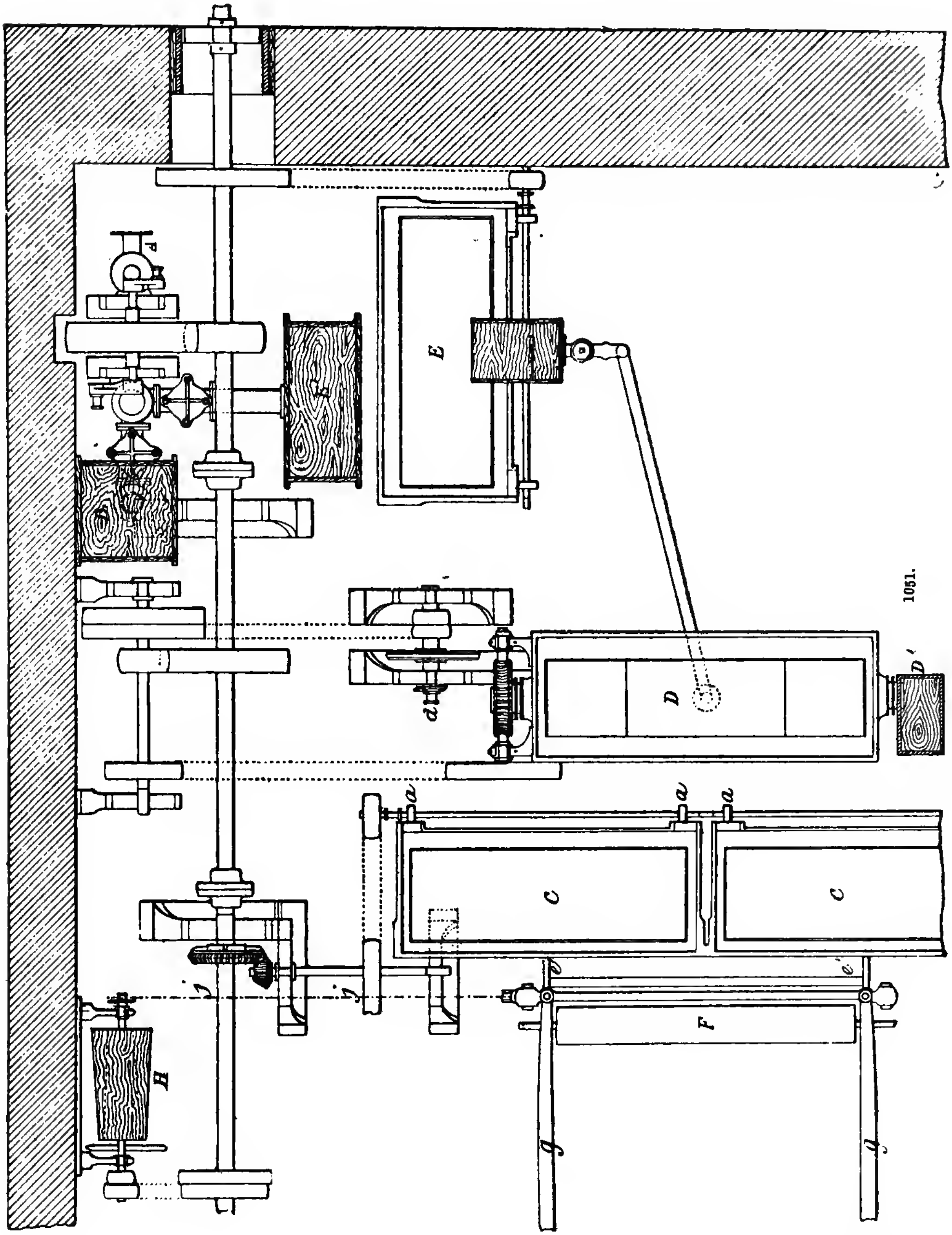
Hand-made Paper.—The preparation of the pulp for hand-made is similar to that for machine-made paper. Generally speaking, however, paper can only be made successfully by hand, when long and strong fibres are used; with short and inferior pulp, it is difficult to form a continuous sheet of any size. Hence hand-made papers are almost exclusively manufactured from pulp prepared from rags, or some such strong material.

A very brief description of the actual process will be sufficient, and it will at the same time facilitate the right comprehension of the machine process. The paper is made on a mould of wire-cloth, with a movable edge of wood, extending slightly above the surface of the mould, called the "deckle." The wire-cloth is generally supported by pieces of thick wire placed beneath it, and these again by wedge-shaped pieces of wood, the thin end being next the wires. To form a sheet of paper, the workman dips the frame into a vat containing the prepared pulp, lifting up just so much as will make a sheet of the necessary thickness. As soon as the mould is removed from the vat, the water begins to drain through the wire-cloth, and to leave the fibres on the surface in the form of a coherent sheet, the felting or intertwining being assisted by lateral motion given to the frame by the workman. The movable deckle is then taken off, and the mould is given to another workman, called the "coucher," who turns it over and presses it against a felt, by this means transferring the sheet from the wire to the felt. A number of the sheets thus formed are piled above each other, alternately with pieces of felt, and the whole is subjected to strong pressure, to expel the water. The felts are then removed, and the sheets are again pressed. After this, they are sized by being dipped in a solution of gelatine; again slightly pressed, and then hung up separately on lines or poles to dry.

The making of paper by hand is comparatively little practised in the present day; some kinds of paper, however, such as bank-notes, and different kinds of drawing-paper, are always made in this way.

Any pattern or name required on the paper is obtained by making the wire-cloth mould in such a way that it is slightly raised in those parts where the pattern is needed; consequently less pulp lodges there, and the paper is proportionately thinner, thus showing the exact counterpart of the pattern on the mould. Such are known as "water-marks."

The Paper Machine.—The pulp, after leaving the beaters, passes into a large vessel called the stuff-chest, of which there are one or more to each machine. As soon as the beater is empty, water is run in to thoroughly rinse out the remaining pulp, the washings also going into the stuff-chest. These may be made either of wood or iron, and should be provided with arms fixed on a vertical shaft, made to revolve by suitable gearing. The arms are for the purpose of keeping the pulp thoroughly mixed, and should only work at a moderate speed, otherwise they would be liable to cause the fibres to go into small knots or lumps. The pulp is drawn from the stuff-chests by means of the pump A (Fig. 1051), and is discharged into a regulating-box (not shown). The object of this box is to keep a regular and constant supply of pulp on the machine. It consists of a cylindrical vessel, having two overflow-pipes near the top, and a discharge-pipe near the bottom. The pulp is pumped in through a ball-valve in the bottom, in larger quantity than is actually needed, the excess flowing away back into the stuff-chests, through the two overflow-pipes. By this means, the box is always kept full, and therefore the stream of pulp issuing out of the bottom pipe is always under the same pressure. It flows from this pipe, the quantity being regulated by means of a cock, according to the thickness of paper required, directly on to the sand-tables. These may be of various sizes and shapes, but should be so large that the pulp takes some little time to travel over them. They consist of long shallow troughs, generally of a sinuous form. The bottoms are partly covered with woollen felt, having very long hairs on its surface, and partly with thin strips of wood placed across the direction of the flow of the pulp, and at a slight angle. They and the woollen felt serve the purpose of retaining any particles, such as sand and dirt, that may have escaped removal in the previous treatment of the pulp, and that are heavy enough to have



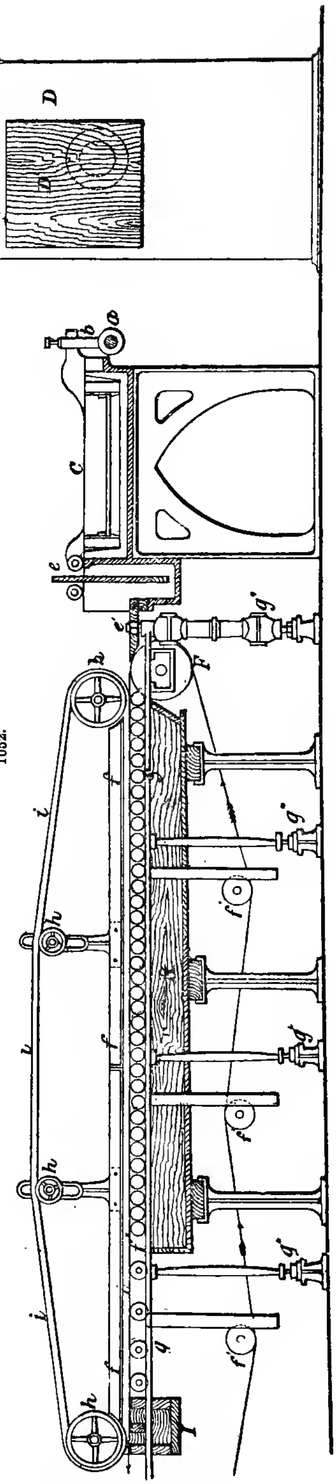
1051.

sunk down during the passage of the pulp over them. As the pulp, when it leaves the stuff-chests, does not contain sufficient water for the purpose of making paper, it is mixed, at the end of the sand-tables where it flows on, with a quantity of water from the "save-all" (see farther on), flowing from the box B (Fig. 1051) placed at a higher level.

Instead of being pumped into the regulating-box, in some mills, the pulp flows into a small vessel below the stuff-chest, and is lifted on to the sand-tables by means of buckets fastened on the circumference of a wheel.

The pulp, after leaving the sand-tables, passes on to the strainers. These consist of strong brass or composition plates, having a large number of very fine V-shaped slits cut in them, the narrowest end being on the outside.

The strainers are for the purpose of removing from the pulp all lumps formed by the intertwining of the fibres, and all pieces of unboiled fibre, which, if allowed to pass on, would show in the paper as inequalities in the surface, or as dark specks. The slits are made narrow at the top, and gradually increasing in width, so as to prevent them from getting choked up. These slits allow only the separated individual fibres to pass through, and their width varies according to the quality of the paper. They are put at distances of about ½ in. apart. Several plates, each containing about 500 slits, are bolted together, and form a strainer. The whole strainer receives a violent shaking motion, to assist the passage of the fibres through the slits. In the machine represented, two of these strainers are shown at C (Figs. 1051 and 1052). The shaking motion is produced by the ratchet-wheel or cams *a* acting on the hammer *b* (Fig. 1052). An improved form, called the "revolving strainer," has of late years been introduced, and is often used in addition to the ordinary ones. The pulp generally passes first through one of these, and then through the ordinary or "flat" strainers, as they are called. A revolving strainer is shown at D (Figs. 1051 and 1052). It consists of a rectangular box, the sides of which are plates perforated with slits. Inside this box, a slight vacuum is formed by means of an indiarubber bellows worked by the crank *d* (Fig. 1051). The vacuum is intended to serve the purpose of the shake in the ordinary form. The box revolves slowly inside a vat containing the pulp, and the strained pulp flows into the box D^1 (Figs. 1051 and 1052), and thence on to the flat strainers. Various patents have been taken out from time to time for flat strainers worked by means of a vacuum underneath the plates caused by the motion of discs of indiarubber or thin metal. The same principle has also been applied to the revolving strainers. After a time, the slits in the plates get too large, owing to the plate having been worn away by the constant friction of the fibres, and as they are very expensive, various attempts have been made to invent plans for partially closing them again. Hammering will effect this, but it is liable to break the plates. Annandale of Beltonford has introduced a method of closing the plates, by means of heavy pressure acting on small steel rollers moving on each side of the slit, in which is placed a small sheet of metal the exact thickness of the width desired. The knots and impurities which collect on the outsides of the strainers must be from time to time removed, otherwise the slits would get choked up. In the case of revolving strainers, all that cannot pass through the slits falls to the bottom of the vat, in connection with which it is the custom now to have an auxiliary strainer, or "patent knotter," as it is called, shown at E (Fig. 1051). All fibre that passes through this one, which is of the ordinary flat kind with shaking motion, goes into a box near E' (Fig. 1051), called the "low box" for "save-all" water (see farther on).



1052.

The pulp, after passing through the strainers, should be perfectly free from knots and impurities, and in a fit condition for making paper. In the machine shown, it passes from the last strainer directly on to the wire, its flow being regulated by a movable gate *e* (Fig. 1052). In some cases, however, it first flows into a small vat, in the centre of which revolves a rod carrying paddles, with the object of keeping the pulp well stirred up. It is carried right on to the wire by means of the apron, a piece of canvas, oil-cloth, or sheet rubber, one end of which is fastened to the breast-board *e'* (Figs. 1051 and 1052), the other end resting on, and covering, the wire to the extent of about 15 in. The edges of the apron are rolled up to prevent the pulp from overflowing. After leaving the apron, it passes under a gate, or "slicer," as it is sometimes called, made of two pieces of brass, overlapping each other in the centre, and bolted together. It is made thus to enable it to be lengthened or shortened according to the width of the paper; its height from the wire-cloth can be altered by means of screws, and should be equal at all points, in order to ensure a uniformly thick sheet of paper. The ends of the two pieces forming the slicer are fastened to the frame *f* (Fig. 1052), or "deckle," as it is called, and this again is carried by two or more rods stretching right across the wire, and fastened by small upright supports on both sides to the frame *g* (Figs. 1051 and 1052). The deckle-frame also carries the grooved pulleys *h* (Fig. 1052), along which the deckle-straps *i*, endless square bands of indiarubber, move. The deckle-straps rest on the wire, and move with it, the width of the paper depending on their position, which can be altered by shifting the deckle-frame along the rods mentioned.

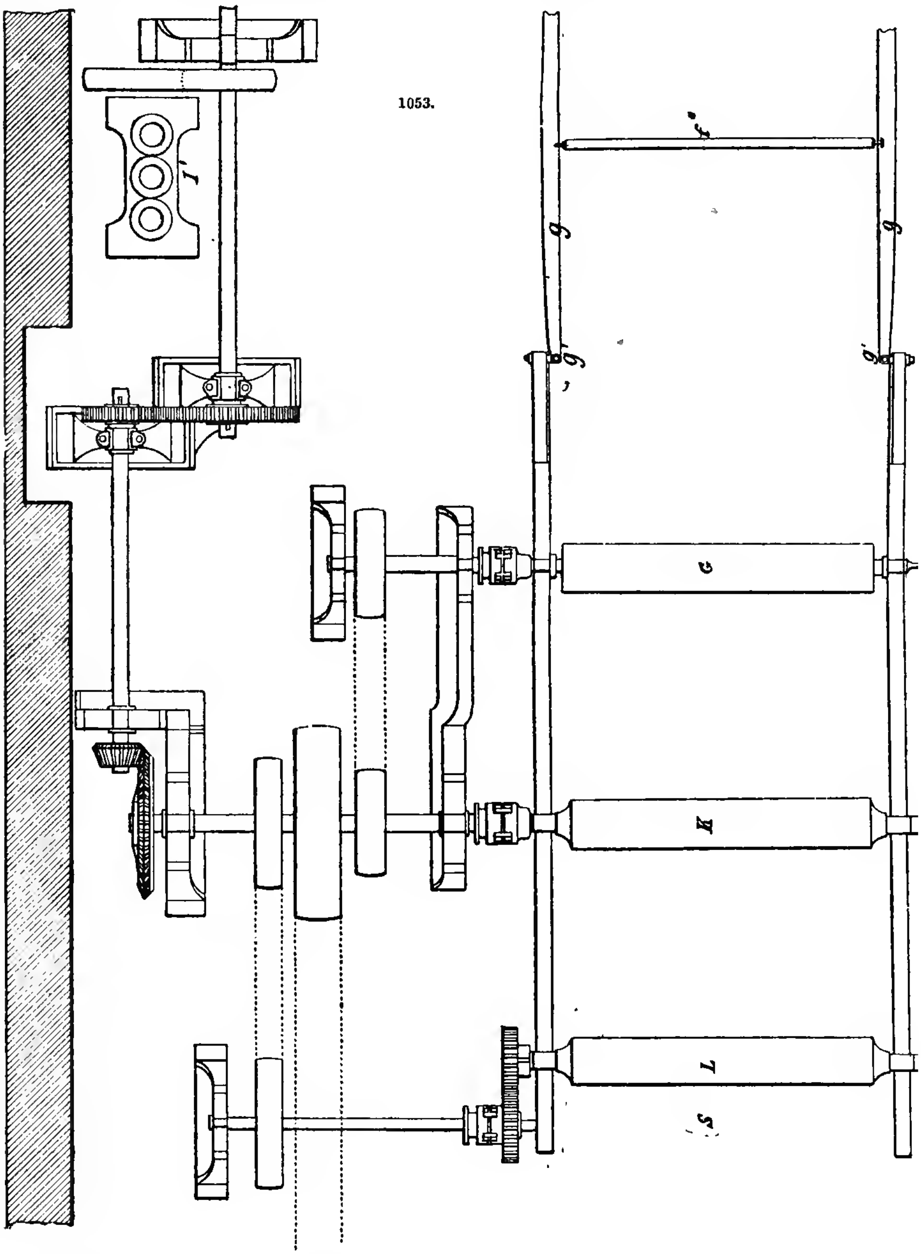
The "wire" is an endless cloth made of very fine wire, the fineness depending much on the quality of the paper required. The mesh varies from 60 to 70 and even more threads to the inch. It is not woven endless, but is joined by very careful sewing, with wire. Its width varies considerably, that on the machine shown being 76 in.; the length is generally 35–40 ft. It is carried by the breast-roll F (Figs. 1051 and 1052), the lower couch-roll G, and the small rolls *f* (Figs. 1052 and 1053), and by a large number of small rolls *f''*. The latter and the breast-roll are supported by the frame *g*, while the small rolls *f'* are supported by brackets attached to it. The course of the wire is indicated by the arrows. The frame *g* works on two pivots *g'* (Fig. 1053), and receives a shaking motion from side to side from the rod *j* (Fig. 1051), in connection with a crank worked by two conical drums H (Fig. 1051). The supports *g''* are also pivoted at their lower ends to allow for the shaking motion. This shaking motion is given for the purpose of weaving or intertwining the fibres. One or more of the rolls *f'* can be moved up or down on the support which carries it, for the purpose of stretching the wire. There is usually a large number of the small rolls *f''*, as it has been found by experience that, probably owing to capillary attraction, they assist the water to leave the pulp. Though a large quantity of water thus passes through the wire-cloth, it is necessary to assist it by artificial means. This is done by means of the suction-boxes I (Figs. 1052 and 1054) connected by pipes with the vacuum-pumps I' (Fig. 1053).

Underneath the wire-cloth, is placed a box called the "save-all" K (Fig. 1052), connected with the box E (Fig. 1051). The water that flows in here contains a considerable quantity of very fine fibres, together with size, alum, clay, and colouring materials, that have passed through the wire, and which would be lost but for the arrangement now universally adopted. It flows into the box E', and is pumped, together with the pulp that has passed through the knotter E (see before) into the high box B, whence the mixed stuff flows on the sand-tables, to be again used to dilute fresh pulp from the stuff-chests. If any pattern or name is desired on the paper, it is done by means of a light skeleton roll, called a "dandy-roll," covered with wires in the form of the desired pattern, placed between the suction-boxes, and pressing lightly on the still moist paper. The paper is thinned where the wire pattern presses, and thus a mark (water-mark) is produced. The other side of the paper has a mark corresponding to the wire-cloth; by using a dandy-roll covered with wire-cloth, the two sides can be obtained alike, such paper going by the name of "wove."

It sometimes happens that the wire-cloth slips slightly to one side. This can be obviated by the machine-man shifting, by means of screws, one of the rolls provided for the purpose with a movable journal, until its axis is at a slight angle to that of the other rolls. An automatic apparatus has been invented for the purpose. Two brass plates are fixed, one on each side of the wire-cloth, to a long rod, connected by suitable machinery with the screws working the movable journal, so that, as the wire presses against one or the other of these plates, the roll is shifted so as to correct this.

The paper, which, even after passing the suction-boxes, is still very wet, passes with the wire-cloth between the couch-rolls G G'. (Figs. 1053 and 1054). These are hollow copper or brass cylinders, covered with a tightly-fitting endless jacket of felt. The pressure of the upper couch-roll upon the lower can be regulated by means of screws or levers. They serve to press out water from the paper, and to detach the paper from the wire-cloth. By dextrous manipulation on the part of the machine-men, the paper is transferred to the endless felt, travelling over the rolls *k* in the direction of the arrows. It is known as the "wet felt," from the condition of the paper at this stage. In its passage along this felt, the paper goes between two iron rolls K, called the first press-rolls, with the object of having the water squeezed or pressed out of it. These rolls are sometimes covered with a thin brass case, and the top one is provided with an arrangement called the "doctor," in order to keep it clean, and free from pieces of paper that may have stuck to it. The "doctor" is a kind of knife placed along the whole length of the roll, and pressing against it at every point.

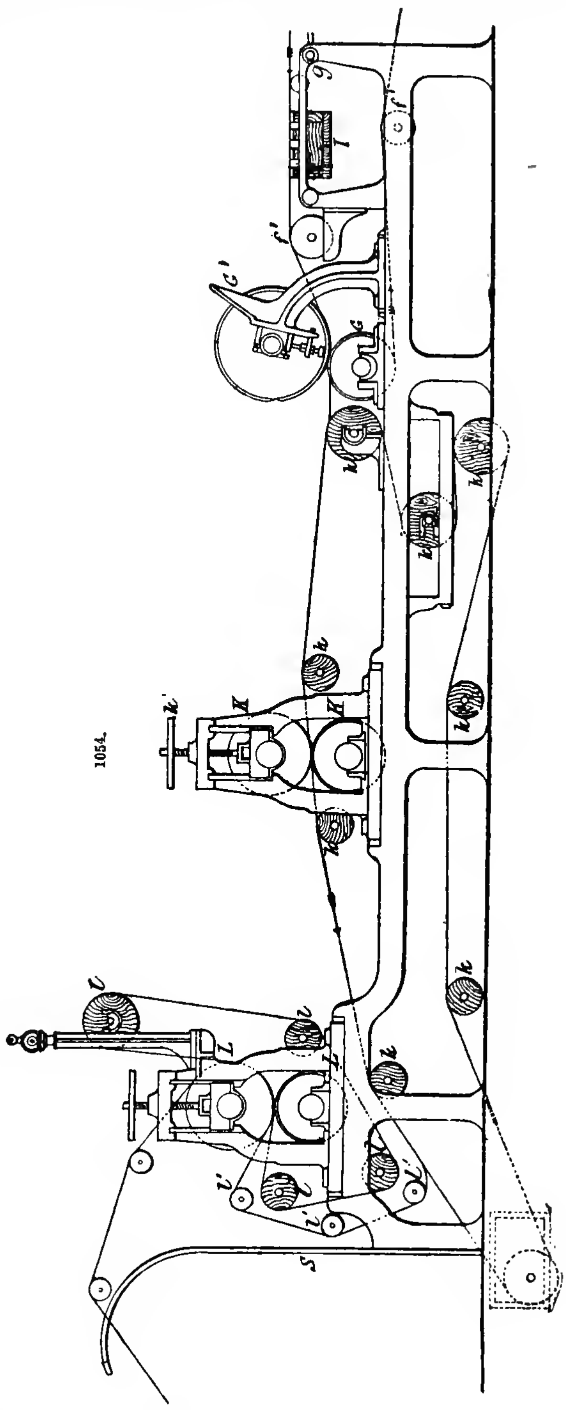
1053.



The pressure on the rolls can be regulated by means of levers, or, as in the illustration, by the screw *k'* (Fig. 1054). It will be readily seen that the under side of the paper that has been next to the felt will, in its still moist condition, have taken to some extent an impression from the felt, while the upper side will have been made comparatively smooth by the pressure against the top roll of the 1st press. In order to make both sides of the paper as nearly as possible alike, it is passed through another set of rolls L, called the 2nd press. This time it is reversed, and enters at the back of the rolls; thus the other side of the paper is next the metal, being taken through by the felt (called the "2nd press felt") travelling on the small rolls *l* (Fig. 1054), the paper, after leaving the wet felt, and before being taken on to the 2nd press felt, travels over the rolls *l'*. The 2nd press felt is necessary, because the paper in its then condition is too tender to withstand unsupported the pressure of the rolls.

The paper, after passing the 2nd press rolls, travels over the drying-cylinders M (Figs. 1055–6–7), the number of which varies somewhat. In the machine shown, there are in all eight cylinders. Between the 2nd press rolls and the cylinders, a passage S allows easy access to the other side of the machine. The paper generally passes over the first two, which are only slightly heated, alone; afterwards it is led over the others by means of felts, as shown. The arrangements shown at R (Figs. 1055–6) are for the purpose of stretching the felts. The cylinders are all heated by means of steam, and are generally divided into two sets, between which, is a pair of chilled-iron, highly-polished rolls N, called "smoothers," the function of which is sufficiently explained by their name. They are also heated by means of steam. The cylinders are usually made of slightly decreasing diameter, in order to allow for the shrinking of the paper on drying. After leaving the cylinders, the paper should be quite dry; it is then led through the calenders, of which there are in some machines as many as three sets, though only one is shown. These are similar to the smoothing-rolls, just described. Pressure is applied by the screws O' (Fig. 1056), or by levers and weights. The friction of the hot calenders on the dry paper develops a large quantity of electricity, which discharges itself in bright sparks.

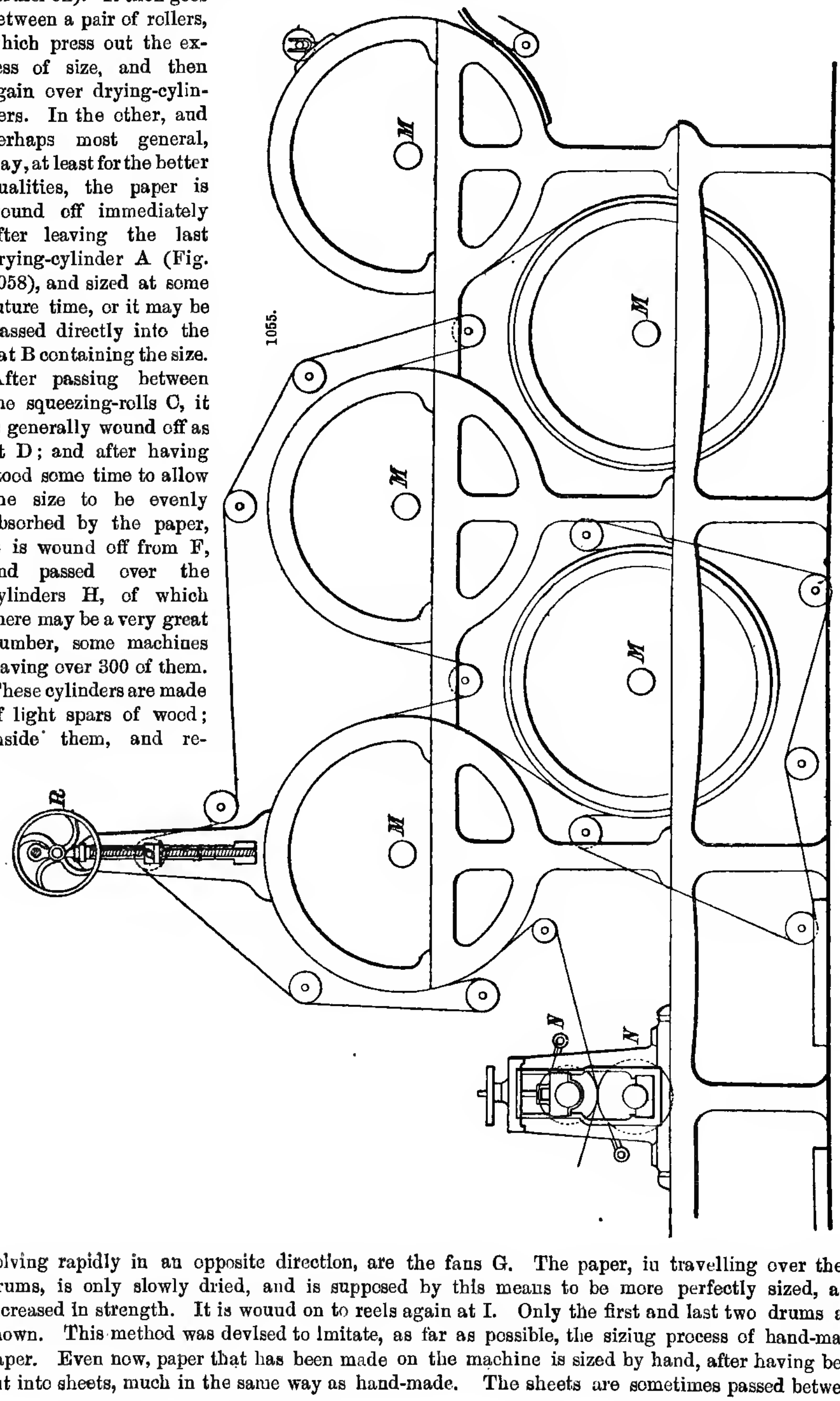
1054.



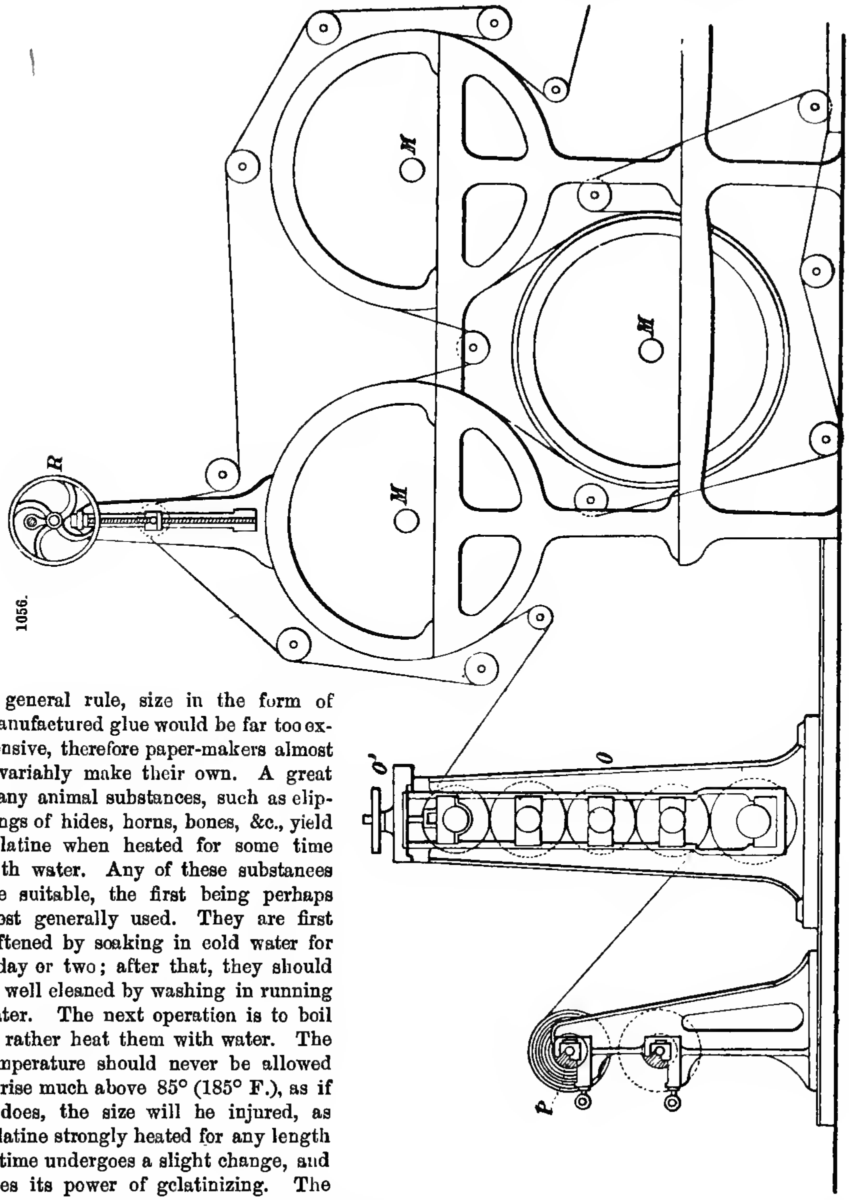
The finished paper, after passing through the calenders, is wound on the reels P. The gearing by which the whole machine is driven is shown in Figs. 1053, 1057.

Tub-sizing.—The foregoing description is of a machine for the manufacture of engine-sized papers; some slight modifications are necessary in the case of tub-sized papers. One method, usually applied to the cheaper qualities of tub-sized papers, is to pass the paper, after being partially dried over a few cylinders, through a vessel containing a solution of gelatine or glue (see farther on). It then goes between a pair of rollers, which press out the excess of size, and then again over drying-cylinders. In the other, and perhaps most general, way, at least for the better qualities, the paper is wound off immediately after leaving the last drying-cylinder A (Fig. 1058), and sized at some future time, or it may be passed directly into the vat B containing the size. After passing between the squeezing-rolls C, it is generally wound off as at D; and after having stood some time to allow the size to be evenly absorbed by the paper, it is wound off from F, and passed over the cylinders H, of which there may be a very great number, some machines having over 300 of them. These cylinders are made of light spars of wood; inside them, and revolving rapidly in an opposite direction, are the fans G. The paper, in travelling over these drums, is only slowly dried, and is supposed by this means to be more perfectly sized, and increased in strength. It is wound on to reels again at I. Only the first and last two drums are shown. This method was devised to imitate, as far as possible, the sizing process of hand-made paper. Even now, paper that has been made on the machine is sized by hand, after having been cut into sheets, much in the same way as hand-made. The sheets are sometimes passed between

1055.



two endless felts dipping into a bath containing the solution of gelatine, the excess of size being squeezed out by the pressure of rolls on the felts. Such paper is dried on sticks in a large room kept at a temperature of about 21° (70° F.), and is called " loft dried " on this account.

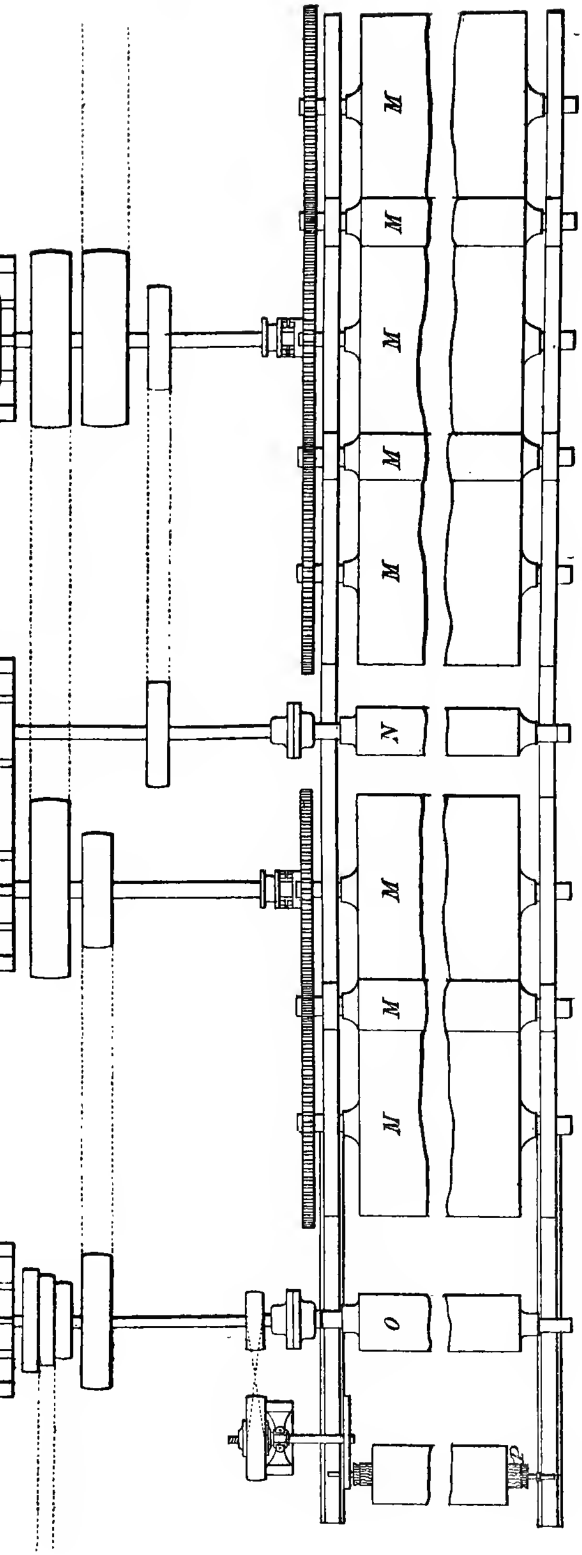


1056.

The gelatine used for tub-sizing is made up somewhat after the following manner. As a general rule, size in the form of manufactured glue would be far too expensive, therefore paper-makers almost invariably make their own. A great many animal substances, such as clippings of hides, horns, bones, &c., yield gelatine when heated for some time with water. Any of these substances are suitable, the first being perhaps most generally used. They are first softened by soaking in cold water for a day or two; after that, they should be well cleaned by washing in running water. The next operation is to boil or rather heat them with water. The temperature should never be allowed to rise much above 85° (185° F.), as if it does, the size will be injured, as gelatine strongly heated for any length of time undergoes a slight change, and loses its power of gelatinizing. The operation should be conducted in an iron or copper vessel, provided with a false bottom, or a casing outside, where steam may be introduced, and it should extend over about 15 hours. The solution should then be drawn off, and filtered into some convenient receptacle. The residue can be again heated with water, and a fresh quantity obtained, which may be added to the bulk. A quantity of alum (about 20 per cent. of the clippings) dissolved in water, is added. The alum is necessary to prevent the decomposition of the gelatine, and to assist in the sizing process, as it helps to give hardness to the paper. After the addition of the alum, the size should be well filtered through woollen felt, after which, it requires no further treatment.

The paper-making machine before described is known as the "Fourdinier," from the names of the original inventors. Modified forms of this machine have been introduced to meet various requirements. One, suitable for the manufacture of very thin papers, resembles the ordinary machine as far as the couch-rolls. The paper is taken off the wire-cloth on to a long endless felt, running round the upper couch-roll, and extending in a slanting direction over the wire-cloth. It is taken off from this felt on to a large cylinder, about 10 ft. in diameter, heated by steam, and placed above the wire-cloth. After passing round nearly the whole circumference of this cylinder, the paper is sufficiently dry, and is then wound on to reels.

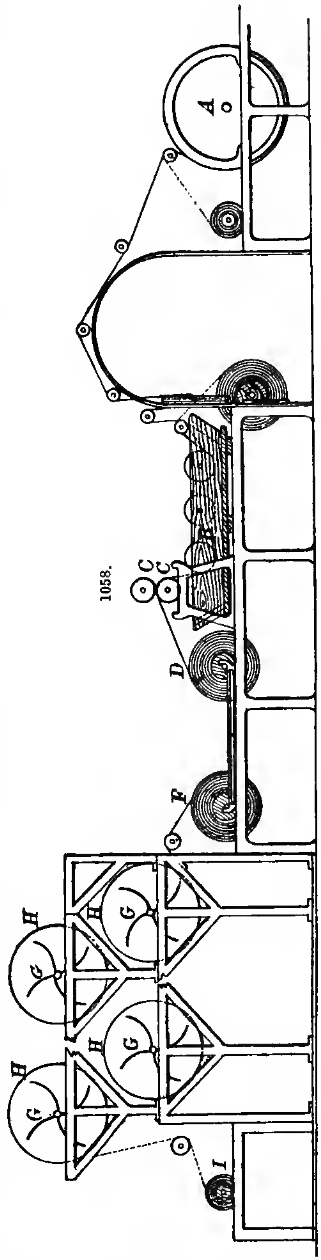
A machine of a very different construction from the ordinary form is shown in Fig. 1059. The pulp, after passing through the strainer A, enters the vat B, in the centre of which, revolves a large drum or cylinder C. This cylinder is covered with fine wire-cloth, and on it the paper is made. As it revolves, the fibres attach themselves to the wire, and the water passes through the meshes, the latter being assisted by means of a pump. The sheet of paper thus formed is taken on to the endless felt on the couch-roll D, and travels along with it to the large drying-cylinder E, heated by steam. It leaves the felt at F, and is then taken on to the cylinder, after travelling round which, it is sufficiently dried, and is then wound off as at G. The felt, on its return journey, passes through the washer H, where it is cleaned, and freed from adhering particles, by the scraper I. It is squeezed free from excess of water by the rolls K. Paper made on such a machine is



1057.

weaker than that made in the ordinary way, because it has not been found possible to give a shaking motion to the cylinder, and thus the fibres are not woven or intertwined.

A modification of this machine is used for making mill-boards, the difference being that it has no drying-cylinder. The felt carrying the paper passes between a pair of press-rolls, which squeeze out the water. The sheet of paper is then allowed to wind round the top press-roll until of the required thickness. When this happens, it is cut off the roll by a knife. The thick sheets so produced are dried, either in the open air, or in a room heated for the purpose.



1058.

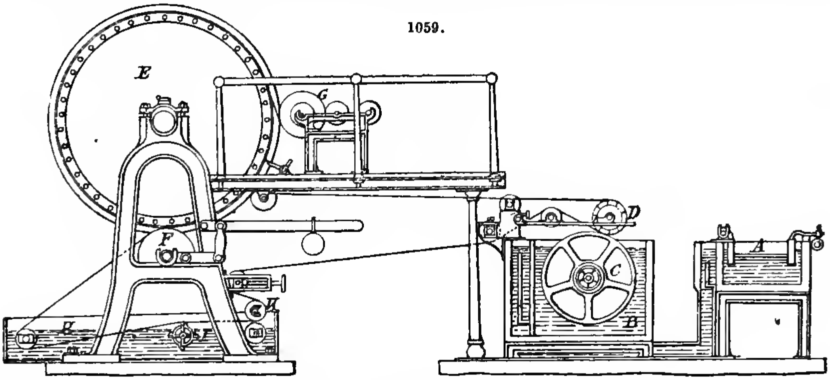
Glazing.—For many purposes, the paper as finished on the machine, does not possess a sufficiently high surface. This may be increased in several ways. One method, called "web glazing," is to pass the paper between a number of rolls, alternately of polished iron and very highly-compressed paper. The construction of such a calender will be understood by reference to Figs. 1060 (end elevation) and 1061 (front elevation). The reel of paper, as taken from the machine, is shown at A (Fig. 1060), its course over the rolls being indicated by arrows. After passing over the bottom roll, it is wound off on a wooden or hollow-iron cylinder B (Fig. 1060), driven by the toothed-wheel shown by the dotted line C, on the same shaft as the wheel D, which is driven by E, keyed upon the bottom roll. The whole machinery is driven by the large toothed-wheel F (Figs. 1060–1), which is itself driven by the small wheel G (Fig. 1060) on the main shaft H. The paper rolls are marked P, and the iron rolls I. It will be seen that there are two paper rolls in the middle, for the purpose of, as it were, reversing the paper, and so making both sides alike. Pressure is applied to the rolls by means of the screws, and by the weight L (Fig. 1060) acting on the compound lever M. The brake, which consists of a strap of leather pressing, by means of the weight and lever N, on the circumference of the wheel O, connected by toothed-wheels with the cylinder on which the paper is wound, is used for the purpose of preventing the paper from leaving the wheel too rapidly. But for this appliance, the paper would be apt to crease. The paper rolls have an inner core of iron, the paper only extending to a depth of about 5 in. The iron rolls are hollow, and are connected with steam-pipes, by which they can be heated.

Another method, known as "friction-glazing," employed for giving a very high finish to paper, is to pass it between a large paper roll and a smaller iron one, the latter revolving at a much greater speed than the former. By this means, a very bright surface can be obtained. It is sometimes assisted by rubbing a small quantity of bees'-wax on the small iron roll. Plate-glazing, a method that is adopted for hand-made and the better qualities of paper, consists in applying heavy pressure to sheets placed between polished plates of copper or zinc. The metallic plates and the sheets of paper are made into bundles, and the whole is passed between two strong rollers, heavy pressure being communicated to them by means of screws or levers and weights applied to the ends of the top roller.

By passing paper between rolls on which devices have been cut or turned, the "repped" and other similar papers are produced.

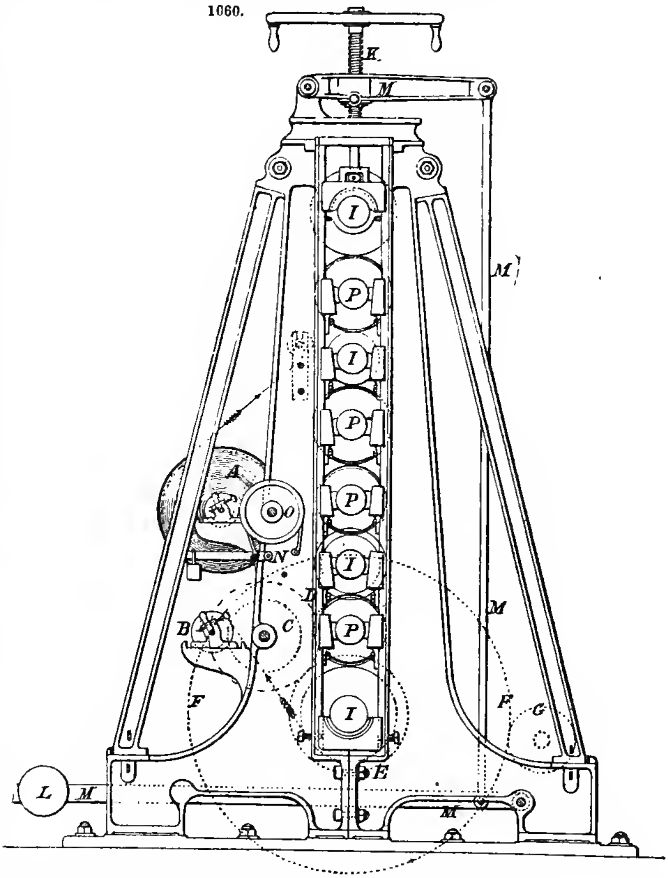
Cutting.—Except for special purposes, paper is usually sent from the mill in the form of sheets. The form of cutter generally used is shown in Fig. 1062. The paper from the webs A is drawn forward by the rolls B; it is then ripped into widths of a convenient size by means of two circular knives, the upper one of which is shown at C. It again passes between a pair of rollers, after leaving which, it meets a knife D fastened to the revolving drum E, and pressing against a fixed knife not shown. The cut sheets then fall upon the endless travelling felt F. The action of the knives will be understood by reference to Fig. 1063. The edges of the two knives are shown at A and B. The knife B has a slot, in which the bolt O slides, and it is kept in position by means of a spring. This spring causes the knife to slide back slightly as it comes against the fixed knife

1059.



A. The position of the paper is shown by the dotted line C. The knife B is set on the drum not quite horizontally, so that one end meets the stationary knife a little before the other, thus acting in every respect like a pair of scissors. Fig. 1064 shows a pair of ripping-knives. The upper one A is kept in position against the lower one B by means of the spring C. The cutting surfaces are slightly hollowed out, so as to have a sharper edge. The paper is shown by the dotted line D. By altering the relative speeds of the drum E and the rolls B, by means of the expanding-pulley G, sheets of any desired size can be cut. The cutting-knives are sometimes placed inclined to the drawing-in rolls B, so that the sheet, instead of being cut into a rectangle, is cut into a rhomboid. Such paper is used chiefly for the manufacture of envelopes, this shape occasioning a smaller loss when the envelopes are cut out.

1060.

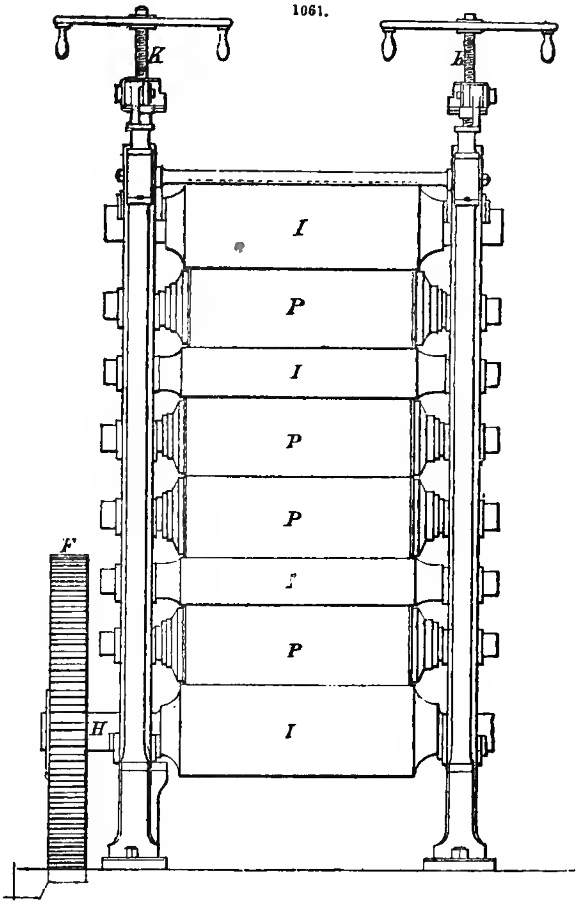


It is often necessary, as in the case of paper having a water-mark, that the sheet should be cut with great exactness, so that the device shall come exactly in the centre. The ordinary cutter cannot be relied on for this purpose, and, in its place, a machine called a "single-sheet cutter" is used (Fig. 1065). It consists essentially of a large wooden drum

A, fixed on a horizontal axis, over which the paper is led by a pair of drawing-in rolls B. The paper is held against the drum by a clamp worked by the arm C. The paper is cut by the knife E moving against the stationary knife D. After the cut, the drum describes part of a circle, the paper being still held, so that it cannot go back with the drum. As soon as it has gone far enough, the clamp is removed, and the drum returns, bringing the paper with it. The length of the arc through which the drum moves, and therefore the size of sheet, is regulated by the length of the crank-arm F. If, from any cause, the cut should not take place at the right time, the man in charge can, by pressing against the clamp, retard the motion of the paper, and thus bring back the cut to the right place. The small roller G is for the purpose of keeping the paper always tight.

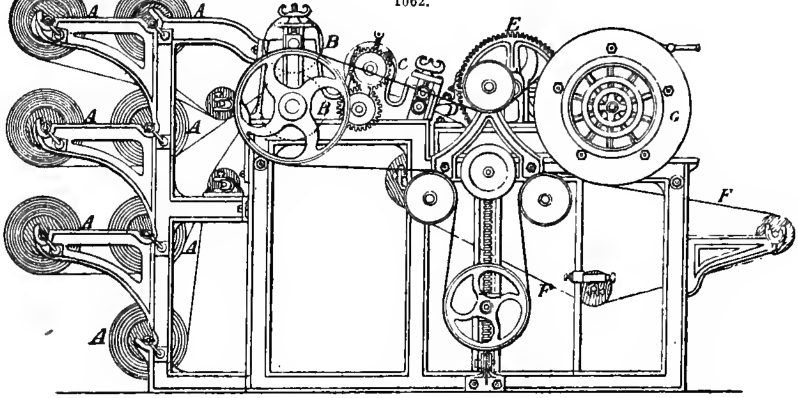
Soda-recovery Process. — In former years, the liquors in which rags, esparto, and other paper-material had been boiled, was run into a river or stream near; but now, owing partly to the fact that it is insisted on by the landowners, but chiefly because it can be made remunerative, all such liquors are preserved, and the soda in them is utilized. The method adopted is to evaporate to dryness, and ignite the residue, which then contains the soda, originally used as caustic soda, chiefly in the form of carbonate, mixed with a quantity of silicate and other salts.

1061.



The ash so obtained is dissolved in water, sometimes filtered, and boiled with a quan-

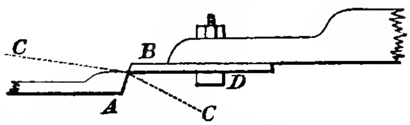
1062.



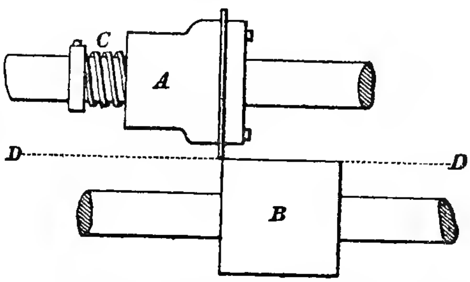
tity of lime sufficient to reconvert it into caustic soda, the lime at the same time being changed into carbonate. The latter is allowed to separate out by settling, and the clear liquor is run off. The carbonate of lime is washed once or twice with water, the liquor, if very weak, being used to dissolve fresh ash, and then, in the best conducted mills, it is allowed to drain on filters, beneath which a vacuum is produced by an air-pump, similar to the arrangement used in alkali-works. Of course the whole of the soda cannot be recovered in this way: loss by leakage, in addition to that left in the fibre, must inevitably occur; this is generally replaced by fresh caustic soda, or good soda ash.

The apparatus for accomplishing the evaporation varies with almost every mill. In some, it is very primitive and crude, consisting perhaps of only a furnace for incinerating the residue, and over it a pan containing the liquor, the latter being heated and evaporated by the heat from the furnace. It is obvious that, with such an arrangement, a large quantity of heat must be wasted. To economise as much as possible of this waste heat, various plans have been suggested. That of Roeckner, of Newcastle, appea s to be to a great extent efficacious. It consists practically of a series of shallow trays B (Fig. 1066) placed in a brick chamber, alternated so as to allow the heated air from the furnace below to play upon the surface of each in succession, on its way to the chimney, with which the whole system is in connection. Above the chamber containing these trays, is a large tank C containing a store of the liquor to be evaporated, placed there so as still further to economise the heat, and from which the liquor runs on to the trays. The furnace A below is of the ordinary reverberatory kind; below it, and connected with it by a kind of damper, is a large chamber J where the calcined residue from the furnace is put to cool, thus preventing any nuisance from the smell of the burning mass. The chamber is provided with a pipe L, through which the vapours pass into the furnace. Several pipes E from the furnace pass through the tank, to assist in warming the liquor. The residne, when cold, is drawn through doors from the chamber below the furnace. Roeckner has devised an apparatus (Fig. 1067), consisting of a small chamber containing a series of pipes A, through which, a stream of cold water constantly runs, in connection with the flue from his evaporator, for the purpose of condensing volatile bodies, and thus preventing, to a certain extent, contamination of the surrounding air.

1063.

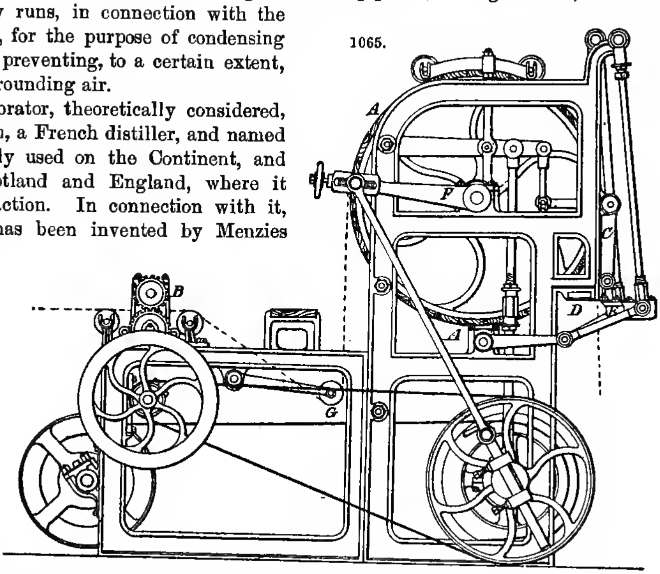


1064.



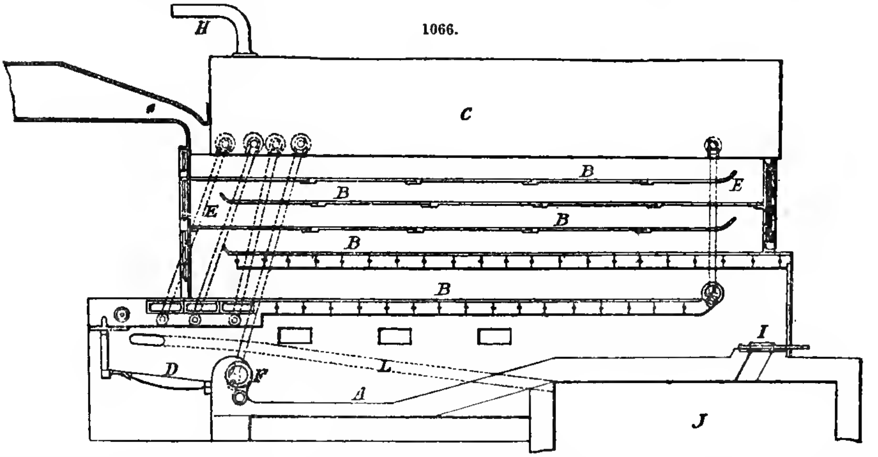
An economical evaporator, theoretically considered, is that invented by Porion, a French distiller, and named after him. It is largely used on the Continent, and at several mills in Scotland and England, where it has given great satisfaction. In connection with it, a "smell-consumer" has been invented by Menzies and Davis. It consists essentially of a large chamber, the floor of which is inclined slightly from the chimney. The liquor to be evaporated is ruu in at the end nearest the chimney, from a tank. Fanners, dipping about ½ in. into the liquor, revolve with great rapidity, and produce a very fine spray, thus presenting a very large evaporating surface. The evaporation is caused by the heat from the furnace on its way to the chimney. The "smell-consumer" consists of a fire-brick chamber, having courses of walls, built in such a way as to retard the draught somewhat, and so give time for the products of combustion from the furnace to be completely

1065.



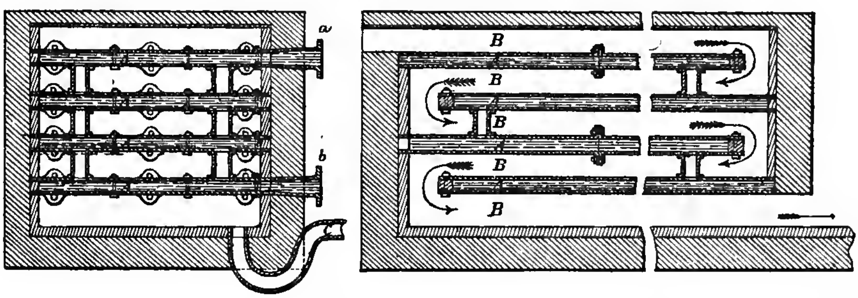
burnt. Time is all that is necessary, as the heat is quite enough, and there is always sufficient oxygen present. The doors are used for cleaning out this chamber. The tank is placed over this chamber, in order to warm the liquor, and thus still further economise the heat. The chamber is for the purpose of retaining any solid particles carried forward. The evaporated

1066.



liquid is run from one or more of the doors along a spout to the pan, from which it is run into the furnace. The furnace is of the ordinary kind, but with two beds. Here the liquor is still further evaporated, and the residue is incinerated. If the latter operation is properly conducted, no nuisance from smells need arise, and the combustion in the smell-consumer is perfect. The draught is regulated by a damper. (Continued on p. 1508.)

1067.



General Considerations. *Varieties of Paper.*—Paper may be roughly classed under three heads;—"Writing," "Printing," and "Wrapping." The different varieties of each are almost endless: the following list gives the principal kinds.

Writing.—Machine-made, hand-made, tub-sized, engine-sized, account-book (machine and hand-made), envelope, &c., &c.

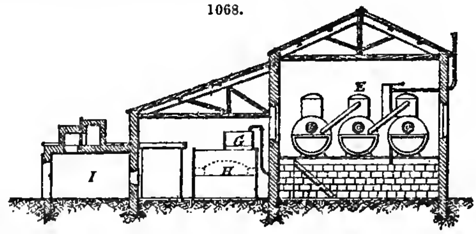
Printing.—Newspaper, magazine, book, plate, map, lithographic, music, coloured printings, bank-note, cheque, &c., &c.

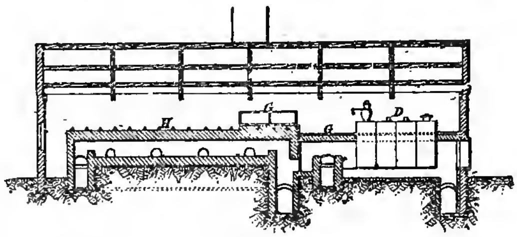
Wrapping.—Bag-paper; grocery-papers; browns—thin, glazed and unglazed; air-dried; machine-dried, cartridge, mill-wrappers, sugar-blues, &c., &c.

Selection of Site for Paper-mill.—In choosing a spot on which to build a paper-mill, the manufacturer has to take into consideration several very important circumstances. Chief of these is the necessity for having a large supply of water at command. Not only is a large quantity needful, but it should (see Beating, p. 1489) be free from impurities, such as suspended matter and iron. The former, it is true, can be removed by settling and filtration; the latter cannot, and is liable to injuriously affect the colour of the paper. Again, as a question of economy in working, it is advantageous to have convenient water-power; therefore for this, as well as for the former reason, paper-mills are usually situated on the bank of a stream. In choosing such a site, paper-makers are probably influenced by the fact that it affords a ready means for the removal of impurities. In properly conducted mills, where suitable apparatus is employed for evaporating the liquors in which the raw material has been boiled, the stream should not be polluted to any very great extent. Generally speaking, the greater the pollution, the more are valuable materials being loss to the manufacturer. It is obvious that the site for a mill should also be chosen with reference to its proximity to means of transit for the raw and manufactured materials.

Soda-recovery Process (continued from p. 1507).—The temperature of the vapours in the chimney is determined by the speed of the fanners. When these run at high speeds, the fine spray reduces the temperature of the combustion-products coming from the furnace, so that in the chimney it is below 82° (180° F.). On reducing the speed, the temperature will soon rise to 204½° (400° F.). An objection to the Porion evaporator is the volatilization of the soda, owing to its intimate exposure in solution to the heat of the furnace by the action of the fanners.

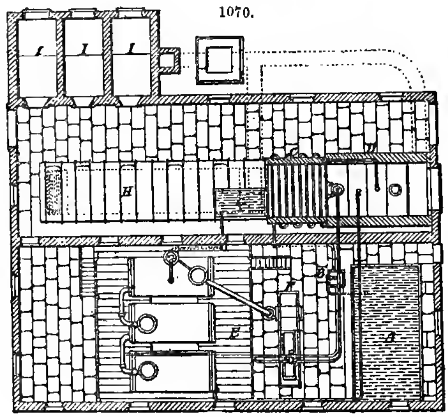
1068.

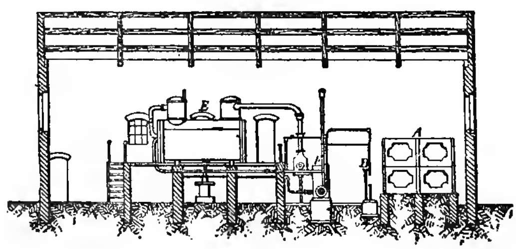




1069.

1070.





1071.

There has been lately erected in Lancashire an evaporator patented by Alfred Chapman, M.I.C.E., partner in the firm of Fawcett, Preston, & Co., Liverpool. In this (Figs. 1068–1071), the evaporation is effected at a low temperature in three vacuum-pans, with the unusual result that the concentrated liquor jellies after extraction from the third vacuum-pan, instead of taking the ordinary form of the concentrated products of other evaporators. It is said that this apparatus gives an excellent product, with great economy of labour and water, and with no drainage of foul liquor from the buildings. Observations extending over three months have proved that it evaporates 22 lb. of water from the liquor per lb. of coal used under the boiler, whereas other evaporators are considered to work well if 14 lb. are evaporated.

The waste liquor is discharged into the tank A, whence it is pumped by the donkey-engine B, through the feed-heater C, into the boiler D, which receives heat from the incinerating furnace H, and, in case of need, from an auxiliary furnace shown on the plan, under the feed-liquor heater. The steam produced in D is taken to the first vacuum-pan at E, and having heated its contents, the products of evaporation pass over into the tubes of the second pan; this, in its turn, gives up its products of evaporation to the third, whence they go to the condenser of the vacuum-engine F. Thus the heat from the furnace H is used for incinerating the concentrated liquor on its bed, for heating the feed-liquor in the feed-heater pipes, and for making steam out of the liquor itself in the boiler; this steam finally drives the donkey-pump and vacuum-engine, and causes the evaporation in the three vacuum-pans E. It is difficult to imagine a more economical apparatus.

Extent of the Industry.—The Directory of Paper-makers for 1881 shows that in England and Wales there are 259 makers, employing 424 machines; in Scotland, 61 makers and 102 machines; in Ireland, 14 makers and 18 machines. These numbers include 41 makers of hand-made paper, using 173 vats, in England; and 2 makers, 4 vats, in Scotland. A rough estimate of the amount of capital invested in the paper industry may be formed on the basis that average mills would represent 20,000–25,000*l.* for every machine.

Imports of Paper and Paper materials.—Our imports of paper in 1879 were as follows :—

Printing- and Writing-papers—75,388 cwt., 109,172*l.*, from Sweden; 73,308 cwt., 150,438*l.*, from Belgium; 44,570 cwt., 79,692*l.*, from Germany; 12,448 cwt., 16,125*l.*, from Norway; 10,235 cwt., 20,137*l.*, from Holland; 9678 cwt., 35,942*l.*, from France; 9187 cwt., 26,657*l.*, from Austrian territories; 3274 cwt., 7108*l.*, from other countries; total, 238,088 cwt., 445,271*l.*

Paper-hangings—7059 cwt., 8351*l.*, from Sweden; 5583 cwt., 44,404*l.*, from France; 880 cwt., 2756*l.*, from other countries; total, 13,522 cwt., 5554*l.*

Brown, Waste, and other (unenumerated) sorts—94,874*l.* worth from France, 87,108*l.* from Holland, 83,299*l.* from Germany, 39,433*l.* from Belgium, 35,555*l.* from Sweden, 12,964*l.* from Norway, 11,593*l.* from the United States, 5194*l.* from other countries; total, 370,020*l.*

Millboard and Pasteboard—194,583 cwt., 100,759*l.*, from Holland; 111,903 cwt., 50,700*l.*, from Germany; 53,319 cwt., 29,954*l.*, from Belgium; 10,203 cwt., 8002*l.*, from Norway; 6711 cwt., 5007*l.*, from Sweden; 3579 cwt., 7918*l.*, from other countries; total, 380,498 cwt., 202,340*l.*

Linen and Cotton Rags—5457 tons, 96,641*l.*, from Germany; 2877 tons, 46,414*l.*, from Russia; 2540 tons, 28,758*l.*, from Turkey; 1941 tons, 30,178*l.*, from Belgium; 1784 tons, 32,011*l.*, from France; 1192 tons, 12,545*l.*, from Egypt; 1051 tons, 16,196*l.*, from Holland; 1086 tons, 12,093*l.*, from other countries; total, 17,928 tons, 274,836*l.*

Esparto and other Vegetable Fibres—68,910 tons, 376,284*l.*, from Tripoli and Tunis; 46,636 tons, 307,488*l.*, from Algeria; 44,091 tons, 357,531*l.*, from Spain; 2334 tons, 14,313*l.*, from other countries; total, 161,971 tons, 1,055,616*l.*

Pulp from Rags and Wood—18,190 tons, 148,018*l.*, from Norway; 4271 tons, 41,969*l.*, from Sweden; 1722 tons, 7517*l.*, from Holland; 752 tons, 6590*l.*, from British India; 735 tons, 5780*l.*, from Belgium; 605 tons, 5179*l.*, from Germany; 1532 tons, 15,015*l.*, from other countries; total, 27,807 tons, 230,068*l.*

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PARAFFIN (Fr., *Paraffine*; Ger., *Paraffin*).

The paraffin of commerce, a beautiful, translucent, snowy-white, wax-like substance, is not, chemically speaking, a homogeneous substance, nor constant in its physical properties. The sp. gr. varies from 0·8236 to 0·9248. The fusing-point of commercial paraffin ranges from about 35° (95° F.), to 55° (131° F.); much higher fusing-points are occasionally met with, but specimens melting at 80° (176° F.) are of curious and scientific, rather than of commercial, interest. Within certain limits at least, and other things being equal, the higher the fusing-point, the more valuable is the sample. Paraffin is insoluble in water and in cold alcohol, slightly soluble in hot alcohol, and completely so in essential and fixed oils, benzol, ether, and carbon bisulphide; the solubilities of the different samples increase as their fusing-points decrease. As will be apparent, this property has important bearings on the refining process, as also the crystalline structure, which it assumes when the tarry matter is removed by distillation. In samples fusing at about 34°–38° (93°–100° F.), the crystals are large and well defined; while in samples fusing at 49°–55° (120°–131° F.), this structure is not so evident, though microscopic examination shows that, if less than $\frac{1}{100}$ part of the size of those in the former sample, the crystals are still there. Paraffins mix with stearine, palmitine, and resins, in all proportions; but it is to be noted, that the melting-points of such compounds are not nearly the mean of those of their ingredients; while the melting-points of mixtures of different paraffins are very nearly so. Another peculiarity of this substance is the condition of plasticity which it assumes, at a temperature very much below its fusing-point.

Chemically considered, paraffin is a mixture of the two elements, carbon and hydrogen; and the analysis of many samples, from different sources, demonstrates that these elements exist nearly in the same proportions as in olefiant gas. Consequently, good chemists, after careful investigation, have been led to conclude contrary to the general opinion, that the solid paraffins are mixtures of the higher olefines, which have a percentage composition of 85·7 carbon and 14·3 hydrogen. The chemical behaviour of these paraffins in the presence of reagents favours the theory which places them in the series represented by the general expression C_nH_{2n+2}; the letter *n* representing the number of carbon atoms in the compound molecule. In this so-called homologous series, which has as its first term methane or marsh gas (CH_4), the other terms are formed by successive additions of the compound molecule (CH_2), the second being ethane (C_2H_6), and so on, each member containing twice as many atoms of hydrogen as of carbon, plus two. The atomic weight of carbon being 12, and that of hydrogen 1, the carbon percentage will increase from 75 per cent. in the monocarbon paraffin, to 85·1 in the 20-carbon, and 85·31 in the 30-carbon; and it is evident that, though always approaching the theoretical percentage composition of the olefine (C_nH_{2n}) series, it could never reach it. It is, however, to be observed, that the percentage in the higher members comes so near, that analysis, owing to errors arising from defective method, cannot settle the question.

The lower hydrocarbons of the paraffin series are, at ordinary temperatures and pressures, gaseous; ascending the scale, we come to liquids under similar conditions, and after that, at about the 20th member of the series, to the solids. Where these have been isolated by fractional distillation, it has been found that, at every step, there is a rise in vapour-density, and boiling-point, and, in the solids, in fusing-point. In some samples of petroleum, many of the members have been found to exist. Ronald isolated eighteen from an American sample, and, apart from the chemical indifference which marks the series, the fact of the association of the higher with the lower undoubted paraffins, strongly favours the generally held opinion as to their family connection. In the laboratory of nature, it is more than probable that the entire series has been produced.

If a piece of solid paraffin is heated for some time in a closed vessel, it is broken up into paraffins of lower molecular value, and partly resolved into olefines; and the higher the structure of the paraffin, the more easily it is destroyed or degraded. This is important, as bearing on the processes of distillation and chemical treatment.

Manufacture.—Paraffin in the native, ready-formed state is widely distributed over the world. Dissolved in kindred oils, it is found in abundance in the United States of America and in Canada, and is known by the name of "rock-oil" or "petroleum" (see Oils, p. 1433). The yield of solid paraffin from American petroleum is not more than 2½ per cent.; in Upper Burmah, petroleum is produced containing from 5 to 10 per cent. of crude paraffin; in Galicia, Wallachia, and on the shores of the Caspian, along with petroleums, are found solid deposits which are richer in paraffin, known by the names of "naphthagil" or "neft-gil," "ozokerit," "ceresine" or "mineral wax" (see Wax—Ozokerit). The percentage in these deposits is from 15 to 40 per cent. Paraffin is also met with in bituminous deposits in various localities.

Large quantities of this substance are produced on the Continent, from brown coal or lignite; but in this case, as in that of the cannel coals and shales, it does not already exist, but is a product of destructive distillation.

The industry in Scotland has, during late years, attained considerable magnitude, as may be gleaned from statistics published lately by Calderwood. He estimates the shale distilled in Scotland, by eighteen firms who have monopolized the trade, at 850,000 tons; the crude oil produced, at 29,000,000 gal.; the naphtha and burning-oil, at 11,400,000 gal.; lubricating-oil, at 5,000,000 gal.; paraffin-scales, 9200 tons; and sulphate of ammonia, 4790 tons.

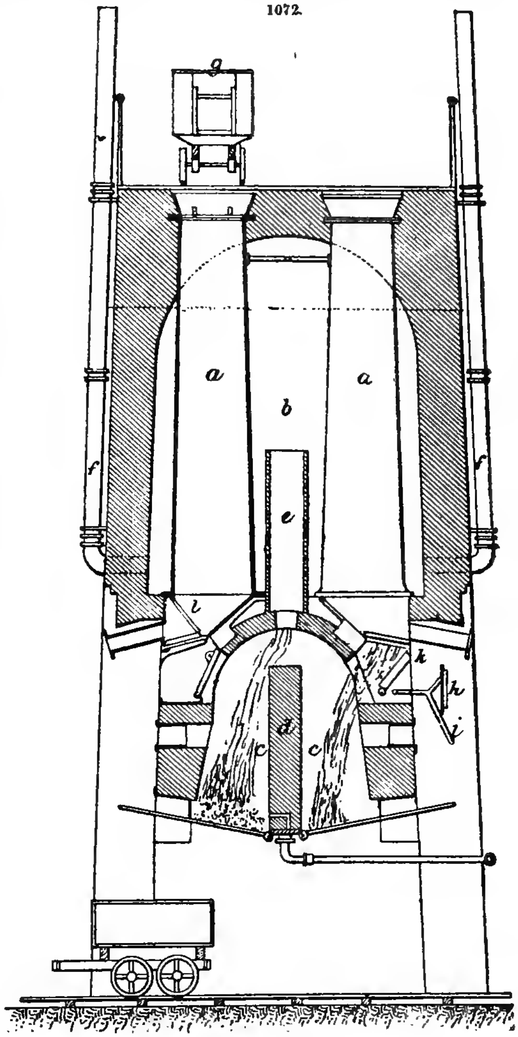
The principle of destructive distillation referred to is also involved in the manufacture of illuminating-gas. In both cases, heat is the active agent. The vessel or apparatus into which the shale or coal is put is called a "retort." Essentially it is a large bottle, made of materials fitted to withstand the action of fire, opening into a condensing arrangement, more or less simple, according to special requirements. In this, its primitive, simple construction, the one opening must needs serve three purposes, namely receiving the charge, allowing the coke to be taken away when the distillation is finished, and drawing off the gases. In practice, there are always two openings, sometimes one for each of the three functions. When heat is applied to the outside of a retort containing shale, from which air is excluded, decomposition takes place, and very numerous and complicated compounds are formed, which come away as vapour. On the degree of heat, however, depends the character of these, notably in this respect:—A very high heat, such as is used in gas-making, produces a maximum of lighter gases, which remain permanently gaseous. The paraffin-distiller knows that the dull-red heat, which will just suffice to loosen the bonds which bind the hydrocarbons to their clay-like matrix, will best serve his purpose; and though he is compelled to exceed the desired minimum, he does so with reluctance and from necessity.

In practice, it is found that the chemical tie which binds the hydrocarbons to the shale, will not be dissolved by a temperature which would volatilize them if free. Again, all the contents of a retort do not come into immediate contact with its sides; and if the material in the middle of the retort is to get just the amount of heat necessary to set its gases free, it must be at the expense of that in proximity to its sides getting too much. Another difficulty arises from the fact that the hydrocarbons evolved have an extended range of boiling-point. It does not seem possible to completely overcome these difficulties; but we must appreciate the ingenuity and skill displayed by engineers who have constructed retorts which fulfil the chemical requirements in a high degree, and at the same time the commercial, which demand economy in labour, fuel, and wear and tear.

The horizontal retort is remarkably simple in construction. At one end of an oval-section body, of variable length and diameter, is the door by which the broken shale is put in, and closed by an air-tight lid. At the opposite closed end, it is connected with a hydraulic main, by a pipe 4–8 in. in diameter. The main and exit pipes are kept low, to favour the ready escape of the vapours, which are dense. Between the main and the retort, is a valve which closes the pipe, when the retort is being charged or emptied. From five to seven of these retorts may be built in one oven, and heated by one fire; and an indefinite number may be connected with the same main. The heat being very low, the condensing arrangements are simple. Steam at low pressure is now very generally introduced with beneficial effect—a gentle flow, carrying along with it the vapours as they are formed.

The vertical retort is more complicated in all its forms. As that invented by Norman M. Henderson, of the Broxburn Oil Co., to whose kindness the illustration and description are due, is much approved, it will be described in detail. It is now in extensive use in the principal oil-works in Scotland, having been erected in the Addiewell works of the Youngs Co., and at the Broxburn, Uphall, Oakbank, and several other works.

1072.



The retorts *a* (Fig. 1072) are 15 ft. long, having a cross-section of a flat-oval form. Four of these retorts are set into one oven, which is a high arched chamber *b*, closed at the top. Straight under the oven, is the furnace *c*, which is a capacious arched chamber, divided into two by the wall *d*, rising to near the top of it. It is connected with the oven by the flue *e*, which rises about 6 ft. from the centre of the arch. This flue acts as a screen to prevent the four retorts, which surround it, from being overheated. The products of combustion enter the oven by this passage, and being hot, float to the top of the arch, replacing the cooler products previously there, which, as they cool, gradually fall down, and pass out at the exit pipes *f* placed at the bottom of the oven.

The retorts are charged from hutches *g*, run on rails along the top of the building. The doors on the top of the retorts are opened, and the hutch contents are tipped direct into them. The doors are then shut close until the charge is spent, which takes 16–20 hours. The retorts are closed below with a removable door *h*, and when the charge is exhausted, this door is taken off by a simple implement *i* for the purpose, and at the same time, a little valve or shoot *k* folds back from an opening in the top of the furnace-arch, and the spent shale, falling down by its own weight, is shot directly into the furnace below. The retort is bevelled at the bottom, so as to let the removable door be made of smaller and handier size, and be within easy reach of the workman. The retorts are emptied in rotation, at intervals of 4 hours, from each side of the furnace alternately, so as to keep the temperature equal throughout. There is little carbon left in the spent shale, and too much draught would extinguish it, so the furnace and oven are constructed so as to cause a very gentle influx of air. The slow current also enables the retorts to get full advantage of the heat of the combustion-products. The spent shale falls into the furnace black though hot, but in 5 minutes it is glowing brightly. It continues to burn for 8 hours. In this manner, is produced with certainty the mild heat fitted to give the highest percentage of products, and the best quality of crude oil. The temperature is thus beyond the influence of the workman, and skilled labour is rendered unnecessary. The non-condensable gases are let into the furnace, and burned along with the spent shale. From what has been said, it will be seen that the lower end of the retort is the coolest part; consequently the oil-vapours are led off from the bottom. Super-heated steam is blown into the top of the retort, so as to sweep the oil-vapours out of the region of heat as soon as formed, to prevent their being broken up into lighter and gaseous products, the heavier being the more valuable. A series of pipes is arranged along the side of the oven, and through these the steam is passed, so that it enters the retort super-heated above the temperature of the oven, and so diffuses the proper distillation temperature throughout the whole mass of the shale; consequently no part requires to be overheated.

The old vertical retorts are heated with coal-fires, and are generally worked at much higher temperatures. The results are altogether dependent on the workmen, as, with such powerful fuel, great care and skill are required to equalize the temperature. At the bottom of Henderson's retort, is a grating *l* (Fig. 1072), which prevents the shale getting down into the corner which is out of the heat; and when the bottom plate is taken off, this grating falls over the oil outlet, and protects it from the spent shale. When the spent shale is thoroughly burned, the bottom plate of the furnace folds down, so as to drop the ashes into a hutch below. To extinguish the embers, the hutch is passed through a tank of water, on the way to the refuse heap. The advantages claimed for the Henderson retort over the old vertical are: a larger yield of the more profitable materials, namely, paraffin-wax, lubricating-oil, and ammonia; increased yield; saving of fuel; long life, and less cost of maintenance; and reduced loss in refining. The saving of fuel, maintenance, &c., is equal to 1*s.* 6*d.* a ton of shale distilled, or 4*s.* 6*d.* on each 100 gal. of crude oil. Assuming, however, the yield of crude oil and ammonia to be the same from either retort, the profit can be illustrated in the following manner:—

Result from 100 gal. of crude oil:—

Henderson's.			*d.*	Old Vertical.			*d.*
5·00	per cent.	naphtha at 4*d.*	20	5·00	per cent.	naphtha at 4*d.*	20
35·00	,,	burning-oil at 4*d.* ..	140	40·00	,,	burning-oil at 4*d.* ..	160
18·00	,,	lubricating-oil at 8*d.* ..	144	13·00	,,	lubricating-oil at 8*d.*	104
10·50	,,	scale at 30*d.*	315	8·00	,,	scale at 30*d.*	240
31·50	,,	loss		34·00	,,	loss	
100·00			619*d.*	100·00			524*d.*

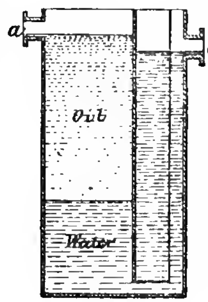
There is thus a difference of 95*d.* or 7*s.* 11*d.* in favour of Henderson's, arising from increased value of products, which, added to the 4*s.* 6*d.* saving in manufacture, amounts to 12*s.* 5*d.* per 100 gal. of crude oil distilled, or 4*s.* 2*d.* per ton of shale.

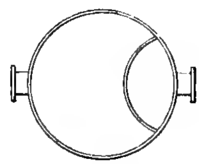
The products of distillation are received into the hydraulic main, which is a long cylinder laid on its side, extending along the bench of retorts, the exit pipe of each retort dipping into it. At the bottom, is collected the water, partly produced from combustion, and partly by the condensed steam. In this, are dissolved various salts of ammonia; it is technically known as ammonia-liquor. Over this in the main, is the crude oil. At the end of the main, before it enters the condenser for the purpose of separating the already condensed watery and oily products, is a trap and separator. The trap is to prevent the loss of vapour, and at the same time to allow the liquids to pass. The separator, Figs. 1073 and 1074, is a vessel of considerable depth, say 3 ft., divided into two portions by a vertical partition, which is carried not quite to the bottom. The oil and water are together led into the larger division of the vessel. The oil, being the lighter body, floats on the top, and by an outlet *a* from this larger division, near its top, is led away to the crude-oil tank. The water, by virtue of its gravity, finds its way under the partition, into the other portion of the separator, seals up the passage against the oil, and, by an outlet *b* placed at a level a little lower than the oil-outlet escapes into its proper receptacle, to be afterwards treated for the manufacture of sulphate of ammonia. The uncondensed gases are led from the main to a series of condensers, where they are cooled down to the normal temperature; and the permanent gases are led away either to be burned in retorts, or to a coke tower, where they are brought into intimate contact with heavier oils, which absorb them. The condenser is in some cases almost exactly like those used in gas-works, its base being a large chest or chests with faucets at top, on which are erected long inverted U-shaped pipes, or condensers.

Generally all the oily products of combustion are collected into the tank, and known as "crude oil." This, after being thoroughly freed from water by sediment, is pumped into a large cast-iron still, and heat is applied till all the volatile portion is driven over. The residue left in the still is merely cinder or coke, which is broken up and sold for the manufacture of ironfounders' blacking.

The condensed distillate is known as "once-run oil." This is pumped into the refinery. The arrangements in a refinery are generally of this nature—At a high level, are one set of large iron, or wooden lead-lined, tanks, which are intended for the acid treatment of the oils at the various stages. At a lower level, is placed another set of similar size, for the treatment with caustic soda. In each tank, which may hold several tons of oil, is a stirrer. One of the most efficient, is that designed by A. C. Kirk, on the turbine principle, and which, for the acid treatment, is driven at the rate of 200 rev. a minute. The stirring is also very effectively done by pumping air into the mass of oil; and this simple method of agitation has much to recommend it, as there is nothing exposed to the corrosive action of the acid, save the iron pipe through which the air is injected. The once-run crude oil is pumped into one of the high-level agitators, with 2½ per cent. of sulphuric acid, sp. gr. 1·840, or refuse acid, in whole or in part, which has formerly been used in the more advanced stages of the process. The oil assumes a beautiful purple tint under the action of the acid, as the brown decomposed matter settles down with the acid. What the precise nature of the reaction is, does not seem to be wholly understood. It appears, however, that the hydrocarbons which have a deficiency of hydrogen yield that hydrogen more readily than those which are saturated, and are so decomposed by the dehydrating agent. Theory would suggest that instead of destroying, it would be more rational to add the required hydrogen, and so build up paraffins, but hitherto this has not been found practicable. After having settled, the acid tar is run off by a valve below, and the supernatant oil is run into the lower-level agitator, where 1½ per cent. of caustic soda, 1·35 sp. gr., is added, with slight agitation. This treatment, besides neutralizing the trace of acid left by the last operation, removes the congeners of phenol. The sediment is known as "refuse soda."

1073.





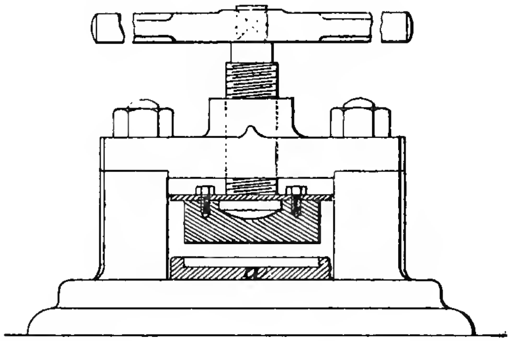
1074.

After the soda treatment, the "once-run treated oil" is again pumped into a still, say 6–7 ft. in diameter, and 16–20 ft. long, of malleable iron, cylindrical in form, laid horizontally. Between the fire and the boiler-plate forming the bottom of the still, is a fire-brick arch, with portholes at the flanks, for the purpose of spreading the furnace-flame equally over the bottom of the still. The oil-still is united, by a goose-neck connection, to an iron condensing-worm of considerable dimensions, immersed in a tank kept full by a continual influx of water, which, when heated, escapes by an overflow. At the extreme end of the condenser, is placed a separator, as before described. The distillation is aided by steam. The still has a manhole on the top, and a valve at one end of the bottom, by which to run off the tarry residue. Up to this point of the process, no attempt has been made at separation of the products; but now advantage is taken of the fact that the oils of lighter gravity distil over at a lower heat, and that as the process of distillation is continued, and the heat is increased, the heavier pass over. During the distillation, the sp. grs. are watched, and the flow of the distillate is diverted to separate tanks, as the required densities are reached. It is usual to make one division when the sp. gr. at the worm-end reaches 0·790, and another at 0·850, when paraffin begins to show. The naphtha and light-oil fractions, after another acid and alkali treatment, are again distilled and fractionized. The very lightest portion, such as is obtained from the coke tower, is used for the production of illuminating-gas, by the impregnation of atmospheric air with its vapour, by simple agitation in a portable gasogen. Naphtha of a sp. gr. of 0·735 is used as a solvent in many of the arts, and also in the subsequent process of refining the wax. That at 0·765 is a heavy spirit, economical for the latter purpose, and safer. These are all volatile at a heat below 100° (212° F.), and are consequently called "spirit." The light-oil fraction, on redistillation, is again divided into "No. 1 burning-oil," 0·800–0·810, No. 2, 0·810–0·820, and No. 3, 0·820–0·830. The oils between this latter sp. gr. and 0·875 are inferior, and used for open-air lamps, or torches, or machinery cleaning, as they possess little lubricating properties. "Washed oils" are those which have been finished by chemical treatment, but an oil finished by distillation is considered the best for burning. The latter fraction of the once-run is cooled by the refrigerating machine of Siddely and Mackay, described under Carbolic Acid (p. 674). The frozen oil containing paraffin is bagged, or put into a filter-press, and after it has been reduced in bulk by filtration, it is spread on canvas wrappers, and pressed in an ordinary hydraulic press. The residue left in the bags is called "scales"; the filtered oil, "blue oil," after treatment with 3 per cent. of sulphuric acid and 1 per cent. of soda, is again, after distillation, cooled down, and crystallization once more shows itself in the formation of paraffin of improved colour, but lower fusing-point. This is separated as above, and the oil, after another treatment, is used for lubricating purposes, and has a sp. gr. of 0·875–0·885. In the several distillations, the early fractions are reserved, and sent to the oil-tanks which contain oil of like gravity and purity; and the latter fractions are sent back in the process for further treatment, as they are less pure. These are the principles which guide the oil-refiner, though practice may vary in details. The tarry residue left in the still is either coked down, in a cast-iron still, or sold as a coarse grease.

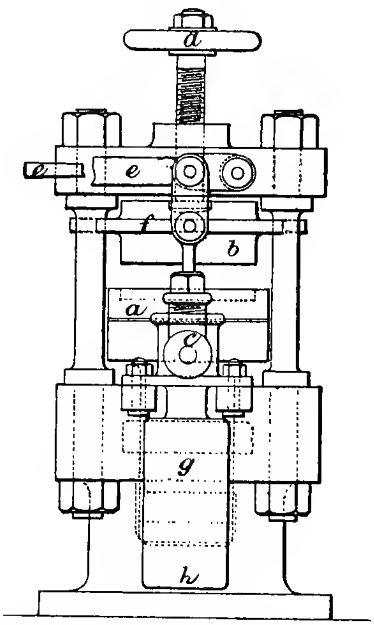
This conducts the reader to a distinct stage of the process, namely the refining of the scales.

Refining.—The solid residue, after hydraulic pressure, is sold to the wax-refiners as "paraffin-scales." If the fusing-point is over 48° (118° F.), it is called "hard," if below this, "soft" scales. When the previous treatments have been well carried out, and the latter pitchy products of distillation cut off in time, the scales will crystallize well and refine easily. Good scales should yield 80–85 per cent. of refined paraffin. The 15–20 per cent. is made up of oil, water, dirt, and degraded greasy hydrocarbons, which must be washed out, or destroyed. As this loss is a very important item to be taken into account by the refiner, some ready means of testing any sample is desirable. An analysis is impracticable from the nature of the material. As a relative test between sample submitted and bulk delivered of same make, the hand screw-press, Fig. 1075, has been introduced. It does not determine how much oil a sample contains, for the best refined scales will not yield their oil to any pressure, nor even their water, within several per cents., but it simplifies the problem very much when, for purposes of comparison, there are two samples of the same dryness. The press is used thus. The cast-iron saucer *a* is taken out of the press; 14 discs of blotting-paper are cut exactly to fit its inside, and two of linen, which latter should be very fine and of close texture; 5 folds of blotting-paper are placed neatly in a saucer, then one fold of linen. On this, 250 gr. of the finely-powdered sample are carefully spread, and covered, first with the disc of linen, and then with 5 folds of the bibulous paper. The saucer is then put into the press, and the power of two men, one on each end of the lever, is applied. After a minute, the pressure is relieved, and the 10 folds of paper, which will have imbibed most of the oil, are replaced by the other four fresh pieces; the same pressure is applied, and the sample is allowed to remain under pressure for 10 minutes, when it is taken out. The very neat sandwich is opened up, the cake is weighed, and the difference between the two weighings is noted, and reduced to percentage. It is of importance that all this should be done in a room carefully maintained at 15½° (60° F.). A better press, as affording a means of estimating the actual pressure applied, is shown in Fig. 1076. It is wrought by hydraulic pressure, and is furnished with a pressure-gauge. The base of the press forms the cylinder, and the dotted lines show the piston, widened at top, supporting a movable saucer *a*, which is pushed by the water in the cylinder by a force-pump *c* against the stud *b*. When the operation has been completed, and the water let off, the piston is pushed down by a screw *d*; then by reversing the screw the press is opened. The pump-lever is at *e*. A pressure-gauge, omitted from the drawing, shows the amount of pressure applied. The plate *f* notched at the corners, slides on columns, and acts as a guide to the stud *b*. The hydraulic cylinder with piston is at *g*, and the water-tank for the pump at *h*. The water and dirt may be estimated by obvious methods. It has been the practice of one of the largest English firms, to subject scales submitted to a further test, by melting, and mixing with strong acid (sulphuric), which destroys the low greasy bodies.

1075.



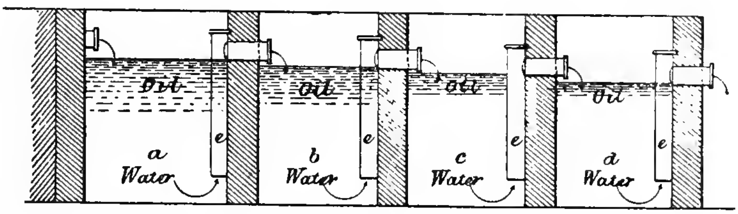
1076.



To a great extent, the process of refining paraffin-scales is one of recrystallization. The lower paraffins and impurities are much more soluble in their oils and naphthas, than the higher and better paraffins, which crystallize, and separate easily from the mother-liquor containing the former. The purification is accomplished in different ways, but attention will be confined to one system, which is perhaps as economical as any, while as to the quality which can be produced by it, there is no question.

The scales are melted in a large pan, by steam introduced directly into the mass, by a bent coil of malleable iron pipe, say of 1¾ in. diameter. When it has been boiled, it is allowed to deposit what mechanical impurities it contains. It is well to have this pan with a tapered bottom, and a large valve below to let off the water and as much dirt as possible. The water is collected in a large separator, constructed on the principle mentioned before, as there is always some paraffin that escapes with the water and dirt. This separator should be very capacious. The same arrangement should be in connection with every pan where there is boiling with open steam, or contact with water; and the water from all these should be led into a very large compound separator, constructed as shown in Fig. 1077. The arrows show the direction of drainage. Division *a* will intercept most of the oil, but a little may escape to the second and third divisions *b c*. The

1077.



separator with division walls is made of brickwork cemented. The pipes, open at top, so as to give facility for cleaning, may be of fire-clay or iron. This first melting-pan has a tap at say 18 in. above its bottom, and when the water and dirt have subsided below this, the clean melted scale is siphoned off into another pan, where it is mixed with 25 per cent. of shale naphtha, or that which has been previously used at a later stage of the process, and is consequently comparatively pure. This mixture is now allowed to run into shallow moulds, of such size that two cakes will cover the platten of the hydraulic press, and about ⅝ in. thick. The press used is that fully described in the article on Candles, p. 587. When cold, each cake is put into doubled mats of coco-nut-fibre, covered inside with canvas, in form like the covers of a book, with the edges thickened by a doubling over of the matting. One of the presses referred to will hold about 80 of these cakes in their wrappers, with wicker mats at frequent intervals to stiffen the two columns of 40 cakes each. When the pressure is applied, the oil flows away in streams, carrying along with it the impurities and low greasy paraffin into a tank below. After standing say 3–4 hours, till the other presses of the set have been filled, the cakes are taken out, and represent about 4½ cwt. of cake of a much paler complexion than when put in. The expressed wash is submitted to distillation, and the naphtha obtained may be used over again; the paraffin, after pressing, is either mixed among the scales, or kept for producing a refined wax of low fusing-point. The paraffin, which, along with dirt and water, escaped from the first melting-pan, is found as a cake on the separator, and is just returned to the pan at the next filling. The dirt, after mixing with a little crude oil, is bagged, and steamed in a vessel over the separator.

Thus the first stage of refining is disposed of. The once-pressed cakes are again treated in the same manner, either with pure naphtha, or with the wash derived from a third pressing. The pressing is done in a separate department, where another set of presses are erected, over a tank to collect the wash. This wash, as has been indicated, may be used for a solvent for the scales at the first stage. The cakes, when taken down, are nearly white; they are again melted, as before, but this time in every case with pure naphtha. It is very important that, in the distillation of this, it should have been carefully fractionated, so as to have no burning-oil left, as any trace of this would leave an odour with the material, which would lower its value. The cakes, when cold, are put into the press again, and come out clear and transparent, but smelling strongly of naphtha; to remove this, they are put into a still or rectifier, heated with a gentle fire, and agitated by a pierced coil of iron pipe, admitting steam into the liquid. The rectifier is connected with a very capacious condenser, so that the naphtha is saved for future use. The wash from this third pressing is concentrated by distillation, and either sent back a stage in the process, or caked, and pressed to finish with another wash, as "refined paraffin," of low fusing-point. The fusing-point of the finished wax, between wide limits, is under the control of the refiner.

The last and finishing stage of the process is the treatment with animal charcoal. The rectified paraffin is freed from water, and put into a double-cased pan. Between the casings, steam at 30 lb. pressure is admitted, which dries the paraffin. Some 5–10 per cent. of freshly burned animal charcoal, as fine as flour, is stirred for ½ hour among the liquid, and then allowed to subside. When clear, which it will be in about an hour, it is run off, at a point just above the sediment, into a filter. This must be of peculiar construction. The case is a jacketed cylinder, closed at bottom, except a small hole with female screw. Another light cylindrical framework of smaller size is inserted in this, and fixed in its place by a male screw, fitting into the hole in the outer case. This screw is a hollow pipe, through which the filtered paraffin escapes. The inside perforated frame is covered with bibulous paper, and the hot paraffin is led from the pan, and allowed to fall between the outer and inner frames. It finds its way through the pores of the blotting-paper, into the inside frame, and escapes by the bottom hole into its receptacle. The unfiltered paraffin is kept hot and liquid by the steam confined in the outer case, otherwise filtration could not go on. The water-white liquid is now put into the moulds to cool, and next day the cakes are ready for boxing. It will be seen that the processes, though simple, are tedious; and in practice, a week elapses, counting from the time when the scale is melted, till it is weighed, and put into cases for sale. It is, however, the residues of the different operations which are most troublesome. One that has not been noticed is the charcoal left in the bottom of pan. More than its own weight of paraffin adheres to it, when all that decantation can do has been done. It has been found best to dissolve out the paraffin with repeated washes of naphtha, which can go to the third wash of the process. Any naphtha remaining can be removed by retorting, and the char be either sold to blacking-makers, or, after reburning, be used again for refining.

Modifications of this method, and other methods, have been adopted, but as these are alluded to in the article Candles, there is no occasion to repeat them here.

The paraffin refined block should be of an opalescent whiteness, perfectly free from taste and smell. When two pieces are struck together, they should emit an almost metallic sound. It should be free from scaliness, and smooth on the surface. Quick cooling and thorough washing and pressing favour this.

The uses of paraffin are numerous. The greatest quantity is employed in the manufacture of candles. It is also used for tapers and vestas, and inferior qualities in the manufacture of matches. It is used by calenderers for sizing and glazing their fabrics. It is also said to be used to impart a finish to woollens, and in some patent process for waterproofing. If the new process of tanning of leather by bichromate of potash should be a success, a very considerable quantity of paraffin of medium quality will be required. To the chemist, it is, from its cleanliness and other properties, fitted to replace other oils in high-temperature baths; and from its indifference to chemicals, is useful for coating any frail substance, such as paper, so that he can improvise a vessel that will hold water or the most corrosive acid or alkali. It is invaluable to the electrician as an insulator, and, when mixed with indiarubber, it imparts to it the property of setting solid when cooled, after it has been melted by heat. A special quality of high melting-point is manufactured for the purpose of coating the inside of barrels holding beer for export.

Imports.—Besides the paraffin manufactured in the United Kingdom, considerable quantities of foreign are consumed. Our imports in 1879 were:—34,273 cwt., value 82,728*l.*, from the United States; 21,213 cwt., 70,591*l.*, from Germany; and 296 cwt., 622*l.*, from other countries; total, 55,782 cwt., 153,941*l.* H. L.

(See Alkalies—Ammonia; Candles; Coal-tar Products; Gas [Coal]; Oils—Mineral; Wax—Ozokerit.)

PEARL AND CORAL.

Two marine products bearing some resemblance to each other in origin, occurrence, mode of procuring, artistic application, and value, are pearl and coral.

Pearl (Fr., *Perle*; Ger., *Perle*).—Many molluscs line the interior of their shells with a coating formed of alternate layers of animal membrane and carbonate of lime; this, in some species, assumes a nacreous or pearly lustre, and forms the substance known as "mother-of-pearl." A superabundance of this secretion is often produced in drops or tuberosities, adhering to the interior of the shell, or lodged in the fleshy part of the occupant; these form the "pearls" of commerce. The formation of mother-of-pearl is evidently a natural and unvarying process with certain species of mollusc, though little research has been made as to the conditions which favour or retard it. The production of pearls, on the other hand, at least in the case of the true pearl mussel, is accounted accidental (possibly on insufficient grounds), and is generally attributed to disease or injury suffered by the occupant of the shell. This seems to be borne out in some measure by the following experiences gained in the pearl-fishery:—(1) When the shells attain great size, with a smooth, clean exterior, free from excrescences, holes, or other blemishes, indicating full and healthy development of the animals, and particularly noticeable where their occurrence is sparse,—there pearls will be extremely scarce; (2) where they are closely crowded, deformed and stunted in growth, studded with excresences, and honeycombed with small perforations penetrating into the nacre,—there pearls will abound. Sometimes 100 pearls may be found in one shell, but in that case, few, probably none, will have a commercial value.

Sorts and Sources.—True pearls are formed only in bivalve shells, but handsome nacreous formations are obtained also from some univalves. The species whose productions are known in commerce are as follows:—(1) The true "pearl-oyster" or -mussel (*Avicula margaritifera*), yielding the most valuable pearls, while the shell itself is valueless; (2) the mother-of-pearl mussel (*Meleagrina margaritifera*), chiefly valuable for its mother-of-pearl, the shells being 6–18 in. across, while the pearls found in them also possess considerable value; (3) the conch-pearl or fountain shell (*Strombus gigas*); (4) the giant clam (*Tridacna gigas*), giving dull, opaque-white pearls; (5) *Pinna squamosa*, black and red; (6) seed-pearls from *Placuna placenta* [*orbicularis*], lead-coloured; (7) the common oyster (*Ostrea edulis*); (8) the horse-mussel (*Modiola vulgaris*); (9) the chank (*Turbinella scolymus*), pink pearl; (10) the "green snail" (*Turbo olearius* [*marmoratus*]); (11) the "Turk's cap" (*Turbo sarmaticus*); (12) the "ear-shells" or "aurora-shells" (*Haliotis spp.*), including the "ormer," of the Channel Islands, *H. iris*, of New Zealand, *H. Mida*, of the Cape, *H. rufescens*, *H. splendens*, and *H. Cracherodii*, of Japan and other localities; (13) the Chinese "pearl-mussel" (*Anodonta herculea*); and (14) the river-pearls obtained from *Alamodon spp.*, *Unio spp.*, and other river-frequenters.

River-pearls, the produce of fresh-water mussels, occur in the mountain streams of Scotland, Ireland, Lapland, Bohemia, and Canada. The marine pearl-fisheries are confined to a portion of the Persian Gulf; the Tinnevelly Banks, on the Ceylon coast; the E. Archipelago; the coasts of Australia, and the lagoons of many of the S. Pacific Islands; and Central America, in both oceans.

Fresh-water pearls are almost always of greatly inferior lustre and value, yet specimens worth 3–4*l.* each are not unfrequently found, and individuals have been known to fetch 50–100*l.* The Scotch pearls have long been famous. During the years 1761–4, London is said to have received pearls to the value of 10,000*l.* from the rivers Tay and Isla. In the dry summer of 1862, there was an unprecedented discovery of pearls in Scotland, the average value fluctuating between 46*s.* and 50*s.*, while 5*l.* was considered a high figure. The estimated value of the total findings in 1865 was 12,000*l.* Prices have since advanced considerably. The Bohemian fisheries are confined to the Horazdiowitz district of the Wotawa.

During the summer months, the Arabs prosecute a small pearl-fishery along the coasts of the Red Sea. The captured molluscs are taken ashore and exposed to the sun, when they quickly open; they are then examined for pearls, and thrown away. The headquarters of this fishery is Jedda. The shipments of mother-of-pearl from this fishery from Alexandria are said to amount to about 12,000 cwt. annually, less than half coming to Birmingham. The pearl-mussel fishery in the Persian Gulf, principally on the banks of the island of Bahrein, is also in the hands of the Arabs. The best beds are said to be level, and formed of fine whitish sand, overlying the coral, in clear water. About 4000–5000 boats are engaged, and the annual value of the harvest may be placed at 600,000*l.* The beds occur at all depths down to 18 fathoms, and probably lower; the chief diving is in 4–7 fathoms. The season lasts from April till September. The shells are mostly taken first to the little port of Lingah, whence a considerable quantity of mother-of-pearl is shipped direct to London, and a lesser amount to the Continent. Many of the pearls go to Bombay, especially those of yellowish colour and perfect sphericity; Bagdad is a great market for the seed-pearls, and those of white hue. The Persian Gulf shells that reach here are mostly small, and dark-edged, but they fetch a better price than Panama and Tahiti shells. The imports are seldom less than 3000–5000 cwt. yearly. The values (in *rupees* of 2*s.*) of the exports from Persian Gulf ports in 1879 were as follows:—from Bahrein: 1000 *r.* to India and 300 *r.* to Persian coast and Mekran, of mother-of-pearl; 18,00,000 *r.* to India, 3000 *r.* to Red Sea and Aden, 4000 *r.* to Persian coast and Mekran, and 4000 *r.* to Koweit, Bussorah and Bagdad, of pearls; from Bushire: 14,000 *r.* to England, of mother-of-pearl; from Lingah: 50,000 *r.* to England, 20,000 *r.* to India, and 4900 *r.* to Persian coast and Mekran, of mother-of-pearl; 22,25,000 *r.* to India, and 15,000 *r.* to Koweit, Bussorah and Bagdad, of pearls. Thus the total ascertained exports had a value of 41,37,200 *r.*, or over 40,000*l.*

The Ceylon or Tinnevelly fishery is situated on the W. coast of Ceylon, in the Gulf of Manaar, southwards of the island of that name, and along the opposite coast of the Indian continent, near Tuticorin. The banks lie in groups: the first, opposite the village of Arippu, comprises the so-called Peria-Par, Peria-Par Karai, Cheval-Par, Kallutidel-Par, and Modaragam-Par; facing the village of Karaitivu, is the bank of that name; and off the village of Chilaw, are Karakupanai-Par and Jekenpedai-Par. These banks are 6–8 miles from the shore, and 5½–8½ fathoms below the surface. They consist of masses of rocky ground, rising from the sandy bottom, and are probably exposed to ocean currents. These grounds are under the control of an Inspector appointed by the local government, and are worked exclusively by the government, who employ native divers, and give them ¼ of the proceeds. Experience has shown that few pearls, and those of little value, are to be found in molluscs under 5 years old; during the 5th–6th years, the value doubles, and is said to double again during the 7th year; the pearls are immature and imperfect if removed too soon, but the animal is liable to death or destruction if left too long. Intervals are therefore allowed to elapse between the fishings, varying in length according to the reports of the inspector. Until 1863, there was but little system in the operations; the yields of the fisheries had been:—1796–1809, 517,481*l.*; 1814–1820, 89,909*l.*; 1828–1837, 227,132*l.*; 1855–1860, 117,454*l.* In 1863, 22 days' fishing produced 11,695,000 oysters, whose yield of pearl was valued at 51,018*l.* The next fishing was in 1874, when 1,700,000 oysters gave 10,120*l.* worth of pearls. The fishing of 1877 lasted 30 days, and afforded 6,850,000 oysters, giving pearls to the value of 18,952*l.* The 1879 harvest was unexpectedly good; 12 days' fishing produced 7,650,000 oysters. The fishery of 1880 lasted from Mar. 9th to April 2nd, and the 11 days' operations resulted in a take of 11,500,000 oysters. This year's (1881) report states that 60,000,000 oysters might be fished, and might realise 60,000*l.*, the sample pearls fished giving the shells an average value of 10–12 *rupees* (of 2*s.*) a 1000. The fishing is conducted with extreme regularity. The divers relieve each other at intervals; when the boats come ashore, their harvest is removed to a shed, ¼ being handed to the divers as their remuneration.

After the pearls are collected, they are classified, sized, and valued. The classification is as follows:—(1) *Anie*, pearls of perfect sphericity and lustre; (2) *anathorie*, failing in one of these points; (3) *masengoe*, failing slightly in both points; (4) *kalippo*, failing still more; (5) *korowel*, double; (6) *peesal*, misshapen; (7) *oodwoe*, beauty; (8) *mandongoe*, bent or folded; (9) *kural*, very small and misshapen; (10) *thool*, "seed." The sizing is effected by passing them through a succession of brass cullenders, called "baskets," having the size and shape of large saucers. There are 10–12 of these. The first is perforated with 20 holes, and the pearls which do not pass through it by shaking are called "of the 20th basket." The succeeding baskets have 30, 50, 80, 100, 200, 400, 600, 800, 1000, each giving the name corresponding with its number of holes to the pearls that do not pass through. After sizing, the pearls are weighed, and their value is then expressed at a rate "per *chow*," which term embraces all the qualities which have been estimated.

China possesses a pearl-mussel fishery near Pakhoi. The grounds are divided into four districts, lying between the S. coast of the Pakhoi Peninsula, the island of Weichow, and the Leichow Peninsula. The fishery takes place every 10–15 years; the last (1875) gave a value of 30,000 *taels* (of 6*s.*). Cochin China has an extensive commerce in mother-of-pearl, obtained mostly in the Bay of Tirwar. On the N. coast of Japan, is a considerable fishery of *awabi* (*Haliotis gigantea*), a mussel affording mother-of-pearl, which is much esteemed by the Japanese and Chinese. The Philippine Islands produce large quantities of mother-of-pearl. The exports were 155 tons, value 17,402*l.*, in 1877, and 152 tons, 17,073*l.*, in 1878; in 1879, 2198 *piculs* (of 139½ lb.), value 16,045*l.*, were shipped to the Straits Settlements and India. The whole extensive range from the Tawi-Tawi Islands and Sulu, as far as Baselan, is one vast continued bed of pearl-mussels, principally of the *behoren* or mother-of-pearl species, called *tipi* by the natives, but there is also a large area occupied by the Ceylon oyster, termed *kapis* by the Malays. The principal banks of the latter are found in Maludu Bay. The fishery is carried on by both Chinese and Malays. The Sulu fishery, about Tawi-Tawi, is described by Moore as being superior in extent and productiveness to all others. The Sulu pearls have always been celebrated as the most valuable produced; the mother-of-pearl shell is distinguished by the yellow colour of the border and back, rendering it unfit for some purposes. Some 2500–3000 cwt. are sold annually. Labuan is the chief mart for the Sulu product; in 1868, the value was 11,554*l.*; in 1870, it had fallen to 5686*l.*, and still lower in 1878. A few inferior pearls are obtained from a small oyster in Borneo. Macassar is the market for the pearl-mussels found by the natives of the Bayos. In Kau Bay, between the N. and N.-E. peninsulas of the island of Halmahera, are pearl-banks belonging to the Sultan of Ternate. The sea about the Aru Islands affords both pearls and mother-of-pearl, which are taken to Dobbo. The pearl-banks on the W. side are rich, but have hitherto been neglected. The head-quarters of the pearl-fishery is the Blakong Tanah, on the E. side of the islands, facing New Guinea. This is the most important pearl-fishery in the whole Archipelago. In 1860, the product was 2500 *piculs* (of 135½ lb.), value 190,000 *fr.*, and 20,000 *fr.* worth of pearls. The island of Timor has pearl-banks, but the yield is trifling.

The great Queensland pearl-fishery in Torres Straits is mostly in the hands of Sydney capitalists. It is carried on by boats, with Malay divers, in water of 4–6 fathoms. The pearl-mussels of Torres Straits have a weight of 3–6 lb., and even 10 lb. The weight and worth of the pearl-mussels exported from Queensland have been as follows:—1874: 2 lb., 12*l.*; 1875: 112 cwt., 799*l.*; 1876: 2886 cwt., 15,665*l.*; 1877: 7768 cwt., 48,723*l.*; 1878: 9530 cwt., 54,149*l.* The official statistics from the station in Thursday Island for the year 1st May, 1878–30th April, 1879, were:—Living pearl-mussels, 425 tons, 1½ cwt.; dead pearl-mussels, 4 tons, 2 cwt.; pearls, 130*l.* worth. The value of the mussel-shell at 130*l.* a ton is 112,320*l.* The pearl-fisheries of the N.-W. coast of Australia give extensive employment, the divers being Malays from the Dutch settlements, and natives; the diving is carried on from the end of September to the end of March. The extent of these banks is probably far from being defined as yet. A vessel engaged in pearling in King Sound, in 1879, got 21 tons of shells in 25 days; the banks doubtless exist between Beagle and Collier Bays, and there is reason to hope that they reach as far north as the Gulf of Carpentaria. The fishing is carried on solely for the value of the mother-of-pearl shell (*Meleagrina margaritifera*), but it also yields a number of pearls, some having a high worth. The shells are of the best kind known, weighing 1½–6 lb. a pair. They are subject to an export duty of 4*l.* a ton. A distinct fishery is carried on in Shark's Bay (W. Australia), particularly on the banks in Useless Harbour. The shell here found is the true pearl-mussel (*Avicula margaritifera*). The shells are very thin, with a beautiful pearly inner surface; till quite recently, they were considered valueless, on account of their thinness, but quantities are now being sent to Havre at a most remunerative price. The pearls themselves are the main object of search, and large numbers must be found; but as there is no duty of any kind levied upon them, statistics are wanting. They have a brilliant lustre, but seldom exceed the size of a pea. The capture of the molluscs is effected by dragging iron-wire dredges over the banks in shallow water. The shells are heaped up ashore for the occupants to rot, when they are easily opened and searched. The pearl-fisheries of W. Australia possess a considerable and growing importance. In 1874, the total ascertained value of the exports of mother-of-pearl was 58,928*l.*, and of pearls, 6000*l.*; the exports of the former in 1876 were 240 tons to London, and 67 tons to Singapore, the price fluctuating at about 250–280*l.* a ton. The discovery of molluscs yielding mother-of-pearl and pearls in Oakley Creek, New Zealand, has been reported.

Diving for pearl is one of the chief occupations of both sexes of natives in the islands of the S. Pacific. The mollusc here sought is the mother-of-pearl-yielding mussel, which inhabits the interior lagoons of the great coral *atolls*. It frequents the clean growing coral, where it can attach itself free from sand or drift, and where there is considerable influx and efflux of tide. It is also to be found in great numbers under the breakers that beat upon the outer reefs, and probably at greater depths in the sea beyond. The animals are gregarious, and love to congregate in large piles, firmly attached to one another. Unfavourable conditions will cause them to migrate *en masse* for a short distance. The attachment to the rock is effected by means of a "cable" springing from the body of the mollusc, and passing through an orifice between the shells at the hinge. During life, the colour of this cable is dark-green to golden-bronze, and a similar degree of brilliancy pertains to the two flat surfaces at the back of the hinge; the exact degree and shade of these colours are said to indicate the presence or absence of pearls within the shell, with such a degree of certainty that experienced fishers will select 75 per cent. of the pearl-containing mussels from a boat-load by this sign alone. The shell comes to maturity in about seven years, at which time, its average weight is 1 lb. empty; the usual size is 10 in. across, sometimes reaching 18 in. When mature, the creature detaches itself from the rock, opens, dies, decays, and the shell becomes coated with coral and parasites, and loses all value, while any loose pearls contained in the shell fall out and are lost. The animals have several enemies, one of the worst being a centipede-like creature which infests stagnant lagoons, and enters the shells and devours the occupants. Almost all well-grown mussels are troubled with lobster-shaped parasites, about the size of shrimps, which inhabit and breed in the mussel-shells.

The shells are secured individually by divers. When landed, they are generally separated into two piles, consisting of those which are supposed to contain pearls and those which are not. The shells are opened by flexible steel-bladed knives; a skilful hand will open one ton of shells per diem, without missing any pearls there may be. The emptied shells (mother-of-pearl) are at once placed in the shade, to preserve their colours. The animals are eaten in times of great scarcity. Pearls, when present, are usually lodged in the muscle whence the cable springs, which, being transparent, easily reveals their presence. When many are found in one shell, they are commonly small and ill-formed. Other pearls occur sometimes loose in the shell; these are always of very fine quality, perfectly round, and often large. Not more than one mussel in a thousand contains such pearls, but when they are present, they are frequently lost by the natives through carelessness in opening. Fine, calm weather is most favourable to the fishing, but not indispensable. No accessory or apparatus of any kind is used by the divers; but they rub their bodies with oil, to avoid blistering by the sun. They can remain under water 1–2 minutes or more, and are able to bring up shell from 20 fathoms. Few shells are got from this depth, but these are exceptionally fine. Many fisheries now supposed to be exhausted still contain great riches in the deeper water; and many lagoons that have afforded nothing in the shallow water will repay search at greater depths. Taking all things into consideration, the cost of raising mother-of-pearl shell in these islands is about 5–6*l.* a ton.

The pearl-fishery of the S. Pacific is carried on chiefly in the Tuamotu [Pomotou, or Low] Archipelago, in the Gambier Islands, and in the Navigator's Islands. Very many other localities are partially or totally neglected. Thus the island of Manihiki, which afforded over 100 tons of shell in 18 months, some 20 years ago, has not been fished since; and the lagoon of Hogolen is known to contain an immense bank of pearl-mussels. The Tuamotus are said to have yielded altogether some 25,000 tons of mother-of-pearl, valued at over 1,000,000*l.* Almost the whole production goes to Tahiti for export. In 1873, the total shipments were estimated to amount to 2000 tons of shells and 200,000 *fr.* worth of pearls. In 1878, Tahiti exported 591 tons of shells, value 35,460*l.*, and 6000*l.* worth of pearls; in 1879, 470 tons of shells, value 28,200*l.*, and 4000*l.* worth of pearls. The export duty of 32*s.* a ton on shells, which was imposed in 1875, was removed in 1878; this fact partly accounts for the increased export in 1878. The classification of pearls in the Pacific Islands is as follows:—(1) Those of regular form and without faults: value, 3*s.* per $\frac{1}{10}$ *grm.*, those weighing 1½–2½ *grm.*, 100–140*l.*; (2) round, white, and of good lustre: value, 30 *grm.* containing 800 pearls, 4*l.*, the same weight in 50 pearls, 60*l.*; (3) irregular form, not free from faults or spots: value, 30 *grm.*, 3–4*l.*, according to degree of tarnish by black blemishes and dulness; (4) knots of pearl, which have adhered to the shell: value, 30 *grm.*, 30–40*s.*, according to regularity and brilliancy; (5) seed-pearls, 2–3*l.* a lb. Mother-of-pearl brings 3–6*d.* a lb. The chief markets for Pacific pearls are Hamburg, Amsterdam, London, and St. Petersburg.

Besides the pearl-mussel, a species of large clam is found in the lagoons of many of the Pacific Islands, affording pearls of unusual value. They are of two kinds, and are locally called *paahua* or *tridachna*; one grows chiefly on the solid coral, and does not attain so great size as the other, which is found not only on the hard reef, but bound to loose rocks, or lodged upon the sandy bottom. The latter attains enormous proportions, and is the kind which yields pearls. These are found in the body of the animal, and are so common that 100 may be gathered in a day's fishing, but they are generally of irregular shape and quite opaque; they are never sought after by the fishermen, and valuable ones are rare, but their systematic search would probably be highly remunerative. Yet another pearl-yielding mollusc inhabits these seas, with a shell like that of an oyster. It is always firmly attached to the rock, and is found singly, so that it is scarce; but it affords perfectly round, lustrous, golden-coloured pearls, about as large as peas.

The Central American pearl-fisheries lie on both the Atlantic and Pacific sides. They occur in the Bay of Panama, about the Pearl Islands, of which St. Joseph is the most important, whence 800–1000 tons of shell have been taken annually. In 1869, we imported pearls to the value of about 40,000*l.* from New Granada, the Atlantic ports of America, and St. Thomas; and the average annual value of the Panama fishery has been estimated at about 25,000*l.* In the lower part of the Bay of Mulege, in the Gulf of California, near Los Coyetes, pearls have been found of great value; and it is generally believed that a series of beds extend from the Gulf of Darien to the Gulf of California. In the latter, and along the shores of Central Mexico and Costa Rica, pearl-fishing has long been a lucrative occupation. There is great variety in the quality of the shells from different localities. The chief fishery on the Mexican coast is between Mulege and Cape San Lucas, and in a lesser degree around the Islas tres Marias, and in the neighbourhood of Acapulco. The molluscs here met with are the *concha nacar* or mother-of-pearl mussel (*Meleagrina margaritifera*), and ear-shells (*Haliotis rufescens*). The fishery is carried on during July–October, wind and cold preventing it at other seasons. The use of diving apparatus is coming largely into vogue. The mother-of-pearl found in the Gulf of California is white, with blue-black or yellow bands, and 3–6 in. across. The size and number have much decreased of late years, on account of reckless fishing, without giving time for the beds to recover; also, it is thought, from the damage done to young molluscs by the heavily-weighted boots of the divers. It has recently been determined to suspend operations, and open the fishery only once in every four years. The Californian shells go almost exclusively to Hamburg, whence Austria, France, and England draw their supplies. The pearls go mostly to Paris, but also to Frankfort-on-Maine and Hamburg. The total Californian fishery is reckoned to produce 6000–7000 cwt. of mother-of-pearl annually. The exports of mother-of-pearl from Costa Rica were 2042 lb. in 1875, 4425 lb. in 1876, 42,446 lb. in 1877, 6750 lb. in 1878, and 3549 lb. in 1879; the value rose from 2*c.* to 10*c.* a lb. Panama, in 1879, shipped 7000*l.* worth of pearls to the United States. Guayaquil shipped at the rate of 13–14 tons yearly of mother-of-pearl about 1871.

In the Bahamas, conch-fishing is an important industry. The only species affording pearl is the common pink conch (*Strombus gigas*). The pearls taken from under its apron are pink, yellow, or black, the first-named alone having any value. They possess a delicate pink tint, and are often beautifully waterlined, which, with their size and colour, determines their worth. They are readily saleable in Nassau (Bahamas), at figures occasionally reaching 20*l.* The value of the total annual export is estimated at 10,000*l.*

Ohio, one of the States of the American Union, is remarkable for an extensive fishery of a kind of river-pearl, in the Little Miami river, Warren County. The fishing season lasts from June till October. Men and boys wade over the banks in the river, and raise the shells with their feet, so as to avoid putting the head under water. The shells are opened with a knife, and in about one case out of 150, pearls—sometimes to the number of three—are found between the shell and the membrane that lines it.

Qualities, Values, and Commerce.—The qualities of pearls and mother-of-pearl vary widely. The best pearls are of a clear, bright whiteness, smooth and glossy, and free from spot or stain. The globular form is most generally esteemed, but pear-shaped ones of large size make handsome earrings. Pearls of dark colour are in little favour. The value, other conditions being equal, increases geometrically with the size. Thus a pearl of 3 gr. is worth about 19*s.*; 4 gr., 32*s.*; 5 gr., 47*s.*; 6 gr., 75*s.*; 8 gr., 114*s.*; 10 gr., 11*l.*; 12 gr., 16*l.*; 14 gr., 20*l.*; 16 gr., 30*l.*; 18 gr., 40*l.*; 20 gr., 50*l.*; 24 gr., 72*l.*; 30 gr., 100*l.* When two or more pearls possess identity of form, size, colour, &c., they assume a fancy value beyond all rules. Mother-of-pearl owes its beauty to the minute corrugations of its surface, which cause the much-admired iridescence. The shells, as imported, are of various sizes and values. The smallest are Panama, weighing about ½ lb. the single valve; Bombay and Egyptian weigh about ¾ lb.; black-edged South Sea, 1 lb.; Manila, Singapore, and Australian, 1½–3 lb. The medium and small shells, being cleanest, bring higher rates in comparison with the larger. The approximate London market values are:—Panama, 60–85*s.* a cwt.; black-edged S. Sea, 65–130*s.*; Bombay and Egypt, 95*s.*–132*s.* 6*d.*; Manila, 135–160*s.*; Australian, 130–220*s.* Pearls are used exclusively for jewellery in Europe and America. Mother-of-pearl has very wide applications for ornamental purposes, such as fans, studs, buttons (see p. 558), card-cases, and multifarious toilet articles, as well as in cabinet-making, inlaying, and papier-maché work. In 1870 (the latest detailed Return), we imported 26,197 cwt. of mother-of-pearl, value 76,489*l.*, and 16,675*l.* worth of pearls. In the ten years ending 1876, France imported 1,376,132 *kilo.* of mother-of-pearl, value 3,159,943 *fr.*, and 118,078 *grm.* of pearls, value 2,007,333 *fr.*; France also now imports about 125,000 *kilo.* annually of ear-shells (*Haliotis*). The imports of mother-of-pearl at Hamburg were 7600 cwt. in 1875, 600 cwt. in 1876, and 3300 cwt. in 1877.

A good remedy against the liability which pearls manifest of losing their brilliancy is to keep them in magnesia. An artificial imitation of pearl is largely made on the Continent, the essential ingredient being guanine, a silvery mucus found on the scales of *Lenciscus alburnus*, which is incorporated with wax, and may be either bored and strung as pearls, or spread to resemble mother-of-pearl. (See also Celluloid, p. 615, for artificial pearl-making).

Coral (Fr., *Corail*; Ger., *Koralle*).—There is still great ignorance on many important points relating to the production of coral. The little that is known leads to the belief that its growth is rapid; that its development is simple; that it accommodates itself to very varied circumstances; and that detached fragments from the bunch or principal stem have vitality, and will attach themselves to fixed substances for continuing their development and forming new trunks. But at what age coral attains its largest size; how long it takes for an exhausted coral bank to recover itself; at what period the eggs are laid; how the products are disseminated; at what period the budding takes place, and how long it lasts: these questions, on which rests the progress of the coral fishery, are as yet unsolved.

Coral stem is divisible into two distinct parts: a central axis, hard and brittle, which is the part used in commerce; and a soft covering or epidermis, which easily yields to the nail when fresh, but is friable when dry.

Coral of various kinds is met with in shops, and sold under the names of "white coral" (*Oculina* [*Madrepora*] *virginea*), "brainstone coral" (*Mendrina cerebriformis*), "black coral" (*G. Antipathes*), and "organ-pipe coral" (*Tubipora musica*), named from the arrangement of its cylindrical dark-crimson tubes. Occasionally "red coral" is found without any colouring matter. Black coral takes a fine polish, and is fashioned into beads, and mouth-pieces for cigars. The dull white is not quite so hard, and not polishing well, is sold cheaper. It is often deteriorated by being worm-eaten.

Coral has the hardness and brilliancy of agate; it polishes like gems, and shines like garnet, with the tints of the ruby. The larger branches are used for carving. Large, perfect, well-shaped beads are by far the most valuable form of coral, and these have greatly increased in estimation of late years. Many of the finest are sent to China, while tons of what may be called "worm-eaten" beads, which would not find favour in Europe, go to India, where they are esteemed.

Much of the coral is wasted in the process of conversion into uniform well-shaped beads, and this, of course, adds greatly to the cost. The manufacturing processes consist of three different operations—cutting, piercing, and rounding; these are principally executed by the females of the Val du Bisagno, in Italy.

The principal commercial varieties of coral distinguished are:—red, subdivided into deep-crimson red, pale-red, and vermilion (rare); black; clear-white; and dull-white (most common). The delicate rose or flesh-coloured, which is the most prized, is sold at very high prices, as it is entirely a fancy article. Red coral is sometimes classified into twelve shades, besides white and pink; sometimes into five commercial grades:—(1) froth of blood; (2) flower of blood; (3, 4, 5) blood of first, second, and third qualities.

Coral is valued according to its bulk, colour, soundness, and freedom from defects. Certain rare kinds, of pale tints, are worth twenty times their weight in pure gold. The ornamental applications of coral are very varied.

All corals possess a certain industrial value as sources of lime for building and manurial purposes; but the red or precious sort (*Corallium rubrum*) is the only one forming an important article of commerce, and to it the following remarks apply.

The localities affording it are the N.-E. and S. shores of the Mediterranean, the coasts of the chief islands in that sea, and a portion of the E. shore of the Adriatic. It usually lies at 2–10 miles from the land, and in water of 30–130 fathoms, finding its most favourable conditions in 80 fathoms. It is said to attain greater perfection in the E. than in the S., and to be rarely found in a W. and never in a N. aspect. It occurs attached to rocks embedded in a muddy sea-bottom, where it flourishes better than in clear or sandy beds.

The headquarters of the Italian coral-fishery are: From the island of Elba to the coast of the mainland by Cecina and Spezia; the so-called *secche corallere* grounds in the Bay of Naples; Nico; the Sorrent peninsula; near Nisida and Cape Miseno, E. of the island of Ischia: both coasts of Calabria; the islands between Sicily and Calabria; near Sciacca, and the island of Pantellaria; the Tizzano ground between Corsica and Sardinia; around Sardinia the grounds of Alghero, Longo Sardo, Bosa, Castelsardo. Isola di S. Pietro, S. Antioco, Maddalena and Caprera, from the Straits of Bonifacio, along the Corsican coast to Cape Corso; thence into French territory, from the Iles de Hyères to Cape Couronne; in the Gulf of Rosas and on the banks of Cape Tarsuela di Mongril, to the limit of the gulf in Catalonia. The Italian coral-fleet in 1869 numbered 200 large and 260 small boats, the crews were a total of 4000, and the yield was 160,000 *kilo.* of coral, valued at 9,600,000 *lire* (of 9½*d.*). Since then, the industry has much increased, if the statement be true that during last year (1880) some 500 boats from Torre del Greco alone were on the Sciacca bank, besides an equal number from four other ports. The annual value of the Sardinian coral is estimated at 60,000*l.*, giving a profit of 13,000*l.*; the exports are 200,000–250,000 lb. a year. The fishery lasts from March till October.

The barks employed are stout craft, rigged with a great lateen sail and a jib or stay-sail. The apparatus, or "engine," as it is called, for detaching the coral from the rocks and hauling it aboard, consists of a huge wooden cross, heavily weighted, and furnished with numerous, sack-like, meshed lines. This implement is thrown overboard in likely spots, trailed astern, and drawn up by means of a capstan. Diving-bells and vessels suited for submarine navigation have been proposed and tried as substitutes for this crude fashion, but have not come into use. A large boat may collect 650–850 lb. of coral in a season.

It has been estimated that the Sciacca bank yielded, between the 1st June and 31st August 1875, 264,000 lb. of coral, which sold for at least 92,400*l.* The bank was said to be 550 yd. long and about 30 yd. thick. Statistics concerning the Italian coral industry, published in 1871, gave the number of boats as 300 from Torre del Greco, 60 from Leghorn, and 100 from Liguria and Sardinia; the number of persons employed, 6000; the catch for each boat necessary to defray all cost, 200 *kilo.* at an average value of 48*s.*, or 480*l.*; and the receipts of coral at Italian ports, 160,000 *kilo.*, value 380,000*l.* The Alghero banks in 1873 employed 239 boats, which gathered 25,384 *kilo.* of red coral, and 9536 of white, total value, 160,080*l.*; in 1874, 159 boats took 12,260 *kilo.* of red and 6758 of white, total value, 93,960*l.* The Cagliari fishery occupied 180 boats in 1875, whose take was estimated at below 1,000,000 *fr.*

The coral-fisheries of Austro-Hungary are exclusively on the coast of Dalmatia, the island of Zlasin being the centre. Each boat obtains some 80–100 lb. yearly, the total value being placed at 6000–10,000 florins (of 2*s.*). The pale-red and very thick Dalmatian coral is much esteemed.

Spanish fishermen collect annually about 25,000 lb. of coral, worth 20,000*l.*, around the Cape Verde Islands.

The coral-banks on the Algerian coast lie in a depth of 12½–100 fathoms, in the neighbourhood of La Calle, the Gulf of Bona, Cap de Fer, Djidjelly, Bougie, Cape Matifu, Tenes, Cape Ferrat, Cape Falcon, Habibas Island, and Cape Figalo. About ⅓–½ of the boats engaged are Italian; they are stout sailing-craft of 6–14 tons, with a crew of 10–12, while smaller boats with 4–6 hands work the coast-fisheries. The total number of boats in the years 1868–76 varied between 202 and 388. Foreign vessels pay 800 *fr.* for a licence to fish, except Italian, which pay only 40 *fr.* The yearly product is stated by the fishermen at 30,000–40,000 *kilo.*; and the total value of the Algerian and Tunisian fisheries is computed at 2,500,000 *fr.* annually. The value of the Algerian exports is placed at 80,000*l.* per annum; the quantity in 1878 was 34,288 *kilo.*, in 1879, 17,876 *kilo.*, value 536,280 *fr.* Each reef is divided into tenths, one of which is worked in a year; thus a period of 10 years intervenes between the harvests from the same spot. On the coast of Tunis, between Biserte and Tabarque, are annually obtained some 25 metric quintals (of 1·96 cwt.) of coral, varying in value from 80 to 90 *fr.* a *kilo.* The ground is worked chiefly by Italian and Greek boats, and the product is taken to Torre del Greco and Livorno.

The coral of the Red Sea is not of the valuable kind. A rich bank is said to have been discovered on the Japanese coast, whose product possesses the peculiarity of being white in the centre and at all the lateral points; but it is apt to scale or break off.

In the N. African fisheries, coral is divided into the following classes:—(*a*) "Dead" or "rotten," including the roots adhering to the rock, and covered with vegetable and mineral incrustations, worth 5–20 *fr.* a *kilo.*; (*b*) "black," which gives a polished black surface, suited for mourning jewellery, and fetches 12–15 *fr.* a *kilo.*; (*c*) "in case," or coral which has been assorted and cleaned when taken from the sea, consisting of branches of all sizes, and worth 45–70 *fr.* a *kilo.*; (*d*) "choice," or finest, selected, large branches, valued at 400–500 *fr.* a *kilo.*

The imports of coral into the United Kingdom in 1870 (the latest specific Return) were:—1600 lb. of "fragments," 418 lb. of "whole," 652 lb. of "*negligées*," and 958 lb. of "beads," the total being 3628 lb., value 14,878*l.*; the figures fluctuate immensely, having been 8106 lb. in 1868, 1087 lb. in 1863, and 16,385 lb. in 1861. These statements take no account of the quantities of valuable coral brought in passengers' luggage. In the 10 years ending 1876, France imported 21,596 *kilo.* of rough coral, value, 1,890,356 *fr.*, and 14,553 *kilo.* of worked, unmounted coral, value 5,078,062 *fr.* British India, in 1879, imported 79,643 lb. of real coral, value 81,862*l.* Quantities are exported from India into Thibet, in pierced grains of round or oval form, the darkest colours being most esteemed. China imports various kinds from Singapore, Sumatra, and the Samar Islands, black being preferred.

An imitation of coral for ornamental work may be made by dipping twigs in a mixture composed of 4 parts of rosin, 3 of bees-wax, and 2 of vermilion, melted together.

The London market value of coral fluctuates very widely. The finest rose-pink specimens range between 80*l.* and 120*l.* an oz.; small pieces of ordinary red are worth about 2*l.* an oz.; while small fragments (*collette*) for necklaces bring about 5*s.* an oz.

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PERFUMES (Fr., *Parfums*; Ger., *Wohlgerüche, Düfte*).

The term "perfumes" is applied to those substances emitting an agreeable odour which are used about the person, the dress, and the dwelling. Besides the gratification of the senses derived from the employment of perfumes, many of the latter are credited with actual disinfecting properties, and are therefore valuable from a hygienic point of view. All the essential oils of plants are more or less powerfully antiseptic, and the culture of strongly fragrant flowers is recommended as a means of counteracting the miasma of undrained swamps.

Perfumes may be divided into two main classes—crude and prepared. Crude perfumes comprise the aromatic substances derived from the animal and vegetable kingdoms. Animal perfumes occur almost exclusively as glandular secretions, and enter into commerce in their natural state. Vegetable perfumes are mostly extracted from the flowers or herbs as essential oils, which are described on pp. 1415–33. Some few plant-odours have the form of balsams, and will be noticed in the article on Resinous Substances. The crude perfumes remaining for description in the present article are those of animal origin, and the few aromatic woods, roots, and fruits which are traded and used in their original condition. Prepared perfumes embrace the numerous extracts or essences, pastilles and ribbons, incenses and satchet powders, waters and vinegars, and nosegays or bouquets.

CRUDE PERFUMES.

Acorus Calamus.—See p. 190.

Agar, Agila, Akyaw, Calambak, Eagle-wood, Kayugàru, or Lignum-aloes.—This curious product is obtained chiefly from the Mergui Archipelago, also from the islands in the Gulf of Cambodia, and from Sumatra. It has been described as consisting of lumps of consolidated aromatic resin, found embedded in the trunk of certain trees, but should rather be considered as diseased wood whose tissues are impregnated with the resin. The latter is found in all parts of the trunk, most frequently in the alburnum or sap-wood, but only where decay has followed intentional or accidental injury. This leads to the inference that the supply might be regulated and increased by a systematic wounding of the trees; it would also appear that the resin is a product of the oxidation of the essential oil contained in the wood, which circumstance might be availed of to artificially augment the yield. Botanists consider it to be produced only by *Aquilaria Agallochum*, but native collectors in Burma state that it is furnished by two kinds of tree, though the substance does not differ. It occurs in very small quantity, and is altogether absent from 19 trees out of 20; the wood-cutters often destroy several trees before finding a particle of it, and it is estimated that some 8000 trees are yearly cut down in the Mergui Archipelago. This is rapidly causing the extermination of the species in those islands, and has led to its attempted cultivation in S. Tenasserim, where 200 seedlings have been planted out. The greater part of the article collected is sent to China, viâ Penang and Singapore, small pieces being used for torches, incense, and medicine. The wood is also cut into fragments, placed in water in a copper vessel, and boiled; from this decoction, the perfume is distilled, and is known as "agar-attar;" it is exported from Burma to Calcutta, for despatch to Arabia and Turkey, and is in high esteem throughout the East. The test of the quality of the resinous compound is that it should melt in the fire like wax, meantime emitting an agreeable odour. The approximate local values per *picul* (of 133⅓ lb.) are:—1st quality (Sumatra), 40*l.* 16*s.* 8*d.*; 2nd quality (Malacca), 25*l.* 10*s.*; 3rd quality (Malacca), 3*l.* 2*s.* 6*d.*

Ambergris (Fr., *Ambre gris*; Ger., *Amber*, *Ambra*).—Ambergris is probably a biliary calculus, or mass of undigested and biliary matters, obtained from the stomach of the spermaceti-whale (*Physeter macrocephalus*), and possibly some other species. It is generally found, after having been ejected by the animal, floating on the surface of the sea. Its presence in the animal is said to be always an accompaniment (either cause or effect) of disease. It occurs in amorphous masses, usually only a few oz. in weight, yet concretions weighing 150–300 lb. have been found. Its general colour is greyish-white, with bands of brown or black, as if marking the addition of layers. It has a waxy texture, pungent, agreeable odour, and fatty flavour; it is lighter than water, melts at 60° (140° F.), dissolves readily in absolute alcohol, ether, and both fatty and essential oils; it contains 85 per cent. of an aromatic substance called "ambreine," extracted by digestion with alcohol of 0·827 sp. gr., filtering the solution, and leaving it to spontaneous evaporation; the ambreine then forms delicate white tufts, converted into ambreic acid by the action of nitric acid. Ambergris is sought after in all the fisheries frequented by the sperm-whale (see Spermaceti, p. 1371). Formerly considerable pieces have been found on the W. coast of Ireland—Sligo, Mayo, Kerry, and Isle of Arran. The exports of ambergris from Morocco are extensive, the supply being contributed by whales cast up on the W. coast. The exports were 27 lb., value 600*l.*, in 1868; 65 lb., 1300*l.*, in 1869; 100 lb., 2000*l.*, in 1870; and 18 lb., 360*l.*, in 1873. It is occasionally found on the coasts of some of the Bahamas; the values of the shipments thence were 10*l.* in 1875, 11*l.* in 1877, 1014*l.* in 1878, and 737*l.* in 1879. In 1869, France imported more than 7000*l.* worth of ambergris from Madagascar and Mayotte. The American whale-fisheries produced 15 lb., value 1454*l.*, in 1876; 132 lb., 21,000*l.*, in 1878; and 81 lb., 8781*l.*, in 1879. Ambergris is valued in perfumery less for its own fragrance than for the permanence it gives to compounds into which it enters, by reason of its slight volatility, insolubility in weak alkaline lyes, and slow decomposition.

Castor.—Castor or castoreum has been noticed under Drugs (see p. 798), as it possesses almost as great importance in medicine as in perfumery. Two or three kinds are distinguished, differing considerably in chemical composition and in odour. The Canadian has the weaker odour, resembling that of old willow-bark; the Siberian or European is much stronger, and recalls that of birch-oil. The pear-shaped sac occurs the most frequently, especially in Canadian. Egg-shaped sacs are suspected by the buyer as containing more carbonate of lime. Adulteration may be detected by dividing the sac, either by breaking or cutting, when the membranes become visible if it is genuine. The main commercial distinction lies between the Russian (Siberian) and Canadian (American), the Bavarian being considered nearly equal to Russian. In a dry state, castor manifests little odour, but it is developed remarkably by infusion in spirit. It is used in perfumery to give permanency to other odours, being rarely esteemed itself. The Hudson's Bay Co. import some 1000–5000 lb. yearly.

Civet (Fr., *Civette*; Ger., *Zibeth*).—Civet is another of the odorous animal secretions contained in glandular receptacles near the genital organs. The true civet cat (*Viverra Civetta*) inhabits portions of the African continent, from Guinea and Senegal to Abyssinia. The Asiatic species is *V. Zibetha*, which is found in many parts of India, the Moluccas, and other island groups. *V. Rasse* is peculiar to Java, where its perfume is largely made use of. In the Moluccas, Wallace found *V. tangalunga*, inhabiting both Batchian and Bouru, and probably some of the other islands. He supposes it to have been introduced accidentally, as it is often captured by the Malays, who procure civet from it, and it is a restless and untamable animal likely to escape. The same species is common in the Philippines, and in all the large islands of the Indo-Malay region. Formerly numbers of *V. Civetta* were kept in confinement at Amsterdam; and a similar collection of *V. Zibetha* is, or was, maintained at Travancore. The aromatic secretion was removed from the pouch by a little spoon about twice weekly, the animal being meanwhile confined in a crib. About 1 dr. was obtained at a time. Flesh, but particularly fish, is the favourite food in confinement. The secretion of *V. Zibetha*, which is the chief kind in British commerce, is prepared for market by spreading on leaves of the pepper-vine, to free it from loose hairs. Civet, when good, has a clear yellowish or brownish colour, and a buttery consistence; it is frequently adulterated with butter and lard. Its undiluted odour is repugnant, but in infinitesimal proportion it is agreeable. Macerated in spirit, it is used chiefly as a fixing ingredient of compound scents, more largely in France than in England, where musk is preferred. The fragrant secretions of the genet or Spanish cat (*V. Genetta*) and of *V. pallida* do not seem to have been utilized.

Musk (Fr., *Musc*, *Graine d'ambrette*; Ger., *Moschus*, *Bizam*).—In common usage, the term "musk" is applied in compound names to a number of products of both animals and vegetables. Foremost is the musk-deer (*Moschus moschatus*), which will be described at length in this article.

The musk-ox (*Ovis moschatus*) affords a valuable skin (see Skins), but its odour is not utilized. The musk-rat or musquash (*Fiber zibethicus*) is provided with preputial follicles containing a substance of musk-like odour, but is valued only for its pelt (see Fur, p. 1032). The musk-rat of India (*Sorex indicus*) diffuses a most powerful odour of musk, as also does the *pilori* of the Antilles. Several Brazilian monkeys are said to emit an odour of musk. The alligator of Central America carries an odoriferous substance in the axillary glands and under the jaw, which, 200 years ago, was extracted and used as a perfume. The musk-glands of the crocodile are similarly utilized by the natives of some parts of Africa. In W. Australia, the aborigines obtain musk from the musk-duck (*Biziura lobata*). Several longicorn beetles exhale a musky odour, notably the British musk-beetle (*Callichroma moschata*); and somewhat similar perfumes pervade some species of *Cerambyx*. The most recent addition to animal musks, or substitutes for musk, has been made by Dr. Bertherand, in the droppings of the gazelle (*Gazella Dorcas*), common in the Sahara. The dried excrement is said to yield to rectified spirit 7 per cent. of a mixture containing a resinous musk-like principle, benzoic acid, a biliary acid, and colouring matter.

Among vegetable musks, may be mentioned the musk-plant proper (*Mimulus moschatus*), common in window-culture. The musk-wood of the Guianas and W. Indies (*Guarea trichilioides*, and other species) smells strongly of musk, the odour being greatest in the bark, which may be used as a perfume. Musk-like fragrance is also exhibited by *Erodium moschatum*, by the sumbul or musk-root (see Drugs, p. 826), by the spikenard of the ancients (*Nardostachys Jatamansi*), by the tuberous moschatel (*Adoxa Moschatellina*), by the silver-leaved musk-tree of Tasmania (*Eurybia argophylla*), by the musk-wood of Jamaica (*Moschoxylum Swartzii*, and *Guarea spp.*), and finally by the seeds of *Hibiscus Abelmoschus*, which plant is better known perhaps for its fibre (see p. 962). This last kind is known as musk-seed, and is commercially valuable as a perfume. The plant is cultivated in Martinique, whence its seed is largely exported to France as *ambrette* or *graine d'ambrette*. It is occasionally imported into London, and fetches about 4*s.* a lb.

Despite the large number of products capable of affording more or less of a musk-like odour, the musk-deer remains the one important commercial source of the perfume. This little animal, scarcely larger than a greyhound, is an inhabitant of the Himálayan range. From the first high ridge above the plains, to the limit of forest on the Alpine range, and throughout probably the whole length of the Himálayan chain, this deer may be found on every forest-clad hill above 8000 ft. It inhabits all kinds of forest indiscriminately, from the oaks of the lower hills to the stunted bushes near the limit of vegetation, but exhibiting a preference for birch forests, where the underwood consists chiefly of juniper and white rhododendron. A variety of the musk-deer, if not the same animal, extends its range into the dry and desert region north of the Himálayas. It is of common occurrence on the Tsanpu river in the neighbourhood of Lhasa, but only, it would seem, where the birch grows. It is abundant in Bhutan, and probably (according to R. Lydekker) ranges northward of that district over most of the open country up to Tibet, and thence across or round the Gobi desert into Siberia.

The animal is nocturnal in its habits, and exceedingly shy and agile. In some districts, it is hunted down by dogs; but it is much more commonly snared, by erecting a fence about 3 ft. high and 1 mile or more long, with openings at every 10–15 yd., provided with strong hempen snares, which catch the animal by the leg. Entrapped animals are sometimes destroyed by polecats and other vermin; in such cases, the musk-pod may be torn, and its contents scattered, but not devoured. The pod is found only in the males; and curiously enough, though their dung smells nearly as strongly as the musk itself, no such odour can be detected in the contents of the stomach and bladder, nor in any part of the body. The females are utterly devoid of odour. The pod is placed near the navel, between the flesh and skin, and is composed of several layers of thin skin, having much the appearance of a full craw of a gallinaceous bird. Its interior communicates with the outer air by means of an orifice that will admit the little finger by slight pressure, but it has no visible passage leading inwards. The musk is confined in this pod in grains of irregular roundish or ovoid shape, varying in size from small shot to a bullet, together with some coarse powder. Its colour when fresh is dark reddish-brown, becoming nearly black when removed and kept. In the cold season, the grains are firm, hard, and nearly dry; in hot weather, they become damp and soft. The pod is fully developed long before birth, indeed it is then disproportionately large. For two years, the contents remain as a soft, milky substance, of disagreeable odour. When first it becomes musk, its weight does not exceed $\frac{1}{8}$ oz.; it increases with the animal's growth, and reaches 2 oz. in some individuals, but the average yield from a full-grown animal is 1 oz., and the proportion of immature animals killed will reduce the mean of commercial pods to $\frac{1}{2}$ oz. The odour of the musk of young animals is less strong, but pleasanter than that of old ones. Differences in food, climate, and situation have not been found to affect the quality. Before the age of 3 years, the quantity is not sufficient to be worth extracting; it is greatest during the rutting season. Occasionally the musk appears to be discharged through the orifice in the pod, leaving the latter almost empty. The dealers also extract the grain musk by its means, and replace it by various substances. The size of the orifice may thus indicate in some measure the degree of tampering undergone.

The natives have two methods of preparing the pods. Usually they cut round the pod, and skin the whole belly immediately after the death of the animal. The pod comes away attached to the skin (not unhaired), which is then spread on a heated stone, flesh-side downwards, and thus dried without singeing the hair. The skin shrivels with the heat, and is tied or stitched around the pod, and the whole is hung up in a dry place till quite hard. Sometimes the pod is put into hot oil, instead of being laid on a hot stone. The object in each case is to prevent the subsequent decomposition of the fleshy skin, but the musk cannot fail to suffer much depreciation by the treatment. The best plan is to cut the pod at once from the skin, and allow it to dry in the sun, which it does in a few hours. A substance commonly used by the natives for adulterating musk or filling sham pods is blood, boiled or baked, then dried, beaten to powder, kneaded into paste, and made into coarse and fine grains in imitation of the genuine article. Many other things are similarly used.

Two forms of musk appear in commerce. "Musk in pod" is the material contained in its natural glandular receptacle; "musk in grain" is the material removed from its natural position, and put into bags. The musk in pod varies in appearance, according to whether the pod has or has not been detached from the animal's skin. The three kinds of musk met with in the London market are (1) Tonquin, Chinese, or Tibetan; (2) Assam; (3) Kabardin (Cabardien) or Russian (Siberian). The first is packed in small chests encased with sheet lead, each chest containing 25 paper packages; it is the most highly prized, and most adulterated. The second is packed in bags, stowed into a wooden or tin-plate box, containing about 200 pods, which are of irregular form, and strong but rank odour. The third kind is much inferior, the pods being smaller, and the odour much weaker and less agreeable; it is too poor to bear any adulteration. Recent exports of musk from Chinese ports, stated in *piculs* of $133\frac{1}{3}$lb., have been:—Canton, exports to foreign countries, 0·84 *piculs* in 1878, 0·63 in 1879; Hankow, exports and re-exports, 32·32$\frac{5}{16}$ *piculs* in 1878, 31·95 in 1879; Shanghae, total exports and re-exports, 39·20$\frac{13}{16}$ *piculs* in 1879; Ichang, exports, 5·84 *piculs* in 1879. The exports of musk from British India were:—7403 oz., value 10,562*l.* in 1874–5; 5267 oz., 11,782*l.*, in 1875–6; 5020 oz., 11,726*l.*, in 1876–7; 3115 oz., 7904*l.*, in 1877–8; 3444 oz., 6954*l.*, in 1878–9. The distribution of the export in 1878–9 was:—2576 oz. to the United Kingdom, 52 oz. to Malta, 540 oz. to Arabia, 70 oz. to Turkey in Asia, and 206 oz. to other countries.

Musk is employed in perfumery mainly to give permanency to other odours. Its fragrance is much affected and even destroyed by some other bodies; it is considerably altered by camphor and valerian, and is quite destroyed by bitter almonds and powdered ergot.

No serious attempt seems to have been made to domesticate the musk-deer, nor to acclimatize it in other mountain regions. The young taken wild are rather difficult to rear, many of them soon becoming blind, and dying. They eat very little as compared with other ruminants, and feed on various shrubs, grasses, mosses, and roots. Those met with in forest-clad country are much finer than those in open ground.

Nag-kassar.—The flowers of *Calysaccion longifolium* and *Mesua ferrea*, two nearly allied species, are often confounded, and both are collected and sold in the Indian bazars for their fragrance. The first species is a tree, plentiful in S.-W. India and in China; its flower-buds, somewhat resembling cloves, are variously known as *suriga, surgiha, soohgee-hoo*, and *nag-kassar*, the last being the name under which they have been imported to this country. The second species is much cultivated in Malabar and in Java. The name *nag-kassar* is sometimes spelt *naghas, nagasar, nagkesur*, or *nag-kushur*. The flowers of both species are largely used in native dyeing in India (see p. 864).

Orange-flowers.—See Neroli-oil, p. 1425.

Orange-zeste.—See Orange-oil, p. 1425.

Orris-root (Fr., *Racine d' Iris*; Ger., *Veilchenwurzel*).—Orris-root is obtained from three species of *Iris*: (1) *I. germanica*, the common "blue flag" of the gardens around London; abundant near Florence and Lucca, ascending to the chestnut region, and found scattered throughout Central and S. Europe, and in Morocco and N. India. (2) *I. pallida*, with much more delicate blue flowers, growing wild in stony places in Istria, and plentiful in the olive-region about Lucca and Florence. (3) *I. florentina*, bearing large white flowers, a native of the Macedonian coast and the S.-W. shores of the Black Sea, notably Hersek, in the Gulf of Ismid, and near Adolia, in Asia Minor; and occurring naturalized in the vicinity of Lucca and Florence. The three species were under cultivation in England at the end of the 16th century. They are all grown for their root in the country about Florence, being known to the peasants of Tuscany indiscriminately as *giaggiolo*. The cultivation is of secondary importance, the plants being placed on the edges of terraces, and on waste stony places contiguous to cultivated ground. The rhizomes are harvested in the autumn of every 3rd year. The plants are dug up early in the autumn, before commencing the next year's growth; the flags (leaves) are cut back, and each root is severed just below the base of the leaves. The head is then replanted, and grows vigorously. It flourishes best in poor soil, and receives no manure. The rhizomes are spread out to dry and ripen in the open air and sunshine, and are peeled and trimmed. Some pieces are bleached by exposure to the fumes of burning sulphur, but such are not available for perfumery purposes. The prepared pieces are classified by the dealers into *scelti* and *in sorte*, and are brought into commerce entire, in fragments (*frantumi*), as parings (*raspature*), as powder (*polvere*), or manufactured into "peas." About Verona, the rhizomes of *I. germanica* (called *giglio celeste* or *selvatico*) are collected and brought into Tregnano and Illasi, distinction being made between the selected long roots (*radice dritta*), the knotty roots (*radice grappa*) used for issue-peas, and the fragments (*scarto*) for perfumery. Some orris-root is exported from Botzen, in S. Tyrol. A sort which has been dried in its outer peel goes by the name of *irisa* in the Indian bazars, and appears occasionally in the London market; it appears to be derived from *I. germanica* [*nepalensis*], cultivated in Kashmir. A low quality of orris-root, the produce of *I. germanica*, is obtained from Morocco. The chief shipments of the root take place from Mogador, Trieste, and Leghorn. The first-named port in 1878 despatched 155 serons, value 410*l.*, to Great Britain, and 27 serons, 65*l.*, to France; total, 364 cwt., 475*l.* In 1876, the total was 834 cwt. France, in 1870, imported a total of about 50 tons of orris-root. The powdered root is largely used in satchets, and its extract in bouquets.

Sandal-wood (Fr., *Bois de Santal citrin*; Ger., *Weisses* [*gelbes*] *Sandelholz*).—The name "sandal-wood" is applied to the aromatic heart-wood of several species of *Santalum*. These are chiefly as follows: (1) *S. album*, a tree of 20–30 ft. in height and 18–36 in. in girth, indigenous to the hilly portions of the Indian peninsula, especially in Mysore, Coimbatore, and N. Canara; found also in the E. Archipelago, particularly Sumba (Chandane or Sandal-wood Island), and Timor; (2) *S. Freycinetianum* and *S. paniculatum* [*pyrularium*] in Hawaii (Sandwich Islands); (3) *S. Yasi*, in the Fiji (Viti) Islands; (4) *S. austro-caledonicum*, in New Caledonia; (5) *S. spicatum* [*latifolium*, *cygnorum*, *Fusanus spicatus*], in W. Australia. The *S. lanceolatum* of N. and E. Australia does not seem to afford a commercial article. The wood of *S. myrtifolium*, in the Madras Presidency, is nearly inodorous. The island of Nossi-bé, on the N.-W. coast of Madagascar, is said to afford some sandal-wood.

The most important of all these sources is the cultivated *S. album* of the Indian reserved forests. The tree occupies patches of a strip of country about 250 miles long, on the eastern slopes of the W. Ghats, just beyond the limits of the Mulnaad or rain-country, as well as a tract further eastward, in the district of Salem and N. Arcot, where it grows from sea-level to 3000 ft. The tree is commonly found in scrub-jungles, and even in open spots in some of the large deciduous forests; but in the plain countries of Mysore, it mostly occurs in hedges and ditches, and on irrigation earthworks. It propagates itself by seeds and suckers, the latter springing up from the long creeping roots wherever these become exposed to the influence of the air, and sometimes developing into good trees at 15 yd. from the parent. It is easily raised from seed, even that which has been stored for months; but transplanted seedlings generally fail. The plantations are now all raised from seed. This should be collected in December–January, and be sown during the early rains in June; 2–3 seeds are dibbled in with 1 capsicum seed, which latter rapidly throws up a plantlet for the shade of the young sandal-trees, and possibly affords them some sustenance. Young sandal-plants flourish best in seed-beds where grass is allowed to grow, as tuber-like processes from their roots prey upon the other growth. Dry, red soils, overlying a stratum of gravel or quartz, are most suitable, the trees maturing in about 20 years; white, strong soils produce trees of stunted growth, mature in 16 years; rich alluvial soils grow very fine trees, requiring 30–40 years to mature, but such trees contain no heart-wood, and are valueless. The maturity of the tree is judged by certain appearances. When the heart-wood is fully formed, the leaves are narrow, and of a dull-green to yellowish-red tint; the small terminal branches are withered, the bark is deeply wrinkled and often moss-grown, and the inner bark, when cut, shows a reddish or yellow instead of white colour. Decay rapidly sets in after the trees have matured.

Mature trees are felled at the end of the year, the branches are lopped off, and the trunk is allowed to lie on the ground for several months, by which time, most of the valueless sap-wood will have been devoured by white ants. The heart-wood is then roughly adzed, and sawn into billets 2–2½ ft. long, for conveyance to the government forest depôts. It is again trimmed with the adze, weighed, and classified according to quality. The chips obtained in the first and second trimmings are called respectively "mixed" and "pure." These, as well as the sawdust produced, and the roots of the tree, are subjected to distillation for the sake of their essential oil (see Oils, p. 1430). In Mysore, all sandal-wood trees are the property of the government; the annual exports (shipped from Mangalore) are about 700 tons, value 27,000*l.* In Madras, the culture is free, but is almost entirely restricted to the reserved forests, which produced 15,329 *maunds* (547½ tons) in 1872–3.

The Indian species grows sparingly in the mountains of Timor, and many of the other islands of the E. Archipelago. The heart-wood is brought down in small logs to Dilli, chiefly for export to China, where it is reckoned only ¼–⅓ as valuable as Indian.

W. Australia less than 20 years since exported great quantities of sandal-wood to China. The trees were cut and trimmed in the bush, some 100–150 miles from the ports (Perth or Guildford);

but indiscriminate destruction soon exterminated the trees from accessible regions. The 47,904 cwt. of sandal-wood imported into Singapore from Australia in 1872, for re-shipment to China, was probably mainly of Pacific Islands' production, possibly some portion also from Queensland.

The headquarters of the sandal-wood trees in the Pacific Islands would appear to have been in the S.-W. portion, including New Caledonia, the Loyalty Islands, New Hebrides, Espirito Santo, and some others. Several thousand tons of the wood were shipped at one time; but the tree has now been exterminated from all the well-known islands, with the exception of New Caledonia, where it is under cultivation.

Sandal-wood is little known in Western commerce, but is one of the most important perfumes of the East, where it is chiefly burnt as incense in religious rites. Bombay yearly imports some 650 tons and exports about 400 tons. The chief market for sandal-wood is China, whose imports (in *piculs* of 133⅓ lb.) have recently been as follows:—Chinkiang, 30,818 *piculs* in 1877, 23,719 in 1878, 25,537 in 1879; Hankow, 15,582½ *piculs*, 40,320*l.*, in 1879; Kiukiang, 4378 *piculs* in 1877, 3451 in 1878, 4108 in 1879; Ningpo, 795 *piculs* in 1877, 963 in 1878, 1073 in 1879; Shanghae, 48,325 *piculs* from foreign countries, and 28,219 from Hong Kong and Chinese ports, in 1879; Taiwan, 322⅓ *piculs* in 1879; Wuhu, 5515 *piculs* in 1877, 5319½ in 1878, 7161 in 1879.

Tonquin-, Tonka-, or Tonga-beans.—Tonquin or *gayac* beans are the fragrant seeds of *Dipterix* [*Coumarouna*] *odorata*, a tall tree of Venezuela, the Guianas, and some neighbouring localities, growing best in loamy soil, and easily raised from cuttings. The beans are used whole for perfuming wardrobes, ground for satchet-powders, and in the form of extract. The odoriferous principle, coumarine, is common to the May grass (*Anthoxanthum odoratum*); to the melilot (*Melilotus cæruleus*), the *zieger-kraut* ("curd-herb") of Switzerland, whose dried and powdered flowers, worked up with the curd, give the peculiar odour and flavour to Schabzieger (Chapziger) cheese; to the Faham tea-plant of the Mauritius (*Angræcum fragrans*); and to the common sweet woodruff (*Asperula odorata*). It acts powerfully upon the brain, and is probably the source of "hay-fever." Tonquin-beans are received in much smaller quantity into this country than into the United States. The exports from the ports of Ciudad Bolivar, in Venezuela, to New York, were 33,083⅝ lb. in 1878, and 133,046¼ lb. in 1879.

Vanilla.—The seed-pods of the vanilla-plant possess an agreeable odour, which is prepared from them by extracting with rectified spirit, and used in the manufacture of compound scents. The pods possess much greater industrial importance as a flavouring ingredient, and their production and commerce will therefore be described at length under Spices.

PREPARED PERFUMES.

Extracts or Essences.—The simplest form of prepared perfume is the extract or essence, consisting of a solution of the principle in rectified alcohol. Some are mere artificial compounds, imitating the odour of the substance whose name they bear. The chief extracts are prepared as follows:—

Ambergris.—(*a*) Ambergris, 3 oz.; alcohol, 1 gal.

(*b*) Ambergris-extract, 1 pint; triple rose and musk extracts, each ½ pint; vanilla-extract, 2 oz.

Cedar.—Cedar-oil, 1 oz.; alcohol, 4 pint; triple rose extract, ¼ pint.

Civet.—Civet, 1 oz.; orris-root, 1 oz.; rubbed up in a mortar, and dissolved in 1 gal. alcohol.

Eglantine or Sweet-briar (imitation).—French rose-pomatum extract, 1 pint; cassie-extract, ¼ pint; orange-flower extract, ¼ pint; rose-extract, ¼ pint; neroli-oil, ½ dr.; lemon-grass-oil, ½ dr.

Heliotrope (imitation).—Vanilla-extract, ½ pint; French rose-pomatum extract, ¼ pint; orange-flower pomatum extract, 2 oz.; ambergris-extract, 1 oz.; almond-oil, 5 drops.

Honeysuckle (imitation).—Rose-pomatum extract, 1 pint; violet-extract, 1 pint; tuberose-extract, 1 pint; vanilla-extract, ¼ pint; tolu-extract, ¼ pint; neroli-oil, 10 drops; almond-oil, 5 drops.

Hovenia (imitation).—Dissolve ½ oz. lemon-oil, 1 dr. rose-oil, ½ dr. clove-oil, 10 drops neroli-oil, in 1 qt. alcohol, and add ½ pint rose-water.

Ilang-ilang.—Ilang-oil, 6 oz.; alcohol, 1 gal. (See also p. 1530).

Jonquil.—Jonquil-pomade, 8 lb.; alcohol, 1 gal.

Jonquil (imitation).—Jasmine-pomade extract, 1 pint; tuberose extract, 1 pint; orange-flower extract, ½ pint; vanilla-extract, 2 fl. oz.

Lavender.—Lavender-oil, 6 oz.; alcohol, 1 gal.

Lavender (Smyths').—Lavender-oil, 4 oz.; alcohol, 5 pints; rose-water, 1 pint; distil to 5 pints.

Lilac (imitation).—Tuberose-pomade extract, 1 pint; orange-flower pomade extract, ¼ pint; almond-oil, 3 drops; civet-extract, ½ oz.

Lily-of-the-Valley (imitation).—Vanilla-extract, 3 oz.; orange-flower extract, 2 oz.; jasmine-extract, 1 oz.; tuberose-extract, 1 pint; cassie-extract, ¼ pint; rose-extract, ¼ pint; almond-oil, 3 drops.

Lime-blossom (imitation).—Agar-attar (lignaloe-oil), 1 oz.; extracts of triple rose, jasmine, and orris, each ½ pint; alcohol, 2 pints.

Lignaloe (*Agar*).—Lignaloe-oil, 3 oz.; triple rose extract, 2 pints; jasmine-extract, 2 pints; tuberose-extract, 2 pints; orris-extract, 1 pint; vanilla-extract, 1 pint.

Magnolia (imitation).—Almond-oil, 10 drops; citron-zeste, 3 dr.; orange-flower pomade extract, 1 pint; tuberose-pomade extract, ½ pint; rose-pomade extract, 2 pints; violet-pomade extract, ½ pint.

Musk.—(*a*) Grain musk, 2 oz.; alcohol, 1 gal.

(*b*) Musk-extract, 1 pint; ambergris-extract, ½ pint; triple rose extract, ¼ pint.

Myrtle (imitation).—Rose-extract, 1 pint; vanilla-extract, ½ pint; orange-flower extract, ½ pint; tuberose-extract, ½ pint; jasmine-extract, 2 oz.

Narcissus (imitation).—Tuberose-extract, 3 pints; jonquil-extract, 2 pints; tolu-extract, ¼ pint; storax-extract, ¼ pint.

Orange-flower or Neroli.—Orange-flowers, 4 oz.; alcohol, 1 gal.

Orris.—Crushed orris-root, 7 lb.; alcohol, 1 gal.

Patchouli.—Patchouli-oil, 1¼ oz.; rose-oil, ¼ oz.; alcohol, 1 gal.

Pea [*Sweet-*] (imitation).—Tuberose, orange-flower, and rose-pomatum extracts, each ½ pint; vanilla-extract, 1 oz.

Pink [*Clove-*] (imitation).—Rose-extract, ½ pint; orange-flower and cassie extracts, each ¼ pint; vanilla-extract, 2 oz.; clove-oil, 10 drops.

Rose [*Chinese Yellow*].—Triple rose and tuberose extracts, each 2 pints; tonquin and verbena extracts, each ¼ pint.

Rose [*Moss*].—French rose-pomade extract, 1 qt.; triple rose and orange-flower extracts, each 1 pint; ambergris-extract, ½ pint; musk-extract, 4 oz.

Rose [*Tea*].—Rose-pomade, triple rose, and rose-leaf geranium extracts, each 1 pint; sandal-wood extract, ½ pint; orange-flower and orris extracts, each ¼ pint.

Rose [*Triple*].—Rose-oil, 3 oz.; alcohol, 1 gal.

Rose [*Twin*].—Rose-pomade, 8 lb.; French rose-oil, 1½ oz.; alcohol, 1 gal.

Rose [*White*].—Rose-pomade, triple rose, and violet extracts, each 1 qt.; jasmine-extract, 1 pint; patchouli-extract, ½ pint.

Sandal-wood.—Sandal-wood-oil, 3 oz.; rose-extract, 1 pint; alcohol, 7 pints.

Tolu-balsam.—Tolu-balsam, ½ lb.; alcohol, 1 gal.

Tonquin.—Tonquin-beans, 1 lb.; alcohol, 1 gal.

Tuberose.—Tuberose-pomade, 8 lb.; alcohol, 1 gal.

Vanilla.—Vanilla-pods, ½ lb.; alcohol, 1 gal.

Verbena (imitation).—(*a*) Lemon-peel-oil, 2 oz.; orange-peel-oil, ½ oz.; lemon-grass-oil, 3 dr.; alcohol, 1 pint.

(*b*) Orange-flower and tuberose extracts, each 7 oz.; lemon-peel-oil, 2 oz.; orange-peel-oil, 1 oz.; lemon-grass-oil, 2½ dr.; citron-zeste, 1 dr.; rose-extract, ½ pint; alcohol, 1 pint.

Violet (imitation).—Cassie-pomade extract, 1 pint; rose-pomade, tuberose-pomade, and orris extracts, each ½ pint; almond-oil, 3 drops.

Vitivert or Kuskus.—(*a*) Dried and chopped vitivert, 4 lb.; alcohol, 1 gal.

(*b*) Vitivert-oil, 2 oz.; alcohol, 1 gal.

Volkameria (imitation).—Violet and tuberose extracts, each 1 pint; rose extract, ½ pint; jasmine-extract, ¼ pint; musk-extract, 2 oz.

Wallflower (imitation).—Rose and orange-flower extracts, each 1 pint; vanilla, orris, and cassie extracts, each ½ pint; almond-oil, 5 drops.

Wintergreen.—Rose-extract, 1 pint; orange-flower and cassie extracts, each ½ pint; lavender, vanilla, and vitivert extracts, each ¼ pint; wintergreen-oil, 5 drops.

Incenses and Pastilles.—These names are applied to compositions which perfume by fumigation, i. e. emit their odour by undergoing slow and incomplete combustion. The following are the chief recipes for their preparation:—

Bruges Ribbon.—Mix ½ pint orris-extract, ¼ lb. gum benzoin, and ¾ oz. gum myrrh, in one bottle; and ½ pint alcohol, ½ oz. pod musk, and 1 dr. rose-oil, in another. Let stand 1 month. Steep undressed cotton tape in a solution of 1 oz. nitrate of potash in 1 pint hot rose-water; dry it; filter and mix the contents of the two bottles, steep the ribbon, and dry it.

Incense-powder.—1 lb. powdered sandal-wood, ½ lb. each powdered cascarilla-bark and gum-benzoin, 2 oz. each vitivert and nitrate of potash, and ¼ dr. grain musk, well sifted together.

Perfumers' Pastilles.—Wood-charcoal, 1 lb.; gum benzoin, ¾ lb.; tolu balsam, vanilla-pods, and cloves, each ¼ lb.; sandal-wood- and neroli-oils, each 2 dr.; nitrate of potash, 1½ oz. in gum tragacanth as before.

Piesse's Pastilles.—Willow-charcoal, ½ lb.; benzoic acid, 6 oz.; thyme-, caraway-, rose-, lavender-, clove- and sandal-wood-oils, each ½ dr.; grain musk, 1 dr.; civet, ¼ dr.; before mixing, ¾ oz. nitrate of potash is dissolved in ½ pint rose-water; the charcoal is thoroughly wetted with this solution, then dried; the mixed oils are poured over it, and the benzoic acid is stirred in; the whole is well mixed, and then beaten up with a gum mucilage.

Seraglio Pastilles.—Gum benzoin, 60 gr.; poplar-charcoal, 190 gr.; sandal-wood, 15 gr.; tolu balsam, 8 gr.; laudanum, 4 gr.; nitrate of potash, 8 gr.; mucilage of gum tragacanth, 9½ gr.

Yellow or Indian Pastilles.—Powder and mix by sifting 1 lb. sandal-wood, 1½ lb. gum benzoin and ½ lb. tolu balsam; add 3 dr. each of sandal-wood-, cassie-, and clove-oils; then 1½ oz. nitrate of potash, dissolved in enough mucilage of gum tragacanth to make a stiff paste of the whole.

Nosegays or Bouquets.—By far the greatest part of the scent consumed is in this form, being, as the names indicate, mixtures of a number of odoriferous extracts. The principal recipes are as follows:—

Alhambra.—Tuberose-extract, 1 pint; geranium-extract, ½ pint; acacia-, civet-, and orange-flower extracts, each ¼ pint.

d'Amour.—Pomade-extracts of rose, jasmine, violet, and cassie, each 1 pint; musk- and ambergris-extracts, each ½ pint.

d'Andorre.—Pomade-extracts of rose, jasmine, violet, and tuberose, each 1 pint; orris-extract, 1 pint; geranium-oil, ¼ oz.

Bosphorus.—Acacia-extract, 1 pint; triple rose, jasmine, tuberose, and orange-flower extracts, each ½ pint; civet-extract, ¼ pint; almond-oil, 10 drops.

Buckingham Palace.—Pomade-extracts of rose, jasmine, cassie, and orange-flower, each 1 pint; ambergris- and orris-extracts, each ½ pint; rose-oil, 1 dr.; neroli- and lavender-oils, each ½ dr.

Caroline or des Délices.—Pomade-extracts of rose, violet, and tuberose, each 1 pint; ambergris- and orris-extracts, each ½ pint; citron-zeste, ½ oz.; bergamot-oil, ¼ oz.

Court.—Rose-, violet-, triple rose-, and jasmine-extracts, each 1 pint; ambergris- and musk-extracts, each 1 oz.; citron-zeste and bergamot-oil, each ½ oz.; neroli-oil, 1 dr.

Eugénie.—Geranium-, triple rose-, and sandal-wood-extracts, each ½ pint; musk-, vanilla-, neroli-, and tonquin-bean extracts, each ¼ pint.

Ess.—Triple rose-extract, 1 pint; orris-extract, 8 oz.; ambergris-extract, 2 oz.; bergamot-oil, 1 oz.; lemon-oil. ¼ oz.

Eszterhazy.—Pomade-extract of orange-flower, and extracts of triple rose, vitivert, vanilla, orris, tonquin-beans, and neroli, each 1 pint; ambergris-extract, ½ pint; sandal-wood-oil, 1 oz.; clove-oil, ½ dr.

de Flora.—Pomade-extracts of rose, tuberose, and violet, each 1 pint; benzoin-extract, 1½ oz.; bergamot-oil, 2 oz.; citron- and orange-zestes, each ½ oz.

Flowers of Erin.—White rose extract, 1 pint; vanilla-extract, 1 oz.

Guards'.—Rose-extract, 2 pints; vanilla-, orris-, and orange-flower extracts, each ½ pint; musk-extract, ¼ pint; clove-oil, ½ dr.

Holy Basil.—Vanilla-, geranium-, and tonquin-bean-extracts, each 2 pints; cassie-, jasmine-, tuberose-, tolu-, orange-flower-, and Montserrat lime-essences, each 1 pint.

Ilang-ilang.—Rose-pomade-, triple rose-, cassie-, jasmine-, and tuberose-extracts, each 1 pint; orris-extract, 2 pints; ilang-oil, 1 oz.; pimento-oil, ¼ oz.; alcohol, 1 pint.

International.—Violet-extract, 1 pint; triple rose-, jasmine-, and tuberose-extracts, each ½ pint; lavender-, vanilla-, sandal-wood-, musk-, and patchouli-extracts, each ¼ pint; lemon-oil, ¼ oz.; citronella-oil, 1 dr.

Isle of Wight.—Sandal-wood-extract, 1 pint; rose- and orris-extracts, each ½ pint; vitivert-extract, ¼ pint.

Italian.—Rose-pomade extract, 2 pints; extract of triple rose, and pomade-extracts of jasmine and violet, each 1 pint; cassie-extract, ½ pint; musk- and ambergris-extracts, each 2 oz.

Jockey Club (English).—Orris-extract, 2 pints; triple rose extract and rose pomade extract, each 1 pint; extract of ambergris, and pomade-extracts of cassie and tuberose, each ½ pint; bergamot-oil, ½ oz.

Jockey Club (French).—Rose-pomade extract and tuberose-extract, each 1 pint; jasmine-extract, ⅜ pint; cassie-extract, ½ pint; civet-extract, 3 oz.

Kew Garden.—Orange-flower-extract, 1 pint; pomade-extracts of cassie, tuberose, and jasmine, and extract of geranium, each ½ pint; musk- and ambergris-extracts, each 3 oz.

Leap-year.—Jasmine- and tuberose-extracts, each 1 pint; extracts of triple rose, sandal-wood, patchouli, and vitivert, each ½ pint; verbena-extract, 1 gill.

du Maréchal.—Triple rose and orange-flower extracts, each 1 pint; vitivert-, vanilla-, orris-, tonquin-bean, and neroli-extracts, each ½ pint; ambergris- and musk-extracts, each ¼ pint; clove- and sandal-wood-oils, each ½ dr.

May Flowers.—Vanilla-extract, 1 pint; rose-, jasmine-, cassie-, and orange-flower-extracts, each ½ pint; almond-oil, ¼ dr.

de Montpellier.—Rose-pomade extract, and tuberose- and triple rose-extracts, each 1 pint; ambergris- and musk-extracts, each ½ pint; bergamot-oil, ½ oz.; clove-oil, 1½ dr.

New-mown Hay.—Tonquin-bean-extract, 2 pints; geranium-, orange-flower-, jasmine-, rose-, and triple rose-extracts, each 1 pint.

Opoponax.—Infuse 1 oz. pod musk, 8 oz. vanilla, 4 oz. tonquin-beans in 10 pints alcohol for 1 month; then add 8 pints millefleur pomade-extract, 4 pints orris-extract, 2 oz. each citron-zeste and bergamot-oil, 1½ oz. rose-oil, and ½ oz. opoponax-oil.

de la Reine d'Angleterre.—Pomade-extracts of rose and violet, each 1 pint; tuberose-extract, ½ pint; orange-flower-extract, ¼ pint; bergamot-oil, ¼ oz.

du Roi.—Pomade-extracts of rose, violet, and jasmine, each 1 pint; vanilla- and vitivert-extracts, each ¼ pint; ambergris- and musk-extracts, each 1 oz.; clove-oil, 1 oz.; bergamot-oil, 1 dr.

Rondeletia.—Lavender-oil, 2 oz.; bergamot- and clove-oils, each 1 oz.; rose-oil, 3 dr.; ambergris-, musk-, and vanilla-extracts, each ½ pint; alcohol, 1 gal.

Royal Hunt.—Triple rose extract, 1 pint; acacia-, neroli-, musk-, orris-, and orange-flower-extracts, each ¼ pint; tonquin-bean extract, ½ pint; citron-zeste, 2 dr.

Piesse's Posy.—Rose-pomade-extract, 1 pint; extract of triple rose, and pomade-extracts of violet and jasmine, each ½ pint; verbena- and cassie-extracts, each 2½ oz.; ambergris- and musk-extracts, each 1 oz.; bergamot- and lemon-oils, each ¼ oz.

Spring Flowers.—Pomade-extracts of rose and violet, each 1 pint; cassie- and triple rose-extracts each 2½ oz.; ambergris-extract, 1 oz.; bergamot-oil, 2 dr.

Suave.—Pomade-extracts of rose, cassie, jasmine, and tuberose, each 1 pint; vanilla-extract, 5 oz.; ambergris- and musk-extracts, each 2 oz.; bergamot-oil, ¼ oz.; clove-oil, 1 dr.

Tulip.—Pomade-extracts of jasmine, violet, and tuberose, each 1 pint; rose-extract, ½ pint; orris-extract, 3 oz.; almond-oil, 2 drops.

Volunteers'.—Orris-extract, 1 pint; cassie- and jasmine-extracts, each ¼ pint; ambergris- and musk-extracts, each 2½ oz.; rose-, neroli-, bergamot-, and lavender-oils, each ¼ oz.; clove-oil, 8 drops; alcohol, 1 pint.

West-End.—Triple rose extract, 3 pints; violet-, cassie-, jasmine-, and tuberose-extracts, each 1 pint; ambergris- and musk-extracts, each ½ pint; bergamot-oil, 1 oz.

Wood-Violet.—Violet-extract, 1 pint; cassie-, orris-, and rose-pomade-extracts, each 3 oz.; almond-oil, 3 drops.

Yacht Club.—Neroli- and sandal-wood-extracts, each 1 pint; triple rose- and jasmine-extracts, each ½ pint; vanilla-extract, ¼ pint; benzoin-flowers, ¼ oz.

Satchets.—Perfumes intended to be placed in satchets, or ornamental receptacles of paper, silk, &c., must be such as retain their fragrance in a dry state. These are ground very fine, and compounded according to the subjoined formulæ:—

Cassie.—Cassie-heads, 1 lb.; orris-root, 1 lb.

Cyprus.—Rose-wood, cedar-wood, and sandal-wood, each 1 lb.; rose-wood-oil, 3 dr.

Frangipanni.—Orris-root, 3 lb.; vitivert and sandal-wood, each ¼ lb.; rose-, neroli-, and sandal-wood-oils, each 1 dr.; musk pods, 1 oz.; civet, ¼ oz.

Heliotrope.—Orris-root, 2 lb.; rose-leaves, 1 lb.; tonquin-beans, ½ lb.; vanilla-beans, ¼ lb.; grain musk, ¼ oz.; almond-oil, 5 drops.

Lavender.—Lavender-flowers, 1 lb.; gum benzoin, ¼ lb.; lavender-oil, ¼ oz.

Maréchale.—Sandal-wood and orris-root, each ½ lb.; rose-leaves, cloves, and cassia-bark, each ¼ lb.; grain musk, ½ dr.

Millefleur.—Lavender-flowers, orris-root, rose-leaves, and gum benzoin, each 1 lb.; tonquin-beans, vanilla-beans, cloves, and sandal-wood, each ¼ lb.; cinnamon and allspice, each 2 oz.; musk and civet, each 2 dr.

Mousseline.—Vitivert, 1 lb.; orris-root, sandal-wood, and black-currant leaves, each ½ lb.; gum benzoin, ¼ lb.; rose-oil, ½ dr.; thyme-oil, 5 drops.

Patchouli.—Patchouli-herb, 1 lb.; patchouli-oil, ¼ dr.

Peau d'Espagne.—Rose-, neroli-, and sandal-wood-oils, each ½ oz.; lavender-, verbena-, and bergamot-oils, each ¼ oz.; clove- and cinnamon-oils, each 2 dr.; then add a solution of 4 oz. gum benzoin in ½ pint alcohol; steep pieces of wash-leather in the mixture for a day or two; squeeze out, and dry. Rub up a paste of 1 dr. each of civet and grain musk with enough gum mucilage to give a spreading consistence; spread the paste on one side of the skin pieces; place two pieces together with the pasted sides facing, and sew up in silk bags.

Portugal.—Orange-peel, 1 lb.; lemon-peel and orris-root, each ½ lb.; orange-peel oil, 1 oz.; neroli- and lemon-grass-oils, each ¼ dr.

Pot-pourri.—Lavender, rose-leaves, and salt, each 1 lb.; orris-root, ½ lb.; cloves, cinnamon, and allspice, each 2 oz.

Rose.—Rose-heels or leaves, 1 lb.; sandal-wood ½ lb.; rose-oil, ¼ oz.

Verbena.—Lemon-peel, 1 lb.; lemon-thyme, ¼ lb.; bergamot-oil, 1 oz.; lemon-peel-oil, ½ oz.; lemon-grass-oil, 1 dr.

Violet.—Black-currant-leaves, cassie-heads, and rose-heels or leaves, each 1 lb.; orris-root, 2 lb.; gum benzoin, ½ lb.; grain musk, 1 dr.; almond-oil, ¼ dr.

Vinegars [Aromatic].—See p. 335.

Waters and Eaux.—The term "water," or its French equivalent *eau*, is applied to some few compound scents, without any very obvious reason. The principal of these are constituted as follows:—

des Carmes.—Fresh leaves of *Melissa officinalis*, 2 lb.; fresh lemon-peel, ¼ lb.; nutmeg, coriander seeds, cloves, cinnamon, and angelica root, all broken fine, each 2 oz.; the whole is placed in a still with ½ gal. orange-flower-water and 1 gal. alcohol, and distilled slowly till 1 gal. has condensed.

de Chypre.—Musk-extract, 1 pint; extracts of ambergris, orris, vanilla, and tonquin-bean, each ½ pint; triple rose extract, 2 pints.

de Cologne.—(*a*) Grape-alcohol, 6 gal.; orange and citron zestes, each 5 oz.; neroli-oil, 3 oz.; rosemary and bergamot oils, each 2 oz.; bigarade oil, 1 oz.

(*b*) Grain-alcohol, 6 gal; lemon, bergamot, and orange-peel oils, each 4 oz.; rosemary and petit grain oils, each 2 oz.; neroli-oil, ½ oz.

Elder-flower.—Distil 12 lb. of the flowers with water until that passing into the receiver has no perfume—usually 15–18 lb.; to the distillate, add 12 lb. alcohol, and distil 5 lb. from it. Of this, mix 2 oz. with 10 oz. distilled water.

Hungary.—Grape-alcohol, 1 gal.; rose- and orange-flower extracts, each 1 pint; Hungarian rosemary-oil, 2 oz.; lemon-peel and *Melissa* oils, each 1 oz.; mint-oil, ½ dr.

Lavender.—English lavender-oil, 4 oz.; alcohol, 3 qt.; rose-water, 1 pint.

Lisbon.—Alcohol, 1 gal.; orange-peel-oil, 4 oz.; citron zeste, 2 oz.; rose-oil, ¼ oz.

de Luce.—Benzoin or Peru balsam extract, 1 oz.; lavender-oil, 10 drops; liquor ammonia, 2 oz.; oil of amber, 5 drops.

de Millefleurs.—Triple rose extract, 1 pint; pomade-extracts of rose, jasmine, tuberose, orange-flower, cassie, and violet, each ½ pint; cedar-extract, ¼ pint; musk, ambergris, and vanilla extracts, each 2 oz.; bergamot-oil, 1 oz.; clove-, almond-, and neroli-oils, each 10 drops.

de Mousseline.—Maréchale bouquet, 1 pint; pomade-extracts of jasmine, cassie, tuberose, and rose, each ½ pint; sandal-wood-oil, 2 dr.

de Portugal.—Alcohol, 1 gal.; orange-peel-oil, 8 oz.; citron zeste, 2 oz.; bergamot-oil, 1 oz.; rose-oil, ¼ oz.

Rose.—The preparation of rose-water has been described at length under rose-oil (see p. 1427).

Imports and Values.—Our imports of unenumerated perfumery, independent of essential oils (see p. 1483), in 1879, were:—From Holland, 687,391 lb., value 25,057*l.*; France, 320,985 lb., 27,676*l.*; China, 4988 lb., 49,561*l.*; other countries, 167,960 lb., 23,772*l.*; total, 1,181,324 lb., 126,066*l.* The approximate London market values of the principal commercial raw perfumes are:—Ambergris, 45–85*s.* an oz.; Aniseed, 26–40*s.* an oz.; Star anise, 80–105*s.* an oz.; Musk, pod, 13–65*s.* an oz., grain, 30–70*s.* an oz.; Civet, 11*s.* an oz.; Castor, 12–26*s.* a lb.; Orris-root, 20–45*s.* a cwt.; Tonquin-beans, 4*s.* 6*d.*–7*s.* a lb.; Sandal-wood, 10–60*s.* a ton.

Bibliography.—C. Morfit, 'Perfumery: its Manufacture and Use' (Philadelphia: 1853); H. Dussauce, 'Treatise on Perfumery' (Philadelphia: 1864); E. Rimmel, 'Book of Perfumes' (London: 1865); R. J. Owen, 'Practice of Perfumery' (London: 1870); G. W. S. Piesse, 'Art of Perfumery' (4th ed. London: 1879); J. Fuchs, 'Castoreum' (Pharm. Jour., Vol. xi., No. 565, p. 875, London: 1881); G. W. Askinson, 'Parfumerie-Fabrikation' (Leipzig).

PHOTOGRAPHY (Fr., *Photographie*; Ger., *Photographie*, *Lichtbildkunst*).

The history of photography is the history of half a century of progress almost without parallel in the annals of science. Many of the photographic processes which followed the discoveries of Daguerre and Talbot have either become obsolete, or have been absorbed in processes of more permanent value.

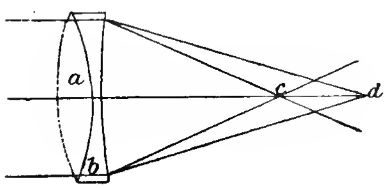
In the present article, it is proposed to deal with the modern phases of photography, leaving out of consideration the early history and progress of the art. It will be convenient to treat the subject under three heads; viz. Photographic Instruments and Appliances, Modern Photographic Processes, and Modern applications of Photography.

Photographic Instruments.—Without the camera and its lens, the majority of photographic processes would be practically useless. The photographic camera obscura—dark chamber—with its image-forming lens, may be likened to the human eye, whose retina finds its mimicry in the sensitive photographic plate upon which the image falls, and is impressed. The eye is a perfect optical instrument, whose lens and iris, or diaphragm, so adjust themselves in focus, and to the varying conditions of light, as to transmit faultless images of outer objects to the retina. The camera-lens, modelled on the same plan, transmits what are termed perfectly achromatized images to the prepared photographic plate. In lieu of an iris expanded and contracted by muscles, the camera-lens carries metallic diaphragms, and has a mechanical arrangement, by which it may be focussed for near or distant objects.

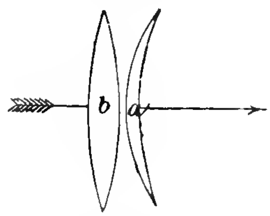
Objectives.—The lens is of primary importance in photography; it becomes necessary, therefore, to point out the conditions which fit the lens for its photographic functions. It will simplify matters to employ the term "objective" in place of lens, since all useful photographic lenses are combinations of two or more lenses of different foci. The first condition is to have the objective perfectly achromatized, i. e. the visual and chemical foci coincident, in other words, the chemical rays which impress the image upon the plate, and the rays which form the visible image upon the screen, should have their focus at the same point. The objective should be also free from spherical aberration; that is to say, the image transmitted by the combined lenses should neither be curved nor distorted.

Should the double-convex lens *a* (Fig. 1078), and the double-concave lens *b*, be made of crown-glass, chromatic aberration will be represented by the points of focus *c d*. The parallel rays of white light incident upon the lens *a* will be split up into seven coloured rays, each having a different degree of refrangibility, and a different focus. The red rays, having a small index of refraction, 1·5258, will have their focus at *c*, while the extreme violet rays, having a greater index of refraction, 1·5466, will have their focus at *d*, and the distance between *c* and *d* will represent the chromatic aberration of the combined lenses. Taking advantage of the difference in the dispersive power of flint- and crown-glass, if the lens *a* is made of crown-glass, whose index of refraction is 1·519, and dispersive power 0·036, and the lens *b* of flint-glass, whose index of refraction is 1·589, and dispersive power 0·0393, and if the focal length of the crown-glass is $4\frac{1}{2}$ in., and that of the flint-glass $7\frac{2}{3}$ in., they will form a lens of 10 in. focus, and will refract white light to a single focus free from colour. By this means, is obtained an achromatized combination suitable for photographic purposes. Spherical aberration may be completely corrected by the forms of the combined lenses. Thus, by combining a miniscus lens (Fig. 1079) *a* with a double-convex lens *b*, the aberration produced by the lenses when used singly will disappear.

1078.



1079.

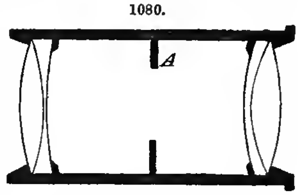


The result of having the objectives corrected is that they throw a sharply defined image upon the screen of the camera, and produce a sharply defined image upon the photographic plate. Suitable objectives must therefore be what are termed "achromatic combinations," and are made by uniting two or more lenses of flint- and crown-glass of different refracting powers.

Objectives supplied by well-known makers fulfil, as a rule, all the conditions necessary for successful photography. They distribute illumination equally over the plate, and are free from flare and distortion.

The objective commonly used in portraiture is made up of four lenses, two of flint-, and two of crown-glass. Seeing that the majority of portraits are taken indoors, with a comparatively feeble light, the portrait-objective must be used with a wide aperture, so as to admit the maximum of light. Even with the best portrait-objective, when no diaphragm is employed, the image is apt to lack clearness and definition on its outer edge.

1080.



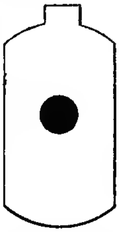
Diaphragms.—In the portrait-objective, as in most other combinations, the diaphragm is placed midway between the front and back lenses, as in Fig. 1080. The object of the diaphragm at A is to impart distinctness to every part of the picture. By employing a very small aperture in the diaphragm, a portrait or landscape may be rendered so distinct all over its surface as to closely resemble a map. Judgment is therefore required in the use of diaphragms, so as to secure the necessary degree of distinctness without losing the effect of relief and distance. The use of small diaphragms is restricted in another way; the smaller the aperture employed, the longer will be the time required to produce a picture.

Waterhouse diaphragms are those most commonly used. They are made of thin plates of blackened brass, pierced with an aperture (Fig. 1081), and calculated to slip into a slit in the inner lens-tube (Fig. 1082).

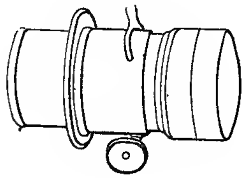
When great rapidity is required, as in photographing children, the diaphragm is dispensed with, and the objective is worked with full aperture. In copying a map or plan full of minute detail, the smallest diaphragm yields the most perfect definition.

Modern objectives for landscape and architectural photography are so perfectly corrected as to produce faultless images. With what are known as "symmetrical" and "rectilinear" lenses, the straight lines of a building are reproduced as straight lines. With the old miniscus, or plano-convex landscape lenses, there was always a degree of curvature and distortion, which greatly marred the photographs taken by them.

1081.



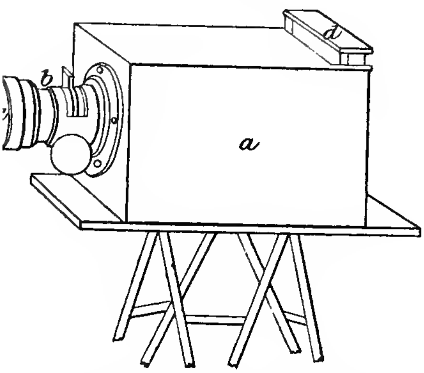
1082.



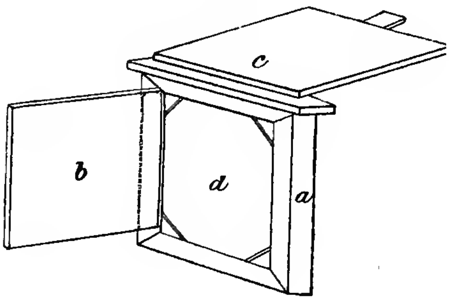
Another improvement effected in the construction of landscape-objectives is the larger field which some of them are made to cover, embracing an angle of over 90°. These render it possible to photograph, without distortion, objects near at hand and of great elevation. Special objectives are also made to cover a large field, and to be used with an aperture wide enough to fit them for taking groups, and instantaneous street views. The London opticians, Ross and Dallmeyer, have indeed brought photographic optics to a degree of perfection which leaves little or nothing to be desired.

Cameras.—The camera obscura or dark chamber of photography, to which the objective is attached, is presented in its rudimentary form in Fig. 1083. The mahogany box *a* is made perfectly lightproof; the objective *b* has a movable inner brass tube with rack and pinion for focussing; *c* is the front cap for timing exposure; and *d* is a ground-glass screen used in focussing,

1083.



1084.



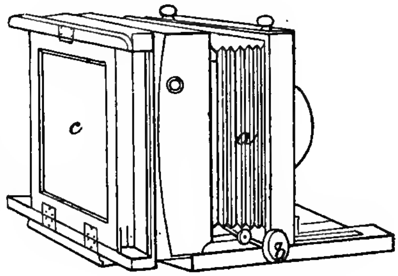
upon which the image falls. By throwing a dark cloth over the head, and the end of camera, the operator is enabled to see and adjust the inverted image on the ground glass. When the image is centred and focussed, the screen is withdrawn, and replaced by a sensitive plate in a dark closed carrier (Fig. 1084). The dark slide is composed of a strong outer frame *a*, while *d* represeuts the open space, with corners upon which the prepared plate rests. Exposure is effected by the front draw-up shutter *c*; and the back shutter *b* opens to receive the plate.

The plate, prepared in a chemically dark room, is then consigned to the slide, which is closed, and carried to the camera, where it is exposed; it is finally taken back to the dark room, and developed.

There are an infinite variety of cameras, each designed to serve some special end, and all of them framed on the principle of the instrument described. But the camera in its most advanced state is a complex instrument, in general form represented by Fig. 1085. The rigid rudimentary body is replaced by a bellows *a*, fixed to the front and back of the instrument. This bellows is expanded and contracted by rack and pinion at *b*, to suit objectives of different foci. The back swings vertically and horizontally, and may be fixed at any angle by pinching-screws. The swing back is useful in obtaining more uniform focus, where a near and distant object have to be photographed together on one plate. Another advantage in this instrument is its perfect portability. The baseboard is so framed as to admit of the camera being folded up into very small compass. The slides or plate-carriers attached to this instrument are both single and double. The single slide is used for the "wet collodion" process, and the double, which carries two plates, for the "dry" process.

Stereoscopic camora.—The stereoscopic camera, in its most complete form, carries two objectives about 4 in. apart. By this means, two pictures of the same object are taken at once. These, when reversed, and combined by the stereoscope, produce a mimicry of objects in relief. (Figs. 1086–7.)

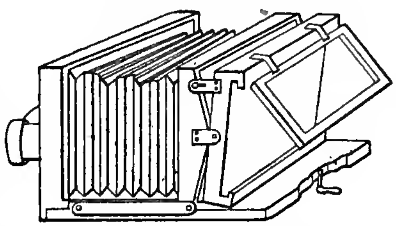
1085.



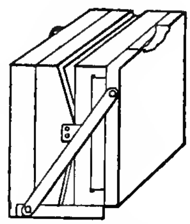
Enlarging camera.—When the object to be photographed is focussed on the screen, and the distance of the objective from the focussing screen is greater than the distance of the objective from the object, an enlarged image of the object is obtained. The enlarging camera is thus capable of considerable expansion, and herein lies the main difference of the enlarging camera from the instrument required for small photographs.

The solar camera for direct enlargement carries a mirror and large condensing lens. The mirror is designed to transmit the solar rays through the condenser, which in turn illuminates the negative to be enlarged. The method by which the enlarged image is obtained is a counterpart of what takes place in the magic lantern, with this difference, that the source of light in the camera is the sun. The limelight lantern has, indeed, to some extent taken the place of the solar camera in modern practice.

1086.



1087.



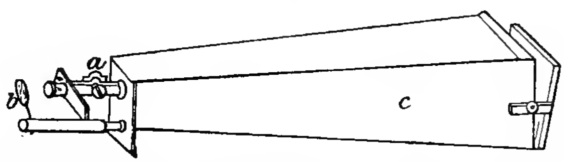
Micro-photographic camera.—The principle embodied in the micro-photographic camera is the same as that involved in the foregoing apparatus. It is shown in Fig. 1088: *a*, microscope; *b*, reflecting mirror; *c*, camera.

Photo-micrographic camera.—The photo-micrographic camera is a diminishing apparatus, and may be set down as the micro-photographic camera reversed. Reduced photographs of official despatches, obtained by this instrument, were largely used during the Franco-Prussian war for transmission by pigeon-post.

Kinnear's portable landscape camera is shown in Figs. 1089 and 1090.

Instantaneous shutters.—With the advent of what are termed "gelatine-emulsion" plates, came the necessity of rapid exposures, exposures too rapid for the handwork of uncapping and capping the lens. This necessity has been met by shutters made to fit the front of the objective. Some of these are pierced with an aperture, which drops over the front of the lens at the moment of exposure. Others open and close instantaneously, by means of electricity or pneumatic pressure. But Dr. Vogel's shutter is perhaps the simplest of all. It consists of a black velvet sleeve A (Fig. 1091), fixed to the front of the camera B. At the end of the sleeve, is a light wooden board C, pierced with an oblong hole D. When the plate is ready for exposure, the board, which has been laid back on the top of the camera, is lifted, and dropped vertically in front of the lens. The passage of the aperture D across the field effects a momentary exposure of the plate.

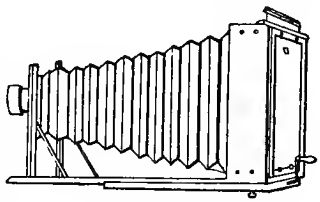
1088.



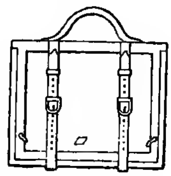
In addition to the instruments described, there are many others used in photography, too complex to admit of anything beyond passing notice in the present article. The simplest of these are actinometers, for determining the actinic power of light. There are instruments for registering barometric and thermometric changes, the vibrations of the magnetic needle, and the phenomena of the interference of the rays of the spectrum. De La Rue, Rutherford, Grubb, and Huggans, are names intimately associated with astronomical photography. Specially-constructed telescopes, made to follow the movements of our globe and of the planets, have been constructed. By means of these, the moon has been photographed, and, more wonderful still, the spectra of planets and of stars.

The Dark Room.—It is most essential in all photographic processes to employ what is termed a "dark room" in all operations connected with preparing and developing the sensitive plate. This dark room is not without light, but its light is of a quality such as in no way affects the plate. It should be lighted from a small window covered with one or two thicknesses of orange paper, and furnished with a blind of Turkey red. When this blind is drawn down, sufficient light should pass through to enable the operator to see what he is about, and yet the light is so inactinic as to be harmless to the most sensitive plate during preparation and development. Beneath the window, there should be a water-tap and leaden sink for washing purposes. Rows of shelves right and left should also be fixed within reach. These are handy for storing bottles. An ample deal bench, flush with the top of the sink, and made to slide over it, facilitates operations.

1089.

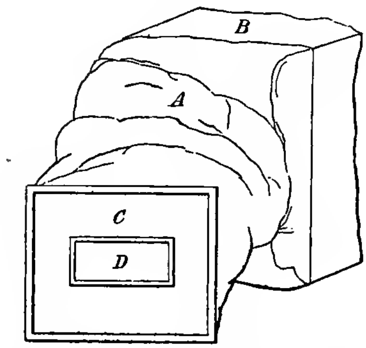


1090.



The Studio.—The "studio" pertains to professional photography, and is worthy of special notice. It is simply a well-lighted apartment in close proximity to the dark room. It used to be constructed almost entirely of glass, but that has become unnecessary, since a photograph can be taken in a fraction of a second. It is indeed advisable to dispense with much of the light of the old studio, so as to secure more artistic effect in portraiture. The apartment should recall a well-appointed drawing-room rather than a photographic studio. In the construction of a studio, it should be borne in mind that a steady north light is the best to work by, and that, by an arrangement of blinds, the light may be so manipulated as to suit any subject.

1091.



White reflecting screens are also of great use in lighting the dark portions of the object to be photographed.

Studio accessories may be left entirely to the taste and skill of the photographer. The intelligent selection and use of these are of the highest importance in the production of artistic photographs.

Camera Stands.—The studio-stand should be a solid piece of furniture, and yet easily moved about. It is so made that, by simple mechanism, the camera may be raised, depressed, or angled, at convenience. Portable tripod stands are supplied for outdoor work. These are so light as to be used as an alpenstock, and, when expanded, so rigid as to render the camera perfectly immobile.

The foregoing summary of the instruments and appliances used in photography is far from exhaustive. It is simply suggestive of the progress made in this direction, and intended also to render the processes of photography more intelligible to the reader.

PROCESSES.—*Collodion Process.*—"Negative" and "positive" are terms employed to denote respectively the photograph taken in the camera and the print obtained from the plate so taken. The negative usually consists of a sheet of glass, which affords support for the chemicals required to produce a photograph. Collodion charged with haloid salts is one of the vehicles used to coat the plate, and is made by dissolving gun-cotton (pyroxyline) in ether and alcohol. Pyroxyline may be prepared in the following manner:—10 dr. cotton, 52 oz. sulphuric acid, 18 oz. nitric acid, 8 oz. water; the cotton should be of fine quality, and boiled for ½ hour in 2 oz. caustic soda and 1 gal. water. It must then be freed from the alkali by washing in water, and dried. The acids and water should now be mingled in a porcelain jar, and left to fall to 65½° (150° F.), when the cotton may be plunged in, and left for 10 minutes. When taken out, it should be washed thoroughly with water, and dried, care being taken not to heat and ignite the compound, as it is highly explosive.

To make the collodion, take 10 oz. alcohol, 5 oz. sulphuric ether, and 100 gr. cotton. The above solution may be fitted for use by adding 5 oz. alcohol, 60 gr. ammonium iodide, 30 gr. cadmium iodide, 20 gr. cadmium bromide. Shake well, and allow to settle for 12 hours.

The collodion may now be used for coating the glass plate. This operation is best conducted in daylight. The fluid is flowed over the glass, and drained off at one corner (Fig. 1092). In about 2 minutes, it will have set, and may be carried to the dark room, and there plunged into an upright