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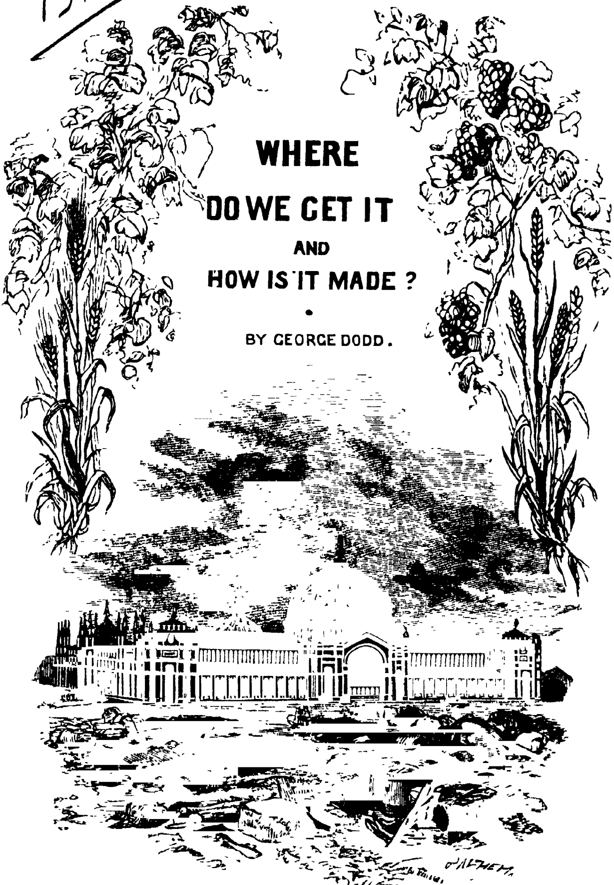
WHERE DO WE GET IT AND HOW IS IT MADE?

BY GEORGE DODD.



LONDON : JAMES HOGG & SONS.

WHERE DO WE GET IT,

AND

HOW IS IT MADE?

A FAMILIAR ACCOUNT OF THE MODES OF SUPPLYING

OUR EVERY-DAY WANTS, COMFORTS, AND LUXURIES.

BY GEORGE DODD,

AUTHOR OF 'THE FOOD OF LONDON,' 'CURIOSITIES OF INDUSTRY,' 'BRITISH MANUFACTURES,' ETC.

WITH ILLUSTRATIONS BY WILLIAM HARVEY.

LONDON: JAMES HOGG AND SONS.

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PREFACE.

THIS volume is intended to afford an answer, as complete as may be practicable in a small space, to two questions which often arise in every-day life. We are surrounded by objects of beauty and usefulness, some of which have been supplied directly by the bounteous hand of Providence; while others have been either made or modified by the hand of man. The young and inquiring are always prone (and it is well they should be so) to put the questions— "Where does it come from?" "How is it made?" The syntax may not be very good, perhaps; but the questions themselves are certainly reasonable. To answer them fully, would be the work of large and learned Cyclopædias and Treatises; but a slight approach to an answer is attempted in this small volume. The whole of the productions of Nature and Art being in imagination spread out before us, we have made a selection from among the more important of those which are directly useful to man, and have described their principal characteristics in as concise and clear a way as possible.

It may not be amiss to remind such readers as reside in or near the metropolis, or who may have opportunities for visiting it frequently, that the *South Kensington Museum* contains a vast store of specimens, excellently well calculated to illustrate many parts of this volume. Indeed, it would scarcely be possible to render full justice to that well-stored establishment. Although a few hours would suffice to obtain a general idea of the contents and arrangements of the place, many days might be well spent in learning all that it could teach us. For instance: the *Food Museum* (the idea of forming which originated with Mr. Twining) illustrates the history, varieties, composition, and preparation of nearly all the best-known kinds of food and beverage. The *Museum of Animal Products* contains specimens of animal substances in various stages of manufacture for useful application: such as wool, hair, bristles, whalebone, horn, tortoiseshell, fur, feathers, down, quills, ivory, silk, leather, oil, &c. The *Museum of Building Materials* contains specimens of substances used in the construction of buildings: such as terra-cotta, decorative tiles, artificial stone, slate, bricks, fire-proof materials, models of roofs and of fire-proof floors, and the like. The *Educational Museum* contains a countless number of objects, models, books, maps, plans, diagrams, and engravings, illustrative of educational appliances, school apparatus, and household economy. The *Museum of Patents and Patented Inventions* contains a very large number of machines and models, some of curious character; together with a complete collection of abstracts, specifications, and diagrams relating to all the patented inventions ever brought before the public in this country. If we do not speak specially of the *Art Library*, the *Museum of Ornamental Art*, the *Collection of British Sculpture*, the *Architectural Collection*, the *Photographic Collection*, and the *Galleries of Pictures* forming the Sheepshanks, Bell, Vernon, and Ellison Collections, it is only because those valuable portions of the establishment belong rather to Fine Art than to the Productive or Industrial Arts.

When we consider that the metropolis possesses, in addition to this interesting storehouse, so many national treasures of an analogous kind, in the *British Museum*, the *Museum of Economic Geology*, and the *Botanic Museum and Gardens* at Kew, we may well congratulate ourselves that the three millions of inhabitants have such admirable means of gratuitously studying specimens of natural products and of human industry.

It may be well also to remark that this little volume makes its appearance in a year when a Great Exhibition of the Arts and Industry of all Nations is about to be held in London, arising out of, and in many ways an improvement upon, the world-renowned exhibition at the Crystal Palace in Hyde Park in 1851. Such valuable collections afford a fine opportunity for studying the productions of Nature and Art—from the crudest materials obtained by the miner, to the highest works of man's ingenuity—from the handiwork of semi-civilized nations, to the wonderful machines and implements of modern Europe.

April, 1862.

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WHERE DO WE GET IT, AND HOW IS IT MADE?

CHAPTER I.

THE SOURCES OF OUR FOOD AND DRINK.

All important as are the animal and vegetable substances which supply the food and beverages of man, several of the most familiar need no description in this volume; because their sources are obvious to all, and because the substances themselves undergo very few processes by man's agency. Such is the case in reference to *meat*, *poultry*, *game*, and *fish*. We all know somewhat of the structure and appearance of the animals, where they are mostly found, how they grow, what they feed on, to what extent they are suitable for man's food, how they are caught and killed, and how prepared for the table. By omitting these and other examples of similar character, space may the more easily be found for notices of edibles not necessarily greater in importance, but more immediately dependent on human ingenuity. As to *beverages*—with the exception of the one which forms the grand basis of all, *water*—most of them will require a little attention here.

1. Bread, its Materials and Varieties.

We are told that bread is the 'Staff of Life!' It is a good phrase; for no other substance furnishes the main support for so large a number of human beings as this—especially if we include under the name of bread other varieties of baked or cooked grain.

Wheat and other Corn.—Corn or grain is undoubtedly the most valuable of all the vegetable productions which the goodness of the Almighty has provided for the food of man; and of all the kinds of corn, *wheat* is the most prized in our own country. *Wheat*, *oats*, *rye*, *barley*, *maize*, &c., contain a nutritious mealy substance within the husk of the grain or seed; and this meal, when prepared into bread and baked, is the most universal of all kinds of diet. We might possibly except *rice*, considering how enormously that grain is consumed in the East.

Let us say a few words concerning wheat culture, as an example of corn-growing generally. Wheat will grow in all climates except the extremes of heat and cold; and this property is one cause of its great value. In temperate climates it flourishes best; whereas rice and maize are the kinds of grain naturally best fitted for warm regions. The meal or flour contained within the seed comprises two very different substances—*starch*, which has a fattening quality; and *gluten*, which has a strengthening quality; thus showing itself especially suitable for the food of man. All the species of wheat, nearly forty in number, belong to the genus called by botanists *triticum*; but some of these are only *grasses*; those of which the seed yields meal for bread are fewer in number, and are called *cereals*. The best known species is the *triticum vulgare*, or *common wheat*; and the best known varieties of this species are the *triticum æstivum* and the *triticum hybernum*. The former of these two is the *spring* or *summer* wheat, better known on the Continent than in England; while the latter is the *autumn* or *winter* wheat, comprising the chief kinds grown in this country. Certain properties in the grain have led to a convenient grouping into *hard* and *soft* wheat; the hard, containing relatively more gluten, is preferred for the best bread and pastry; the soft, richer in starch or farina, is the best for fermenting into beer, spirits, and vinegar.

The best soil for English wheat is a deep clay loam, with a dry subsoil. To ensure the most profitable return, wheat is made to form part in a *rotation* of crops in the same field, recurring once in three or four years. By skilful subsoiling, tillage, and manuring, land at one time fitted only for inferior crops is now made to yield good wheat. A rotation much practised in Norfolk consists of one year wheat, then turnips after good manuring, then barley, then clover, and then return a second time to wheat. These systems of rotation seem to act something like a variation of diet upon man, each kind performing its own proper part in maintaining the organism.

The seed, in the present day, is mostly sown by the aid of *drills* or *drilling machines*, which deposit it at equal intervals in the ground. This mode is more rapid and efficacious than that of *broadcast*, where the seed is scattered over the surface of the ground, or *dibbling*, where it is dropped into holes made by a hand-implement. From September to November, according to the nature of the soil and the state of the weather, are the usual sowing months in this country. *Harrowing* then covers the seed with earth, slightly disturbing the soil by means of a series of spikes or tines. Every variation of weather has its peculiar effect, good or bad, on the growing crop; and it is the farmer's business, during the winter, spring, and summer, to attend to these variations, and also to keep the crop as clear as possible from weeds and insects. If all goes well, the fields 'laugh with corn' as the autumn approaches: the golden harvest is waiting to be gathered. The straw which supports the ear of corn is cut down near the ground, sometimes with a *scythe*, but more generally in this country with the *sickle* or *reaping-hook*, a bent blade with a very sharp edge. A good reaper will lay the straws very equably, so as to lighten the labours of those who collect the corn into sheaves, and the sheaves into stocks, or shocks. In these stocks the corn is nearly upright, the ear at the top, to facilitate its drying. *Reaping-machines* are now coming into use, to supersede both the scythe and the sickle.

The above will convey some idea of the mode of cultivating most kinds of grain. *Rice*, from its peculiar character, requires a much warmer climate, and a much more abundant supply of water, than corn generally so-called.

FLOUR AND MEAL.—It is customary to call wheat-meal *flour;* but the contents of all the seeds, whether wheat, rye, oats, barley, buckwheat, or maize, are equally meal or flour when ground into powder and separated from the husk or bran.

The *threshing* of corn is the separation of the grain from the straw. The trampling by the feet of oxen and horses, and the pressure by the wheels of carts, were means adopted in ancient times; but the *flail* and the *threshing-machine* are the kinds of apparatus now employed. The flail is a staff, with a hinge in the middle, so contrived as to enable the thresher to strike effective blows on the corn spread out on the barn-floor. The barns or threshing-places are constructed with much care, to ensure dryness and effective ventilation. By long and careful beating, the corn is separated from the straw; but this corn is a mixture of good grain and chaff, or refuse; and a further separation is necessary. The corn is thrown into one among many kinds of *winnowing-machines*, where a current of air blows away the thin, light chaff; and a further sifting through a *riddle* clears off the refuse still more completely. On large farms these processes are now much more effectively carried on by means of *threshing-machines*, worked either by horses or by steam-power. Revolving beaters thresh out the corn in a very short space of time; and the subsequent winnowing and sifting are performed by the same machine.

The *grinding* of the corn into flour involves two processes—the crushing of the mealy portion of each grain, and the separation of the bran or husk. The ordinary mode of grinding is by means of two *mill-stones*, flat circular stones four or five feet in diameter. The lower one is fixed; the upper one revolves over it with a speed of a hundred turns or more in a minute. The lower surface of the upper stone and the upper surface of the lower are channelled into grooves. The corn is admitted through a hole in the centre of the upper stone; it falls into a narrow space left between the two; the revolution of the upper stone, aided by the grooves, crushes the corn to powder; and the flour, mixed with the bran or husk, is whirled out from between the stones. Improved corn-mills have been introduced within the last few years, to economize more completely the flour contained in the grain, and to prevent it from being unduly heated by the great friction. In some of these new contrivances, mill-stones are used very different in shape from those just described.

The *dressing* of flour is the separation of the meal from the bran. It is in fact merely a sifting through a sieve; but in modern machines this is very completely effected. The *bolting machine* is a cylinder covered with a peculiar kind of cloth; the meal is thrown in; the cylinder is made to revolve; and levers or rods beat against the cloth until nearly all the fine flour is driven through the interstices, into a box which encloses the cylinder. The *dressing-machine*, on the other hand, is covered with wire cloth; and so ingeniously are the arrangements managed, that the flour becomes separated into many different degrees of fineness, each of which escapes into a receptacle distinct from the others. The flour then becomes separated into the kinds known as 'best,' 'seconds,' 'middlings,' and 'pollards,' leaving the bran or husk in the cylinder.

The *windmill*, with which so many picturesque country scenes are associated, is still the principal means of working the machinery for grinding corn: the force of the wind turning the sails, and this force being transferred to the upper stone. At the present day, however, many of our great towns are provided with *steam flour-mills*, in which steam-power does the work with a wonderful degree of efficiency. There is one establishment in London where thirty pairs of mill-stones, and half as many dressing-machines are worked by steam-power.

It is interesting to note, that when the British army was going out to the Crimea in 1854, the Government sent two steamers, called the *Bruiser* and the *Abundance*, fitted up completely with corn-mills and bread-ovens. The same steam-engine which propelled the *Bruiser* propelled also the corn-mills; and these mills had a power of grinding 24,000 lbs. of flour per day. The *Abundance* had the machinery and the ovens for making and baking 18,000 lbs. of bread daily, from the corn which the other vessel had ground. Thus the troops at Balaklava were supplied with bread with a regularity and carefulness seldom practicable during the horrors of war. Poor fellows! they had troubles enough else to endure; and it is well that their bread was thus served out to them regularly.

Bread and Biscuits.—The making of meal into bread is a process simple enough to be known to the rudest nations; nevertheless, much care is needed in pursuing the operations properly. Mix flour or any other meal into a stiff paste, flatten it into a cake, and put this cake on a hot plate until baked—thus we produce bread such as forms the chief sustenance of millions of persons in various parts of the world. Common *biscuits*, such as those which constitute ships' bread, are one kind of such cakes; and Scotch *oatcakes* are another. If we ask for the lightness, whiteness, and softness of *loaf-bread*, something further is necessary, involving the use of *leaven* or *yeast*.

In making an ordinary English wheaten loaf, processes are adopted to affect differently the gluten and the starch. Flour and water are mixed into dough. Instead of being baked at once, this dough is allowed to remain cold for some time; it ferments slightly: some of the starch becomes changed into carbonic-acid gas. In the effort of this gas to escape from the adhesive mass, the dough is made hollow or porous throughout its substance; and the loaf-bread, in consequence, becomes more light, soft, and digestible than cake-bread. To assist in bringing about this change, the baker adds either *leaven* or *yeast;* the former is a bit of dough in a state of fermentation; while the latter is a kind of froth obtained in brewing beer or ale.

There are many variations in bread-making adopted by bakers; but their general character may be understood from the following description:—Mashed potatoes, yeast, a little salt, and a little flour, are mixed with water to form what is called *ferment*, which is allowed to attain a particular condition before being used. Flour for making the bread is poured from a sack into a trough; and to this is added the ferment mixed with water. The whole is worked up into a dough, which is left to swell and bubble up into what the baker calls *sponge.* The management of this sponge, and the time at which the dough is separated into masses to make loaves, greatly affect the quality of the bread. The loaves are placed in an oven, and there kept until baked. Out of one quarter, or 480 lbs. of wheat, about 400 lbs. are converted into flour, which is made into probably 120 4-lb. loaves; but there is no uniformity in these particulars.

Nearly all the London bread is made by processes the building of new suburbs. Some years ago it was supposed that the United Kingdom consumed more than a *thousand million* quarts of milk annually, the produce of nearly half a million cows; and that nearly a hundred million quarts were needed for the metropolis alone! But there are no means for testing the truth of these suppositions. Formerly there were several large dairies near London—of which the chief was Laycock's, at Islington—containing from two to six or eight hundred cows each. The cows were milked twice a day, and the milk was sold to dealers, who retailed it from house to house. The cows were carefully tended, and were fed liberally with turnips, mangold-wurzel, hay, and sometimes distillers' grains. Farmers can afford to sell milk wholesale at sixpence per gallon; and as the London retail price is generally fourpence per quart, the profit is considerable. The difference is made still greater by the dishonest admixture of water with the milk by some of the retailers. Since there have been seven or eight railways connecting London with the country districts, the milk trade has assumed a new phase. The companies bring up milk from distances of ten, twenty, fifty, or more miles, at the rate of less than one penny per gallon, carrying back the empty cans free of charge. It has thus been found, in many instances, that milkmen can conduct their trade in this way more profitably than by keeping cows themselves. Every morning may be seen carts rattling through the streets, bringing tall cans of milk from the railway stations; and itinerant dealers sell what they call "railway-milk," at a lower charge than the regular milkmen.

The great value of milk for many domestic purposes has led ingenious men to devise modes of preserving it for a more or less lengthened period. Sometimes it is boiled, sometimes scalded, sometimes kept secluded from air; and a way has even been devised of converting it into a solid. Our heroic Arctic explorers have often had the enjoyment of milk, conveyed in their ships in well-secured tin cases. True, in all these instances the milk loses something of its rich and pleasant qualities; but it is nevertheless a most valuable addition to the diet of those who, for whatever cause, are placed beyond the daily reach of fresh milk.

Cream is the richest portion of the milk, which rises to the surface when kept still for some time. At the great dairies large shallow vessels, frequently of glass or white ware, are kept for containing the milk; and the cream is skimmed from the surface as fast as it is formed. Considering the cheapness of milk, the retail price charged in London for cream is certainly enormous; being sometimes as high as three shillings per quart.

Butter and Butter-making.—In order to understand how the formation of butter occurs, it is necessary to know something of the relation between *milk*, *butter*, and *cheese*. When milk has been allowed to stand some time, it separates into *cream* and *skim-milk*, the former of which floats on the latter. When cream has been treated in a certain way, it separates into *butter* and *butter-milk;* when skim-milk has been treated in a certain way it separates into *curds* and *whey;* and when butter-milk and curd have been treated in a certain way, they produce *cheese*. It thus arises that all these liquid and solid substances are very intimately connected.

The making of butter is the most delicate operation in dairy husbandry. All the vessels employed must be scrupulously clean, the dairy-house dry and airy, and the dairywomen neat in their habits; for the milk is soon spoiled if not carefully managed. The milk is drawn from the cows into vessels, and strained through fine cloth sieves into broad shallow pans of glass, earthenware, white wood, or metal. After remaining several hours in a place where a cool breeze may pass over it, nearly all the cream has risen to the surface of the milk. This cream is collected either by skimming, or by drawing away the skim-milk from beneath it. The cream is kept in glazed stoneware jars until there is enough in quantity for one making of butter. The butter is separated from the butter-milk by *churning* the cream, which is nothing more than a violent shaking or agitation. Churns are made in many different forms; but there is in all a flapper or paddle whisking round rapidly. In a period of time varying from ten minutes to an hour, according to circumstances, the butter nearly all separates from the butter-milk, and is taken out of the churn by hand. The separation, however, is not quite complete; and unless it is made so the butter will soon spoil. For this reason the butter is beaten with a flat wooden spoon or bat, and washed with clear spring water, until all the buttermilk is expelled. This butter-milk is used as a cheap substitute for real milk in poor families, or as food for pigs.

If the butter is to be sold as *fresh*, it is made up either into long *rolls*, or into flat *prints*, impressed by a wooden mould. By far the larger portion, however, is sold as *salt* butter. To produce this, the butter is usually put into firkins holding half a hundred-weight each, with three or four pounds of the best table salt, and sometimes a little sugar and saltpetre. Great care is necessary in combining the salt well with the butter, to prevent the latter from becoming rancid.

In some districts the milk and cream are churned up together, producing a greater quantity of butter, but not of such fine quality. The milk in such case, is placed in deep jars, and there kept till a slight acidity commences; it is then poured into a large churn, sometimes with the addition of luke-warm water; and the whole mixture is churned till the butter makes its appearance. The butter-milk which forms a residue of this process, is better than that obtained by the other method; it contains curds as well as whey.

The quality of butter depends on many minute circumstances. If, by imperfect management, any curd gets into the butter, a 'cheesy' taste, and a tendency to spoil, are the result. The best butter comes from the milk of cows fed in rich natural meadows. On an average, from three to four gallons of milk yield one pound of butter; and a good cow will supply from a hundred and fifty to two hundred pounds in a year. A very inferior kind, called *whey-butter*, is sometimes produced from the whey resulting from cheese-making.

It is supposed that the milk of nearly two hundred thousand cows is required to furnish the metropolis alone with butter. The kinds mostly in demand are *Dorset*, *Cambridge*, and *Epping* butters; so named from having been originally, perhaps, chiefly brought from those places. *Irish* butter, rendered very salt for better keeping, is largely sold for exportation. *Dutch* butter, rather peculiar in taste, is imported into England to a considerable extent.

Cheese and Cheese-making.—The relation between butter and cheese is, as we have seen, a close one. Yet the principal cheese districts are not the principal butter districts; for different qualities of milk are required in the two cases. The poorer kinds of cheese consist of little else than curd, as they are made from skim-milk only; but the richer cheeses contain also a considerable portion of butter. The various sorts of cheese—such as *Cheshire*, *Cheddar*, *Stilton*, *Double and Single Gloucester*, *Bath*, *Yorkshire, Dutch, American, Parmesan, Gruyère, Neufchatel,* &c.—differ much in flavour, appearance, and facility for keeping, owing to the operation of a variety of causes; such as the kind of cow from which the milk is obtained, the nature of her food, the climate and weather, and the dairy operations. Indeed there is probably no article of food which presents greater differences of quality than cheese. Some are soft and rich, intended for consumption soon after being made, such as Bath, Cream, and Yorkshire cheese; others, such as Cheshire, Gloucester, and Dutch, are hard and dry, being intended for long keeping; while Stilton, Gruyère, and many other kinds, are intermediate in quality.

In the usual mode of making cheese, the chief circumstance attended to is the separation of the curd from the whey. This would take place naturally if the milk were allowed to become sour through long keeping; but as such a process would be injurious, the separation is hastened by the action of a curious substance called *rennet.* This rennet is a portion of the inner layer of the stomach of a calf or a pig, cleansed and dried; it is boiled in strong lime; and the liquor thus prepared is the acidifying agent employed in cheese-making. The experience of the dairyman teaches him how much rennet to supply to a given quantity of milk. The warm summer months are the most suitable for the cheese-maker. When the rennet has been added to the milk, the curd soon forms; and this curd is squeezed by the hand of the dairywoman until broken up into small pieces—as a means of insuring the better separation of the whey. In some districts an instrument called a *whey-cutter* is used to expedite this process. The whey is then removed, to make whey-butter, if rich enough, but to be given to pigs if poor in quality. The curd, freed as much as possible from whey, is put into a *cheese-vat*, generally a wooden tub with holes in the bottom. A cheese-cloth is placed over the vat, and the curd is heaped upon the cloth, until there is enough to fill the vat. The cloth is folded over the curd, and the vat, with its contents, is put into the *cheese-press*. These presses vary much in kind; but they all comprise a sort of piston, or sinker, which sinks down into the vat, and presses on the clothfül of curd. The pressure applied is very great, and is allowed to remain two or three hours. For the best cheeses, there are several repetitions of pressing, and the cloth is changed more than once, to ensure as much as possible the removal of every drop of whey. When the pressing is finished, the curd, now become cheese, is put into a salting-tub, where it is exposed some days to the action of brine; after which it is rubbed day after day with dry salt; or, for some kinds of cheese, the salt is mixed with the curd itself before pressing.

Many variations occur in cheese-making, which need not be noticed here. Some cheeses, such as those of Suffolk, are made from milk which has been deprived of nearly all its cream; and they are as a consequence very poor and dry in quality. All the rich cheeses have much cream or butter in their composition. Cheshire prides itself on its skill in cheese-making. In no other district is there so much care taken to expel every drop of whey. Not only is the curd much broken and beaten before being pressed, but sharp skewers are thrust through the mass in every direction, to furnish channels through which the whey may flow.

Many cheeses are artificially deepened in colour. It does not appear that any good quality is thereby imparted; and it seems a pity that such a useless process should be continued, merely to give an apparent richness to the cheese. The colouring substance is usually *arnatto;* a cake or roll formed of the sediment obtained by steeping the rind and pulp which surrounds the seeds of a South American plant called the *Bixa Qrellana.* Some cheese-makers employ orange-carrot juice, some marigold-flower juice. Gloucester and North Wiltshire are the kinds of cheese most deeply coloured; Cheshire more slightly; while Stilton and Cheddar are left in the natural tints.

Competent persons have estimated that the enormous quantity of twelve thousand tons of cheese, nearly *thirty million pounds,* are made annually in the county of Cheshire alone. It is supposed that Great Britian consumes a hundred thousand tons of all kinds of cheese annually. To English workmen and labourers, cheese is an article of almost daily food.

3. Tea and Groceries.

It is impossible to say which, among many articles of secondary importance in reference to the food and drink of man, are more necessary to us than others. Meat, fish, poultry, game, bread, milk, eggs, butter, cheese—these having been disposed of, there seems no other group so important as that which includes *tea, coffee, cocoa, chocolate,* and *sugar*. All these substances are of foreign growth, and are generally included under the designation *Colonial* or *Tropical* produce, although those names are not in every case correct. The commodities are more familiarly known in England as *Groceries.*

Tea Culture.—This delightful beverage is obtained by infusing the leaves of a plant grown largely in China, and to a small extent in other parts of Asia. It was about two centuries ago that the beverage was first known in England, where it was regarded as a curious luxury beyond the reach of the commonalty. The East India Company, in 1664, bought *thirty-four ounces* of tea, to present to Charles the Second as an Asiatic rarity! A taste for the beverage having once arisen, the Company made the purchase and sale of the prepared leaves a part of their regular trade; and thus matters progressed, until, at the present time, we consume eighty million pounds of tea annually.

The tea-plant belongs to the genus called by botanists *thea.* In different parts of China it is called *tcha, cha, tha,* and *tsia;* and from this source the botanical and English names are evidently derived. The plant will flourish in many kinds of soil and climate; but the strength and flavour of the infusion are greatly affected by minute changes in these particulars. In cultivating the plant, the Chinese make holes in the ground, four or five inches deep and three or four feet apart; and several seeds are dropped into each hole. Little more is needed till the rainy season arrives, when the young sprouts require to be watched. Weeding is the chief process needed during three years; at the end of which time the first crop of leaves is yielded. Sometimes the young plants are transplanted, to form a bush that will facilitate the gathering of the leaves.

Great care is observed in the gathering. At various periods of the year, from March to August, gatherings take place; the leaves being picked off according to their condition at the time, and carefully laid aside. The gatherers prepare themselves for their work by two or three weeks of careful regimen; keeping their persons scrupulously clean, and refraining from eating any food that would affect the breath, lest the delicate leaves of the plant should be injured thereby; moreover, they cover their hands with gloves during the picking. When picked, the leaves are dried and prepared for market, if possible on the evening of the same day. The leaves are carried into houses where furnaces are conveniently arranged.

On each furnace is a flat iron pan; and on this, when hot, the leaves are placed, after having been partially dried in the sun. By means of heating, shifting, and turning, they become quite dry. They are removed by the hand or with a shovel, and are thrown into mats or baskets. In small portions they are then placed on a table, and rolled between the palms of the hands into the curly form so familiar to us. The drying and rolling are repeated several times, until a peculiar kind of juice or sap has been expelled. The number of times of roasting and rolling determines in part the quality of the tea. A lighter tint is given to green tea by steaming the leaves before roasting. The well-known flavour of tea is developed almost solely by the roasting, as the unroasted leaf possesses scarcely flavour or odour. About three pounds of leaves are roasted down into one pound of dry tea.

It seems most probable, although not certain, that black and green tea are different species, in the forms in which the finer kinds are sold. But the Chinese are suspected of practising much deception—one mode of which is, to prepare coarse black tea in such a way as to imitate the finest sorts both of green and black. In the best green, the leaf only is included; in black, the stalks also are retained; and moreover the green comprises younger and more tender leaves. The Chinese never use their best tea until it is at least twelve months old.

The names *Hyson*, *Bohea*, *Twankay*, *Pekoe*, *Souchong*, *Congou*, &c., are all of Chinese origin, referring to different kinds of tea-plant, different modes of preparation, or different districts of growth. The very choicest kinds never come to England; they are too delicate to bear the sea-voyage; and moreover the wealthy Chinese, who do not like to part with them, are willing to pay very high prices, even as much as fifty shillings per pound. The commonest kinds are made up into hard brick-shaped lumps, and are carried overland to Russia and Central Asia, where they serve as *money*, in addition to their more obvious use. Tea is brought to England in chests containing on an average about sixty-four pounds each.

China is still the great storehouse for tea; the quantity grown elsewhere is comparatively trifling. Nevertheless the culture is gradually becoming important in India and some other countries.

The Chinese mostly drink the infusion without milk or sugar. They allow the hot water to remain on the leaves only long enough to extract the more volatile and aromatic properties. The poorer classes, however, boil their tea, to obtain as much taste as possible for a little money; for it is to them truly one of the necessaries of life.

Coffee and Chicory.—The beverage known throughout so large a portion of the world by the name of *coffee* (or its equivalents *café*, *caffé*, *koffe*, *kofé*,) is a decoction from the berry of the coffee-plant, the *Coffea Arabica* of botanists. The portion of the berry used comprises so much of the seed as envelops the future plant. The coffee-tree, when full grown, is an evergreen shrub, with shining oval leaves, and berries that gradually change from red to purple. The native country of *Mocha* coffee is the region on both sides of the Red Sea; the coffee of Ceylon, the West Indies, &c., is not of so fine a quality. In Arabia the tree is grown in well-irrigated grounds, in a deep soil, and in the midst of other trees whose foliage protects the young coffee-plants from the heat of the sun. The plant begins to produce fruit or berries in the third year; but the quality is better at the fourth or fifth year. The berries do not acquire all their good qualities for many months after their removal from the tree.

Coffee is sometimes used raw, for medicinal purposes; but its fragrant and aromatic qualities are not developed until after roasting. The composition is very remarkable; for the berry is found to contain a gum, a fat or butter, a resin, a bitter, an albumen, and an aroma; most of which conduce to its wholesomeness as a material for beverage. The roasting requires to be very carefully conducted. In the best method, the coffee is placed in a cylindrical vessel, which is made to rotate over a clear fire. There is one particular stage or degree of roasting better than all others, to be known only by experience. When this degree has been attained, the coffee is found to have undergone remarkable changes; it emits a powerful and agreeable odour; it loses about a third of its former weight; it has swelled to nearly double its original bulk; instead of being heavy and hard, it is light and easily crushed; and its colour is changed to a light chesnut tint.

In English shops, and among English families, the roasted berry is often kept a long time before being ground, and the ground coffee kept a day or more before being used. But both practices are injudicious, as leading to the waste of good qualities. The roasting, the grinding, the making or decocting, and the drinking, should follow each other as quickly as possible. Coffee is sometimes made by *infusion*, or simply pouring boiling-water upon it; sometimes by actual boiling; the former plan best developes the delicate aroma, while the latter gives greater strength to the beverage. Many ingenious forms of apparatus for coffee-making have been introduced within the last few years — such as Parker's steam fountain coffee-pot, Loysel's percolator, &c., intended to draw out the strength of the coffee without vitiating its flavour.

There is now consumed, in the United Kingdom, forty million pounds of coffee annually. The consumption has greatly increased since the introduction and spread of temperance principles among the working-classes. Besides this, there is supposed to be at least half this amount of *chicory* also used, as an addition to the coffee. This is a very remarkable mixture; for while coffee is, as we have seen, the berry of a tropical plant, chicory is the dried root of a European plant; and yet the two suit very well together when roasted and ground. The chicory-plant is the same as that which yields the well-known salad, *endive;* but differently cultivated. The roots, when gathered at the proper time, are well washed, placed in a cutting-machine, and sliced up into small pieces; the pieces are dried, roasted in cylinders over a steady fire, and pulverized. A drink prepared from chicory alone is a very poor substitute for coffee; but if used as an addition and not as a substitute, it is economical and wholesome. Whether or not it be pleasant, is a matter of individual taste. Being much cheaper than coffee, it is now mixed with it to a very large extent.

COCOA AND CHOCOLATE.—These agreeable and wholesome drinks are obtained from a plant to which the ancients gave the name of *Theobroma*, or 'food for the Gods,'—an excess of praise to which in our days the world is not inclined to assent. There are several species of the plant, but the one which yields the beverage is chiefly the *Theobroma Cacao*, found in many of the tropical countries of Asia, Africa, and America, and familiarly known as the *Chocolate-tree.*

Cocoa and chocolate, as generally understood in England, are two names for the same substance in different stages of preparation. It is the *bean* of the plant, imbedded in a soft pulp, that is so valuable to us; the other portions are not so much prized. About twenty-five or thirty beans are contained in each capsule or pod. The pulp surrounding them is often eaten by the Mexicans as a pleasant food. The bean, when ripe, contains much oily albuminous substance of an agreeable flavour and nutritious quality; it is on this ground that cocoa is so much recommended as a material for beverage. At the first sowing, the seeds are placed two or three together in the same hole, the holes being wide apart: an intermixture with other plants, for the sake of shade, takes place at the transplanting. The pods may be gathered at many different periods of the year, but the wild kinds only yield one harvest annually. One person can attend to about a thousand plants, which will yield from fifteen hundred to two thousand pounds of beans. The oil contained in the beans is sometimes expressed from them, and used separately under the name of *cocoa-butter*, as an article of food, or for making ointments. The beans vary much in size, shape, colour, number, bitterness, and oily constituents. The average size is about that of a sweet almond; each is covered with a dark skin, and contains two kernels of a brownish violet colour.

The beans, when collected, are dried in the sun or air. Some kinds contain more oil, or butter, than others, and are on that account more valuable in supplying the material for candles, soap, and pomade. It is well to bear in mind, however, that this *oil of cocoa*, or *butter of cocoa*, is quite a different substance from *cocoa-nut oil.* *Cocoa,* we may also mention, has nothing to do with *cocoa-nuts:* much confusion having arisen in common language from using the word *cocoa* as a translation both for *cacao* and *cocos,* the names of two very different plants. To return to our subject. When the beans are to be sold by grocers in the retail form as cocoa, they undergo very little preparation. They may be called *beans, seeds, kernels,* or *fruit:* the first name is the best; but whatever we call them, they are used nearly in the natural state. When simply crushed, they are called *cocoa-nibs;* when crushed more finely between rollers, they become *flake-cocoa.*

If the product is to be called *chocolate* rather than *cocoa,* the beans are carefully picked or sorted, and gently roasted in an iron vessel. The roasting is continued just to the point when the aroma becomes developed. They are turned out, cooled, ground, and sifted. The husks are sometimes thrown away, but they still contain a nutriment which may be, and ought to be, rendered available. The kernels are bruised and ground down into a paste; and this paste, when solidified in moulds, constitutes *plain* or *common chocolate.* If other substances are added to the paste, various names are applied to the mixture. These other substances may be sugar, honey, long pepper, arnatto, vanilla, cloves, aniseed, musk, ambergris, cinnamon, rice, almonds, starch, &c. Plain chocolate is mostly prepared in England; aromatic chocolates are more prevalent on the Continent.

The wholesome beverages made from the cocoa-bean are coming more and more generally into use. We consume now between three and four million pounds of the bean annually.

Sugar and Treacle.—The invaluable substance, *sugar*, is derived from many different sources, among which are beet-root, maple-juice, palm-juice, honey, milk, birch sap, sycamore sap, grapes, figs, dates, plantain, and liquorice. But the great supply for the English market is derived from the *sugar-cane*, the *Saccharum* of botanists. The saccharum is a plant widely diffused throughout the hot regions of the earth, and is very beautiful when in full growth. It was first cultivated in Asia, whence it spread to other quarters of the globe. New plants are usually obtained by slips or cuttings, consisting of two or three of the upper joints of a full-grown cane. The slips are planted horizontally, in holes or in trenches; and in a week or two, sprouts make their appearance above the surface of the ground. The canes are ready to cut when they are dry and smooth on the outside, and when the soft pith is full of sweet sap. Their height varies from eight to twenty feet, with prominent joints at intervals. In the first season after the planting they are called *plant canes;* but when two or more successive crops are raised from the same roots, all after the first are called *rattoons.* Under careful management rattoons have been obtained twenty years in succession.

When the canes have been cut down near the ground the tops are removed, and the rest, divided into pieces, are tied up in bundles, and carried to the *sugar-mill.* The juice is here crushed out of the canes by mills of different kinds—sometimes a sort of pestle and mortar, sometimes a vertical wheel running round on a platform, sometimes rollers of wood or iron working against each other. The juice is received in vessels beneath the mill, and the spent canes, under the name of *megass*, or *trash*, are used as fuel.

The next process is to obtain the sugar from the juice. This juice is an opaque, thick, sweet, olive-green liquid, which will spoil within an hour unless subjected to further processes. It is admitted into large open pans called *clarifiers;* a little lime-water is added; and the mixture is heated nearly to the boiling-point. A scum rises to the top; the fire is allowed to die out; and after reposing some time, the juice—bright, clear, and olive-coloured—is drawn off from beneath the scum. From the clarifier the juice passes to another vessel called the *evaporator*, where it is boiled to send off the watery portion. It now changes its form to a thick adhesive *syrup.* This syrup is conveyed into vessels called *coolers*, where it remains until it becomes a soft mass of crystals imbedded in a thick viscid liquid. The crystals are *sugar;* the viscid liquid is *molasses.* The mixture is taken to the *curing-house*, where it is put into casks having small holes in the bottom, with a plantain-leaf in each hole. The molasses gradually drains away through the holes, leaving granulated *raw* or *moist sugar* in the casks.

Some kinds are prepared into what are called *clayed* or *Lisbon* sugar; but in England, nearly all that is not used in the moist brown state is converted into *refined*, *lump*, or *loaf* sugar, by a series of remarkable processes. The brown sugar, as imported in hogsheads, is put into a large vessel; water, and a few clarifying substances are added; and the whole is heated by steam. The hot mixture passes into a series of cloth filtering-bags, and flows out as a clear, transparent, but reddish liquid. It then passes through a very thick layer of powdered charcoal, and comes out as clear and colourless as water. To bring this sugar-syrup to the state of real sugar, it is boiled in a vessel called a *vacuum-pan*, and made to flow into another vessel as a thick liquid, which cools down to a viscid mass of crystals. This mass is poured into conical moulds, each of which has a small hole at its apex or point, which is turned downwards; the liquid portion of the mass slowly oozes out, leaving the sugar in the form of a white crystalline solid, the well-known *sugar-loaf*. The thick liquid which flows from the moulds is *Treacle*, very sweet, but uncrystallizable.

Sugar-candy (so named from the Hindu appellation, *shukur kund*) is a substance in which the sugar has been allowed to crystallize upon strings into curiously-shaped masses, instead of in moulds. In England it is only made as a sweetmeat; but in

India and China it is regarded as the best kind of refined sugar.

Nearly all classes in England spend a portion of their means, be it little or much, in purchasing the commodity with which pastry, confectionery, and beverages are sweetened. The consumption of sugar in the United Kingdom is now *ten million hundred weight*, or considerably over a *thousand million pounds*, annually.

4. Other Colonial Produce.

A little must be said concerning *Tobacco* and *Spices*. Tobacco is certainly not a *food*, in the ordinary sense of that term; yet it affects in various ways the diet and beverages of millions of men; and under any aspect it is a commodity which must not be left unnoticed here. As to Spices, which might or might not be included under Grocery, they must be briefly treated as articles of colonial produce.

Tobacco and Snuff.—Tobacco is the leaf of a plant called by botanists *Nicotiana*, the chief species of which is the *Nicotiana tabacum*, or common Virginia tobacco. The plant grows in various countries; but the Southern States of America are those in which the cultivation is most extensively carried on. Much care is required in the field-operations. The seed is sown in prepared seed-beds, and the young shoots are transplanted at a proper season to narrow beds of rich earth. Everything is made subservient to the production of ten or twelve large fine leaves, on a stem from three to six feet in height. If the tobacco is planted in May, it is fit for gathering in September; and all must be gathered before the slightest symptom of frost appears. The whole plant is cut down, close to the ground; and when it has had time to dry in the open air, the leaves are stripped from the stem. They are sorted into kinds, according as they grow on the top, the bottom, or the middle of the stem. Ten or twelve leaves being tied together into a bundle, they are again dried, and packed carefully and closely in large hogsheads, containing ten or twelve hundred pounds each. In these hogsheads the tobacco is brought over to England.

Some kinds are not packed in this way. The leaves, placed together in bundles, are bound very tightly when the air is moist, and are exported without being put into casks.

When hogsheads of tobacco reach England, they remain under the custody of the Custom-house officers until the duty is paid. If the tobacco has been injured by the sea-voyage, the owner would rather lose it altogether than pay the duty, which is much higher than the value of the tobacco itself; and hence there are the means, in the Queen's warehouses at the various docks, of burning damaged tobacco—tobacco on which the owner will not pay the duty, and which the Customs officers will not allow to leave the warehouse unless the duty be paid.

The tobacco, when sold by the importers, passes into the hands of manufacturers, who bring it into the various forms required by the retail consumers. These forms are—tobacco for chewing, tobacco for smoking in pipes, cigars, and snuff. The compact masses of leaves are dug out of the hogshead, sprinkled with water, and separated leaf from leaf. For most kinds of tobacco, the stalk is separated from the leaf; but the kind called *bird's-eye* is produced by shredding up stalk as well as leaf. The leaves are pressed together into a flat compact mass, and shredded into fine filaments by means of cutting machines. The different sorts of smoking-tobacco, called *shag*, *returns*, *bird's-eye*, Cavendish, &c., owe their qualities to many different circumstances—the quality of the plant itself, the nature and richness of the soil, the retention or rejection of the stalk with the leaf, the degree to which the leaves are moistened previous to the shredding, and the fineness of the shredding.

Cigars are made by rolling up tobacco-leaves into small oblong masses. Much art is requisite in doing this well, so as to make them of equal hardness throughout. Cheap cigars have the interior made of the commonest tobacco—sometimes not tobacco at all, but some other leaf made to imitate it. Foreign cigars pay an enormous duty when imported into this country,—no less than nine shillings per pound.

Snuff is made chiefly from the stalks of the plant, stripped from the leaves, dried, ground into powder, and sometimes scented. Some kinds consist wholly of stalk, some wholly of leaf, while others are a mixture of the two. The degree to which the tobacco is dried before grinding exerts much influence on the quality; those snuffs which are high-dried having a sort of scorched odour peculiar to themselves.

We consume about thirty-five million pounds of tobacco yearly—a large quantity, certainly, of a commodity that is in no sense a necessary of life. Yet there is reason to believe that, in the last century, the consumption per head was greater than it is now.

Spices and Condiments.—A few of the principal spices and condiments may now be noticed, just sufficiently to show the main differences between them.

Cinnamon grows chiefly in Ceylon. It is the inner bark of a tree called the *Laurus cinnamomum*, which grows to a height of twenty or thirty feet. The leaves, flowers, footstalks, and berries, all emit the well-known cinnamon odour; but the tree is so cultivated as to throw the aromatic quality chiefly into the inner bark. The shoots are cut off at a particular period of growth, and the bark peeled from them. The bark is a pale yellow substance, not much thicker than parchment. The pieces, after being dried in the sun, are put the smaller within the larger, so as to form pipes or rolls. *Cassia*, like cinnamon, is the bark of a plant growing in tropical climates, and is gathered and prepared nearly in the same way. *Cloves* are the berries of a tree, the *Caryophillus aromaticus*, growing chiefly in the Molucca islands. The calyx, with the embryo seed, are beaten from the tree when at a particular stage of ripeness; and these, when dried in the sun, form the cloves of the shop. The whole tree is highly aromatic; but the berries are most rich in a peculiar essential oil, to which the fragrance is chiefly due. *Nutmegs* are the nuts or fruit of a plant, the *Myristica moschata*, growing abundantly in the Spice Islands of the East. And the same tree produces also *mace*, which is a membraneous skin covering the thin black shell in which the nutmeg is contained. Nutmeg and mace together are imbedded in a pulpy substance forming the fruit of the tree. At a particular stage of ripeness the fruit bursts, and then the spices are gathered. The mace presents a kind of leafy network of a light red colour; it is laid out to dry, then packed in bags, and pressed very tightly for the market. The nutmeg has a shell larger and harder than that of a filbert. The nuts are dried, first in the sun and then over a fire; and when broken, the kernel is extricated from the shell. *Pepper* is the small berry of a plant, the *Piper nigrum*, growing in many parts of the East. The plant is about four years old when the berries begin to be fit for gathering. When gathered and dried upon mats, the berries constitute the *black pepper* of the shops; but when steeped in water to remove the outer husk, the interior becomes *white* pepper. The taste is believed to be chiefly due to a kind of resin formed in the berry, and the odour to a volatile oil. *Allspice* is the popular name for a berry known in commerce as *pimento*, and sometimes (from the place of its growth) *Jamaica pepper*. Its popular name is supposed to have been derived from the circumstance that the berry comprises the qualities of all, or at least many, of the spices. The allspice tree is the *Eugenia pimento*. The berry, about the size of a pea, contains two dark-brown seeds. The seed and the husk of the berry both possess an aromatic stimulant property, midway between those of pepper and cloves. *Ginger* is the root of a plant called the *Zinziber officinale*, growing in many tropical countries. The plant has a perennial root, which creeps and increases underground in tuberous joints, from each of which arises in the spring a green reed-like stalk. *Black* and *white* ginger are from the same plant; they differ only in preparation. The tubers or roots are taken up after the annual stalks have withered; they are scalded in boiling water, dried in the sun, and then constitute black ginger. To obtain white, the tubers are scraped clean and dried, without being scalded. *Capsicum* is the green pod of an Indian plant, now acclimatised in England. There are several kinds, called *Guinea pepper*, *cherry pepper*, *bell pepper*, &c. It is not exactly a spice, but the green pods are used for pickling.

While on the subject of these spices it may be as well to mention that the numerous *culinary vegetables, fruits, seasoning herbs,* and *salads,* which form such important additions to English household economy, are not of a nature to call for description in this work; their culture belongs to ordinary gardening, the general nature of which is pretty well understood by most persons.

5. Malt Liquors and Vinegar.

Many of the substances described in the last two sections, indeed most of them, are valuable to us chiefly in the preparation of beverages. Still more is this the case in reference to those about to be noticed. *Malt* is prepared, *hops* are grown, and both are bought and sold, almost entirely for the *beer* and *ale* brewed from them. It will also be seen why *vinegar* comes into this section.

Malt and Malting.—Malt is the principal source of all kinds of beer and ale; seeing that those beverages depend chiefly on something which is contained in the malt. True, this something exists also in raw or unmalted grain, but not in so convenient a state for development. When the starch of any kind of grain is converted into sugar, that grain then becomes *malt;* and the process of managing this change, in reference to barley, constitutes *malting.*

In a malt-house, barley is steeped in water for two days or more; it swells by imbibing moisture, and becomes half as heavy again as before. When the steep-water has been drained off, the wet barley is emptied out upon the *malt-floor*, where it is spread in a *couch* or layer fifteen or twenty inches deep. During several days, the grain is frequently turned and spread out with wooden shovels; until at length the layer is only a few inches in depth. The grain becomes warmer and warmer, and certain changes occur in its nature. There is a particular stage of this change, which is found best for the purposes of the brewer; and it is the maltster's business to check it at this stage. The grain is taken from the malt-floor, and placed in a *malt-kiln*, where it is dried. By this time the starch or mealy portion of the grain has been converted into sugar, and the barley has become the mawkish sweet substance called *malt*.

Brewers distinguish between *pale* or *amber*, *brown* or *blown*, and *black* or *roasted* malt. The pale malt gives *strength* to beer or ale, the brown gives *flavour*, and the black gives *depth of colour*. The pale is the most important of the three. All kinds of grain can be malted, but barley is the best fitted for this process and the subsequent brewing.

About forty million bushels of barley are now annually converted into malt in the United Kingdom.

Hops and Hop-picking.—The remarkable and beautiful hop plant belongs to the genus *Humulus* *superbus*, growing in many parts of Europe and America. What we call *hops* are only the female flower of the plant, sometimes called *cones* or *catkins*; and it is to obtain these that the hop-culture is carried on. A very precarious culture it is, on account of the many sources of injury to which the plant is subject. A rich mellow soil, an aspect open to the sunny south, pure air, and careful attention, are necessary to the production of a good field of hops; and even then, unforeseen visitations will sometimes bring the field nearly to ruin, as was the case in most parts of England in 1860.

The plant is raised either from seeds, or from young shoots taken from the bottom of the stems of old plants. When the ground is prepared, wide deep holes are dug six feet apart, in rows also six feet apart; and three young plants are placed in each hole, at a small distance asunder: the remainder of each hole being filled up with very rich soil. A stick is fixed in the centre of each hole; and around this stick the *bines* or stems of the tender plants entwine as soon as they begin to grow. By careful attention, a few flowers may be picked the first year; but in general there is no hop-picking till the second year. In the intermediate winter, the root of each plant is protected by a little mound of earth. Early in the spring the mounds are opened, and the wants of the young plants carefully attended to; and at the same time *hop-poles*, twelve or more feet in height, are substituted for the short sticks. Much turning, digging, examining, weeding, and hoeing are necessary during the season. Under favourable circumstances, about 4 cwt. per acre of hop flowers may be obtained in the second year, and from 8 cwt. to 15 cwt. in the third.

It is a pretty sight when the hop-picking season arrives. About September, when the flower presents a fine straw colour, just beginning to turn brown, it is ready for picking; and then all hands are in requisition. In the hop counties, chiefly Kent, Sussex, and Worcester, there are not labouring hands enough obtainable in the vicinity for this duty; and strangers arrive from other places, attracted by the comparatively high wages offered. Barns and sheds are hastily fitted up for their reception, and food and drink are supplied to them in order that they may have long days of steady work. The picking is thus conducted. Each pole in turn is dragged out of the ground, and rested obliquely on a frame or bar called a *bin*, which has a canvas bag suspended open beneath it. Men and women, boys and girls, pick off the flowers, and drop them into the bag. Sometimes they make no selection; but in other hop-gardens they are expected to separate the flowers into two or three distinct heaps, according to colour, size, and general appearance.

When picked, the hops are brought into a building, where they are dried on a hair-cloth in a kiln, until just such a stage when the leaflets become brittle and rub off easily. They are then pressed into sacks with great force; the finer kinds into *pockets* of $1\frac{1}{2}$ cwts. each, the coarser into *bags* of $2\frac{1}{4}$ cwt.

As this very fluctuating crop varies in quantity from 1 cwt. to 20 cwt. per acre, the hop-grower is kept in much uncertainty throughout the greater part of the year; and this uncertainty induces a species of gambling in the trade, besides great variations in price. The use of the hop, as we have implied, is mainly for brewing. It imparts a pleasant bitter to beer and ale; it gives an aromatic flavour; it makes the liquor fine and clear; and it fits the beverage for long keeping. No other plant or herb is known which has so many properties fit for these purposes as the hop.

Beer and Ale.—Whoever brews a good cask of beer or ale is a chemist, whether he knows it or not; for much chemical nicety is called for in the operation. These beverages are brewed chiefly from malt, hops, and water. A kind of sugar is extracted from the malt, and is converted into an imperfect alcohol or spirit; this spirit, by further operations, and by the addition of extract of hop, becomes beer or ale.

The malt is selected according to the required kind of beverage—pale for the finest ale; pale, with a little brown, for common ale; and pale, with brown and black, for beer, porter, and stout. The malt is crushed or ground fine or coarse, according to the nature of the beverage to be brewed. The ground malt is placed in a large wooden vessel called a *mash-*

tun, having a double bottom, the upper one being pierced with holes. Hot water is introduced, and the malt and water kept well stirred for a considerable time. The water, which has become sweet by extracting the sugar from the malt, is allowed to settle, and is then drawn off in the state called *wort*. The wort is made to flow into a copper, where hops are added, varying from four to thirty pounds to a quarter of malt. When the hops have been boiled and stirred well up with the wort for some time, the whole contents of the copper are pumped into a large vessel called a *hop-back*, where the liquor drains through a perforated bottom, leaving the hops behind. The liquor is cooled either by being spread in a thin layer exposed to a current of air, or by passing through pipes exposed on the outside to a current of cold water. From the cooler the liquor is conveyed to a large vessel called the *fermenting tun*. The peculiar substance called *yeast* is added in small quantity; the wort undergoes an agitation throughout its whole mass; and the sugar contained in it gradually changes into a kind of spirit or alcohol. This process is stopped at a particular stage, by the drawing off of the liquor into smaller vessels, and the clearing away of the yeasty scum or froth. By insensible degrees the liquor changes its character from sweet-wort to beer or ale. To improve this malt-liquor in various ways, it is transferred from the smaller vessels into a large tank, thence into large vats for storing until wanted, and thence into the casks in which it is sold. The *fining* or *clarifying* is generally effected in the cask; isinglass, or some other substance, thrown into the beer or ale, clears it from impurities, and renders it bright and transparent.

The porter breweries of the metropolis are among the largest manufacturing establishments in the kingdom. Some of them, such as Messrs. Barclay's and Messrs. Hanbury's, consume a hundred thousand quarters of malt in a year, and possess vats capable of containing a hundred thousand gallons. The ale trade of Burton, such as that of Messrs. Bass and Messrs. Allsopp, is also conducted on a very large scale. It is supposed that about six hundred million gallons of beer and ale are annually brewed in the United Kingdom.

Vinegar and Vinegar-making.—This liquid, rather a seasoning than a beverage, is related to beer in two ways—both are or may be made from grain, and both undergo fermentation. Vinegar, however, is a more remarkable liquid than beer or ale; for it can be made from raw grain, malted grain, sugar, molasses, treacle, wine, beer, ale, cider, or perry. Indeed, whatever contains sugar, or starch that may be converted into sugar, can be made to yield vinegar. English vinegar-makers mostly employ malt. The malt is brewed into sweet-wort, almost exactly in the same way as for making beer and ale; but the wort, instead of being boiled up with hops, as in brewing, is at once cooled, and transferred to fermenting vessels, where, by the aid of yeast, it is made to ferment. The brewer's fermented liquor is beer or ale; but the vinegar-maker employs the appellation *gyle*. The gyle, after giving off a sediment and a froth, is made to flow into casks, where it gradually acetifies, or becomes converted into vinegar. During a period of several months, the gyle is acted upon by the oxygen of the air, through the open bung-holes of the casks; a chemical change gradually goes on, and the imperfect beery quality of the gyle changes to the acid quality of vinegar. Singularly enough, the same effect may be produced by placing the casks in a close room heated to a high temperature. It seems as if the required change depended on the access of air, whether the air be hot or cold. There are only a few vinegar works in and near London; but the strong acetic odour from those works (wholesome, though not always pleasant,) is perceptible all around. After *stoving* or *fielding*, as the hot air and cold air processes are called, the vinegar is clarified or brightened, and then put into casks for sale.

6. Wines, Spirits, and Effervescing Drinks.

It is a beautiful exemplification of nature's chemistry that, as has already been shown, the selfsame corn that yields our loaves of bread will, when differently treated, yield the beverages beer and ale; and that another modification will result in the production of wholesome antiseptic vinegar. We shall now see that ardent spirits, the source of so much misery to reckless persons and their families, are also obtained mainly from corn. It will be convenient in this section to compare three kinds of beverages—the vinous, the alcoholic, and the effervescing.

WINES, FOREIGN AND BRITISH.—Wine is in almost all cases produced from fruit, and true wine from one particular kind of fruit—the *grape*. Various species of grape are specially cultivated for this purpose; and the quality of the wine produced depends on a wonderful number of minor circumstances connected both with the cultivation of the grape and the operations of the vintage.

Let us select *Sherry* as an example, from which some idea of the whole group of wines may be formed. Sherry is the principal wine of Spain, deriving its name from *Xeres*, the chief town of the wine-district, not far from Gibraltar. Some of the firms at this place possess cellars containing three or four thousand butts of Sherry always in store. At the principal vineyards, the vines are planted about five feet apart. During the early part of each year, great attention is bestowed on the growing plants, in pruning, loosening the soil, weeding, cutting off useless sprouts, removing or killing insects, and driving in stakes to support the coming crop. The grapes are allowed to hang till perfectly ripe, which generally occurs about the middle of September. They are picked carefully and carried away in baskets to the building where the wine is to be made.

In the making of Sherry, the grapes are first exposed for a day or two to the heat of the sun, and then thrown into a large square wooden trough. A coarse wooden screw, worked by a lever, stands in the centre of the trough. Men with wooden shoes get into the trough, and jump violently on the grapes, crushing them into a pulp, and then heaping them up under and around the screw. The lever being worked, the pulp becomes violently compressed by the screw, and the juice, or *must*, flows through holes into vessels beneath. The skin and husks, after having had water added to them, are again pressed, to produce wine of inferior quality. The must is allowed to undergo a fermentation, which converts it into wine, and the careful management of which is essential to the good quality of the wine produced. The difference between *light* and *brown* Sherry depends partly on a difference in the quality of grape, and partly on a different mode of treatment. The wine is stored in casks, which are ranged according to the age of the vintage. The older the wine, the higher is the price obtainable for it. The merchant takes a little old wine from one cask, to improve the quality of that in another, and then immediately fills up the vacancy; so that the choice casks are always full of old wine. A cask of Sherry, said to be fifty years old, may thus contain wine of thirty or forty seasons.

The various kinds of wines—such as Sherry, Port, Madeira, Claret, Burgundy, Champagne, Hock, Moselle, Marsala, Tokay, Cape, &c.—owe their distinctive properties to many different circumstances: such as the kind of soil, the species or variety of grape, the aspect of the country, the mode of cultivation, the process of fermentation adopted, and the cellar management. Some, such as Port for the English market, are made stronger by the addition of brandy. Until 1861, England was almost wholly dependent for wine on Spain and Portugal, the countries of Sherry and Port, owing to defective commercial and Custom-house treaties; but now light and wholesome French wines are obtainable at reasonable prices. The casks in which foreign wine is brought to England have different capacities and different names. Thus, a *butt* of Sherry is one hundred and eight gallons, a *pipe* of Port is one hundred and fifteen gallons, a pipe of Madeira ninety-two gallons, and a *hogshead* of Claret about sixty gallons.

British, or *Home-made* wines, known to the excise officer as *sweets*, are not properly wines. They are made from fruits of various kinds, the juice of which is obtained by pressure, and after a slight fermentation and fining, is flavoured by the addition of sugar and various herbs and seeds. Such wine is made in England for sale at a price intermediate between those of ale and spirits; and it is also largely made by country families for domestic consumption. The wines are made from a considerable number of vegetable substances, including *dried* *fruit,* such as raisin, fig, and date; *fresh fruit,* such as gooseberry, currant, cherry, raspberry, mulberry, strawberry, apple, elder, whortleberry, grape, damson, bullace, apricot, orange, juniper, lemon, peach, and quince; *roots,* such as rhubarb, ginger, celery, parsnip, turnip, and beet; and *flower* and *sap,* such as cowslip, elder-flower, rose, clove, gilliflower, violet, carnation, lavender, primrose, balsam, pine-apple, and birch.

Cider and *Perry* might either be regarded as apple and pear *wine,* or apple and pear *beer;* for they occupy a position midway between the two. Cider is thus made. The apples are placed in a stone trough, and crushed to pulp by a heavy stone runner or roller; the pulp is placed on horsehair cloths, which are made up into bags. Several of such bags are placed one upon another, and pressed heavily with a screw-press. The thick brown juice which exudes from the bags is received in vessels, where it is exposed to the air for two or three days; it ferments, and deposits a sediment, leaving clear cider at the top. The cider, after racking, fining, and keeping, is ready for use. Devonshire and Herefordshire are the chief cider counties, producing beverages which differ in quality according to the kind of apples employed. Cider is drunk very largely in and near the counties where it is made, but only to a limited extent in other parts of England. *Perry* bears the same relation to pears that cider bears to apples, and is made nearly in the same way.

Spirits, Foreign and British.—There is, as we have stated, a strange connexion between *bread*, *beer*, *vinegar* and *spirits:* utterly unlike as they are in appearance, and greatly as the first differs in quality from the other three.

All kinds of grain and many kinds of root and fruit will produce spirit, as also will sugar. *Brandy* is obtained from wine and grape husks, *rum* from sugar and molasses; *whiskey*, *gin*, and *hollands*, from corn. The corn may be wheat, rye, barley, or oats; it may be malted or unmalted; and it is a manufacturer's question to determine which will best suit his purpose. The corn is ground or crushed, just as for brewing; it is mashed with warm water into a sweet liquid, and the liquid exposed to fermentation, just as for brewing; but here the similarity ends. Instead of being boiled with hops to make beer, the fermented liquor is *distilled*, to change it into spirit, or rather, to extract the spirit from it. The wort or sweet liquor is fermented with *wash*, which is poured into large copper stills. These stills are closed when the wash has been poured in, and have then no other aperture than a pipe through which vapour can pass. Water becomes steam at a temperature of 212°, whereas spirit becomes vapour at so low as 180°. This will give a clue to what occurs within the still. By keeping up a certain heat the distiller can send off from the still all the vapour of the spirit in the wash, and as much or little as he pleases of the steam or watery vapour. The vapour passes from the still into another vessel, where it cools down into a liquid, which is weak spirit. This liquid, by one or more subsequent distillations, may be procured of any required strength. The *spent wash*, remaining in the still after these processes, is useful as a fattening diet for swine.

Thus is produced *raw spirit*, as it is called in England; *whisky* in Scotland and Ireland; *hollands* in the Netherlands. The different qualities depend on a multitude of varying circumstances, in the materials used and the processes followed. All the various liquids called *gin*, *British brandy*, *British rum*, and *cordials*, are made from this raw spirit by redistillation with water, and with the addition of various seeds, herbs, fruits, leaves, and flowers. This secondary operation is called *rectifying*.

Brandy is made in most wine countries, such as France, Spain, and Portugal; that from France, especially the town called *Cognac*, being the most esteemed. Not only is the wine itself distilled, but also the *marc*, or residue of the last year's pressings of the grape. The best Cognac brandy is obtained by a peculiar mode of treating a certain white wine made in the neighbourhood. Brandy is white when first distilled; it darkens by keeping, and is purposely made darker by the addition of burnt sugar and other substances. *Potato* brandy, *carrot* brandy, *beet* brandy, and *pear* brandy are also made, but they retain the flavour of the substances from which they are made.

Rum is distilled from the sugar-cane juice, from the skimmings of the juice in the boiling-house, or from treacle or molasses. When the rum manufacture and the sugar manufacture are carried on in the same establishment both are rendered more profitable; and thus the same colonies that send us sugar also send us rum. The best rum is made from molasses; about a gallon of the former from a gallon of the latter.

The annual consumption in the United Kingdom is now about twenty-five million gallons of British spirits, and five millions foreign. The foreign wine consumed by us is about eight million gallons annually.

EFFERVESCING DRINKS.—Several well-known beverages are neither infused like tea nor decocted like coffee, neither fermented like beer nor distilled like spirits. They depend for their qualities partly on their taste, and partly on a sparkling effervescence which they exhibit when poured out into a glass. *Soda-water*, *ginger-beer*, and *lemonade* are the best-known examples of this class. The names of all three denote the substances to which the flavour is chiefly due, while all owe their sparkling quality to the action of carbonic-acid gas. There are many methods of producing each of the three; but in every case there is in a closed bottle of the beverage a certain quantity of carbonic-acid gas struggling to escape, and the action of this gas, bubbling up through the liquid when poured out into a glass, imparts to it that sparkling, effervescent, or aerated quality which is so much relished, especially when the beverage is taken in warm weather. In making soda-water for sale, apparatus of considerable strength is employed, on account of the bursting tendency of the gas when confined in bottles. It may be mentioned, as among the many curiosities of the Great Exhibition at Hyde Park, in 1851, that more than *one million* bottles of effervescing drink were consumed within the building!

Thus have we traced, in a very slight way, some of the most interesting facts connected with the growth and preparation of the substances used for the food and beverages of man. The gifts of Providence, in this way, are as beautiful as they are bountiful. And if we watch the industrial proceedings of society, especially in a highly civilized state, we shall be struck with the vastness of the arrangements connected with this food question. The area of ground occupied in the production of food, the number of persons employed, the various kinds of skill required, the ingenious construction of the necessary implements and machines, the amount of capital involved, the manufacturing establishments built for the operations, the modes of conveyance from place to place, and the arrangements for wholesale and retail trading—all are more extensive than would, at first thought, be generally supposed. Few there are, indeed, who are in the habit of reflecting how greatly these matters occupy the thoughts of all around us. The strivings, the successes, the failures to obtain daily sustenance, occupy far more of the thoughts of mankind than any other subject whatever. It might possibly be surmised that men of thought, feeling, lofty aspiration, refinement of sentiment, should be exempt from this general characteristic; and this in some cases is true. But let such a man have his little ones around him, whose daily wants need a daily supply; then he, like other men, bends his lofty spirit to the practical affairs of home life. It is hard work to be a sublime poet or a deep philosopher when the cupboard is bare; the man himself feels this, and feels it all the more acutely if there are others dependent on him. The exceptions are just of such a kind as to prove the general rule: our daily exertions relate to daily food more extensively than to any other subject whatever.

THE MATERIALS FOR CLOTHING.

1. COTTON—ITS GROWTH AND MANUFACTURE.

COTTON CULTIVATION.—COTTON SPINNING.—COTTON WEAVING.—COTTON BLEACHING AND DYEING.—CALICO PRINTING.—LACE, NET, AND HOSIERY.

2. FLAX AND THE LINEN MANUFACTURE.

FLAX GROWING AND DRESSING.—FLAX THREAD AND YARN.—LINEN AND CAMBRIC.

3. WOOLLEN AND WORSTED GOODS.

WOOL AND ALPACA.—WOOLLEN AND WORSTED SPINNING.—WOOLLEN AND WORSTED WEAVING.

4. THE SILKWORM AND SILK GOODS.

REARING THE SILKWORM.—SILKEN GOODS.

5. LEATHER, GUTTA-PERCHA, AND INDIA-RUBBER

LEATHER AND TANNING.—GUTTA-PERCHA.—INDIA-RUBBER.

6 HATS, BONNETS, FURS, FEATHERS, & FLOWERS.

BEAVER AND SILK HATS.—STRAW PLAIT AND STRAW BONNETS.—FURS, FEATHERS, AND FLOWERS.

Chapter II.

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CHAPTER II.

THE MATERIALS FOR CLOTHING.

ANOTHER of the great necessities of mankind, *clothing*, one which distinguishes human creatures in so remarkable a way from all the lower animals, now claims attention. Here manufacturing, properly so called, is more indispensable than in the preparation of food; more processes and tools, more machines and engines, are needed. The subject is a large one, and can only be touched in its principal points. The fibres which are woven into dress-materials, such as *cotton, flax, wool, alpaca,* and *silk; leather, gutta-percha,* and *india-rubber,* for subsidiary articles of clothing; *fur* and *straw-plait* for hats and bonnets: *feathers* and *artificial flowers* for ornament: these are the subjects which will rapidly pass under our notice.

1. COTTON, ITS GROWTH AND MANUFACTURE.

Various circumstances have rendered *cotton* the most important of all materials for clothing at the present day. It has so many advantages, that a larger and larger portion of the earth's inhabitants are becoming clothed in cotton. Our own country derives support for so many thousands—even millions—from the cotton manufacture, that any deficiency in the raw material is regarded as a terrible evil. We have seen ample indications of this, in the stoppage of trade arising from the discord between the Slave States and Free States of America in 1861-2.

COTTON CULTIVATION.—Cotton is a delicate fibrous substance, enveloping the seed of a particular genus of plants, the *gossypium* or cotton-tree. There are many different kinds, the fibres being longer and more silky in some than in others. The tree grows to a height varying from three to twenty feet. When at its prime, the seed-vessel contains three or more lobes or cells; in each cell there is a seed; and the cotton-fibres fill up all the space between the seeds and the seed-vessel. The long silky-fibred cotton, used by the spinners and weavers of fine muslin, and called *sea-island* cotton, is grown near the sea-shore of some of the American States; but the shorter and coarser fibres, often called *upland*, and grown in the interior, are much more extensively useful, being made into calico, chintz, gingham, printed cottons, &c. Brazil, Egypt, and India are the other chief sources of supply; but it is probable that, in future years, our spinners will be supplied from many additional places.

The general operations in a cotton-field are nearly as follow: The seed is sown in spring; and when the young plants appear above ground, much attention is paid to the hoeing and weeding. When August arrives, the bolls or tufts of cotton are found to be ready for picking. The planter endeavours to complete the picking just before the frost of winter begins to show itself. The negroes (for four-fifths of all the cotton used in Great Britain is the product of negro-labour), pick the cotton in a very simple way. They fasten bags round their waists, walk along between the rows of plants, pick the bolls, throw them into the bags, empty the contents of the bags out upon a sheet, and finally carry the laden sheet to the weighing-house. A good hand will pick one hundred-and-fifty to two hundred pounds in a day. About three hundred bolls, weighing a little over three pounds, is a fair produce from one tree in each season.

The cotton, when picked, comprises seed as well fibre; one-third only of the weight is available; the remaining two-thirds must be got rid of. A machine called a *gin* is here brought into use. Revolving teeth or spikes open the tufts of cotton, and shake out most of the seeds and small particles of dirt. The more completely this is done, the higher price will the cotton fetch in the market; it is better attended to in America than in India, and this is one reason for the higher favour in which American cotton is held. After the ginning or cleaning, a screw-press is employed to condense or pack the cotton into bales averaging about four hundred pounds each; and these bales are then shipped to Liverpool and elsewhere.

It is in the above way that the United States alone have produced, year after year, the marvellous quantity of *three million* bales, of four hundred pounds each, far exceeding a thousand million pounds of cotton! All the cotton worked up annually into calico and other goods, in the mills of Europe and America, is believed to amount to more than double of this quantity. Our own country alone, in 1860, worked up nearly a thousand million pounds. These are indeed almost inconceivable quantities; considering that each little tuft or boll, weighing far less than a quarter of an ounce even with the seeds, has to be separately picked from the tree by hand.

COTTON SPINNING.—Supposing, now, that a bale of cotton fibres has been brought to Liverpool, or to Glasgow. It is to be converted into thread for sewing and lace-making, or into yarn for weaving.

When the bales are opened, the contents of two or more are mixed, to equalise the quality. Several layers are raked and turned over, until well mingled. This mass is then *scutched* or *willowed;* that is, it is exposed in a machine to the action of beaters or staves, which revolve rapidly, and open the tufts of cotton by repeated beatings. This done, it is next *spread;* the cotton is spread out into a layer of definite length, breadth, and thickness, in order that there may be no irregularity in the subsequent operations. This layer or lap of cotton, however, although pretty equable in thickness, has the fibres crossing each other in every direction. To straighten them is the object of the next process, *carding.* Cylinders studded all over with sharp spikes are made to rotate rapidly, nearly in contact with another series of spikes by which the cotton is held; as a consequence, the fibres are combed out straight, much on the same principle as hair is combed. The cotton leaves the carding machine as a beautifully soft fleece or layer, called a *carding.* This carding passes between rollers, so formed as to bring it to the state of a thick but soft cord, called a *sliver.* To render all the fibres still more parallel and equal, is the object of the process of *drawing*, during which several sets of rollers compress, draw out, and double the fibres over and over again.

Down to the present stage, the fibres have not undergone any *twisting.* The mixing, scutching, spreading, carding, and drawing have by degrees brought the cotton to the state of a soft, delicate, even cord, possessing little or no strength. To give it strength, the cord is passed through a *roving-machine*, which slightly twists all the fibres. After this comes the important process of *spinning.* This spinning, conducted in various ways, is a combination of drawing-out and twisting—drawing-out to bring the thread to any required degree of fineness, and twisting to impart the requisite strength. The *spinster*, or female spinner of primitive districts, both drew out and twisted the thread by her *distaff* and *spindle;* the first form of *spinning-wheel* did the same more effectually; the *spinning-jenny*, invented nearly a century ago, expedited the process by combining eight spinning-wheels in one; the *spinning-frame* went further, by combining the action of eighty or a hundred spinning-wheels; the *mule-jenny* modified the process in such a way as to produce finer and softer yarn than had ever before been made; until at length the steam-worked *spinning-machine* triumphed over all mechanical difficulties, and afforded the means for spinning a large quantity of yarn in a wonderfully short space of time. Revolving bobbins, and cylinders, and stretching-frames, combine to give the requisite drawing-out and twisting to the cotton. The yarn is made up into hanks of 840 yards, which receive designations according to the number of them to the pound; thus, a hank of No. 40 contains $40 \times 840 = 33,600$ yards, or about 20 miles of yarn. If the cotton is to be spun into *thread* for sewing, instead of *yarn* for weaving, it is rendered more hard and solid.

Some of the kinds of yarn now made are very much finer than No. 40; but even if that were taken as an average of the whole, the quantity of cotton now annually worked up in the United Kingdom would, if made into such yarn, extend *twenty thousand million miles*, or more than two hundred times as far as the distance from the earth to the sun! Such are among the wonders of our modern cotton-manufacture.

Cotton Weaving.—The varieties of cotton goods are almost endless; nevertheless, if we can understand how *calico* is made, we may infer sufficient concerning the other kinds.

To weave the better kinds of calico, the yarn is *singed;* that is, it is passed quickly over a series of gas-jets, whereby the little loose filaments on the surface are singed off. Next comes the *dressing.* This consists in applying to the yarn a composition of starch, gum, flour, or chalk, in a semi-liquid state. The professed object is to facilitate the weaving processes, by strengthening and smoothing the yarn; but the makers of cheap calico unfairly employ a large quantity of the composition to give to the cloth an appearance of being stouter and heavier than it really is.

In the ordinary or plain kinds of weaving, the *warp* or long threads are wound round a beam belonging to a *loom;* while the *weft* or cross threads are wound on a revolving spindle in a little boat-like implement called a *shuttle.* A *warping* frame or machine is employed to wind the yarn with the utmost regularity around the beam: there being as many threads thus arranged as there are to be long threads in the cloth. From the beam, when in the loom, the warp-threads are stretched out in a horizontal layer, with certain apparatus attached, by which some of the threads can be lifted up a little way at certain parts, and then lowered again. The weaver, seated at one end of the loom, goes through a very singular series of duties. He puts his foot upon a treadle or pedal, by which some of the warp-threads are lifted up, and others depressed; the space between these two groups is called the *shed*. He throws the shuttle, say from right to left, through this shed, thereby passing a weft-thread across the warp. He moves with his left hand a frame called a *batten*, which drives up that weft-thread closely. He next reverses the movements of the treadle or shuttle, raises the group of warp-threads which he had before depressed, forms another shed, and throws the shuttle from left to right. Every alternate thread is raised; so that by these successive alternations with the treadle, shuttle, and batten, the weft-threads become interlaced among the warp, forming with them a cloth or textile fabric.

Countless are the changes produced by varying the action of the several parts of the loom, and by using steam-power instead of the weaver's hands and feet. If the threads be selected of different colours, there may be produced *stripes*, *checks*, and *shots*. If weft-threads cross the warp in an irregular instead of a regular way, *twills*, *diapers*, and *dimities* may be woven. If both these conditions be followed, the weaver can produce *sprigs*, *flowers*, and *spots*, on the cotton goods. If he would produce imitations of a velvety texture, as in *cotton-velvet*, *fustian*, and *velveteen*, he so treats some of the warp-threads as to produce a nap, pile, or soft surface. Nearly all these operations are now performed by power-looms in large factories, much more quickly than by the hand-loom weaver in his humble room.

How much cotton cloth of all kinds is annually made in this country, no one accurately knows; but this at least is known—that after supplying our own home wants in 1860, we sold three thousand million yards to other countries: enough to form a bandage that would wind eighty times round the earth!

COTTON BLEACHING AND DYEING.—When the weaver has done all that falls to his duty, certain remarkable processes of a chemical nature ensue, to impart whiteness, colour, or pattern to the cloth. The first is *bleaching*. This consists in simply taking away the discolorations. In the last century cotton or linen cloth was wont to be steeped for several days in a potash liquor, and then for several days in sour buttermilk; after which it was spread out on the grass in the open air for several weeks, by which it was gradually bleached or whitened. A series of beautiful chemical discoveries led gradually to the adoption of chloride of lime as a bleaching agent, by which the effect is produced in a wonderfully short space of time. The cotton is washed and boiled, steeped and rinsed, in several kinds of liquor, one of which is a solution of chloride of lime; the bleaching is then effected in a few hours instead of several weeks. The cloth having now become white, it is squeezed between rollers, to expel as much moisture as possible; and then it is dried. The drying is now generally effected by two processes: first, by whirling round the cloth very rapidly in a hollow wheel perforated at the exterior; and, secondly, by hanging up in a hot closet.

Another important operation, *dyeing*, is necessary only for a comparatively small portion of cotton goods; silk and woollen goods are much more generally dyed. Although dyeing is simply the imparting of colour, it requires the exercise of much chemical knowledge and general tact. The work to be accomplished is, not merely to cover the surface; for this colour, even if it did not wash out, would leave one surface of the cloth in an unsightly condition. Effective dyeing consists in *staining* the fibres throughout, and permanently, in such a way that washing will not remove the colour; and the dyer has to study what kind of drug will best produce this result upon the particular sort of cloth under treatment.

The number of substances used in dyeing is very considerable; most of them are noticed in Chapter VI. The actual processes of dyeing involve a series of steepings, boilings, and washings, in water, pure or coloured as the case may be. Some colouring substances are what is called *fast*, but not *brilliant;* others are brilliant but not fast; and it is the dyer's business so to manage as to combine these two qualities. Certain chemicals called *mordants* are necessary to this purpose. This name is derived from the Latin word for "biting:" seeing that the mordant enables the dye-colour to bite into the fibres of the cloth. The mordant itself seldom gives colour to the cloth; it modifies and fixes the colours afterwards applied. The results are beautiful as well as important. If a piece of cotton were dyed simply with a solution of madder-red, for instance, the red would wash out; but if the cotton has previously been steeped in a mordant, the red becomes permanent. If the mordant be acetate of alumina, the madder-dye afterwards comes forth in its proper red colour; if it be acetate of iron, the madder assumes a blackish colour; and if the two acetates be combined, the colour comes out chocolate. The mordant, also, often gives a peculiar lustre to the colour, irrespective of any change of tint. Sometimes several mordants and several dyes are used in succession; and any one of the number may be applied either hot or cold. It will thus be seen that there are immense resources at the command of the dyer, depending on his knowledge of the chemistry of colours.

All the arrangements for the dye-house are such as to facilitate the mixing, heating, and using of liquids. Drug-mills are at hand, to grind some of the dye materials to powder; abundant supplies of clear water are provided; tanks, boilers, furnaces, and cauldrons either provide the heat or contain the liquid; winding machines are employed to dip the cloth regularly and equably into the vessels of dye-liquor; and other kinds of apparatus are at hand for wringing, drying, smoothing, and finishing the dyed goods.

Calico Printing.—This is a very beautiful operation; for it requires not only chemical knowledge, but a knowledge of the harmony of colours, and of taste in the arts of design. All kinds of cotton goods are bleached, and most kinds are dyed, before being printed.

There are several different modes of printing cotton. In one, wooden blocks are prepared with the pattern on one surface, and are pressed down on the cloth by hand. In another, several such blocks are fixed in a frame, and are worked by machinery. In a third, the pattern is engraved on a flat copper-plate, which is pressed down upon the cloth. In a fourth, the pattern is engraved on a copper cylinder, over the surface of which the cloth is made to travel. In all these cases alike, mordants and colours are used as a kind of ink, applied to the block, plate, or cylinder. Besides these mechanical differences, there are many chemical variations in the mode of proceeding. Sometimes the whole piece is dyed, and then the dye removed by chemical substances called *discharges*, laid on by printing in a certain pattern. Sometimes the pattern is printed on with a paste called a *resist:* the cloth is then dyed; and the dye colour can easily be washed off the spots which have been covered with the resist. Sometimes steam, sometimes spirits, are employed to fix the colours on the cloth, or to modify in some way their appearance.

Most printed cottons are now done by the cylinder method; which, when the colours are numerous, is in every way a remarkable process. Occasionally as many as ten colours are printed *simultaneously* on one piece of cotton, by ten cylinders engraved with different parts of the design; but the number seldom exceeds three or four. Such is the perfection to which the machines have been brought, that one of them will print a *mile* of cloth in one hour.

The preparing of the designs is an important work. The pattern designer draws a pattern on paper; so selecting his colours that they will both look well and print well. If the printers are satisfied with the sketch of the designer, the engravers transfer the design to the blocks, plates, or cylinders. Let us suppose the cylinder method to be adopted. Copper cylinders are prepared, as many as there are colours in the pattern; so much of the design as is engraved upon each cylinder is to be printed in one colour. The pattern is sunk in, not raised upon, the surface. When the printing is to be effected, the cylinders are so arranged horizontally, that each as it rotates can dip into a trough containing its own particular colour, mixed as a thickish liquid. A long knife then comes in contact with the surface, and scrapes off every particle of colour, except that which has sunk into the engraved lines of the device. The cloth is made to travel over rollers and beams, and to come in contact with all the four cylinders in succession, being pressed upon each during its passage. So beautifully is everything timed and placed, that the cloth arrives at each cylinder exactly at the instant when the latter is duly charged with colour; while the parts of the cloth printed by one cylinder are exactly those which are left untouched by the others.

Printed muslins, mousseline-de-laines, printed calicoes, chintzes, and other goods, are all done by modifications of the processes above described.

LACE, NET, AND HOSIERY.—Cotton thread is worked up into lace, net, and hosiery, by a kind of weaving in which no loom is employed.

In making the best *lace*, in which flax thread is more frequently employed than cotton, a drawing is laid upon a pillow or cushion; pins are stuck into the cushion to follow the lines of the device; and threads, wound on small bobbins, are twisted round the pins, and round each other: thin thread is used for the groundwork, thick for the device; and all the threads become so knotted or linked together as to form a piece of lace. According to the mode in which this is done, so are produced one or other of the many kinds called *Brussels, Valenciennes, Mechlin, Alençon, Lisle, Maltese, Honiton,* and other sorts of lace; some of which have square meshes, some diamond-shaped, some six-sided some eight-sided. Sometimes the ornaments or figures only are made in this way, and are sewn upon a groundwork of ordinary net.

One of the most remarkable of modern growths in manufacture is that of *bobbin-net*, or cotton made by machinery. In the last century, various kinds of light and open cotton goods were made, midway between muslin and lace in character, and called *whip-net*, *mail-net*, *patent-net*, *drop-net*, *spider-net*, *balloon-net*, &c., by peculiar applications of the loom. Next, by modifications in the stocking-frame other fabrics were made, to which the names of *spider-net*, *point-net*, and *warp-net*, were given. At length a most beautiful piece of mechanism was contrived—the *bobbin-net machine*—based on the experience derived from all that preceded it. Bobbin-net is now made by this machine at a price that would in former years have appeared absolutely incredible. Some of this net is as much as five yards in width; and the commonest is sold so low as sixpence per square yard. The threads are wound round and amongst each other in a way that combines something of ordinary weaving with something of lace-making; but the apparatus is far more elaborate than any kind of loom, especially when its arrangements are for making *figured* net.

The making of *stockings* and other kinds of *hosiery* bears more resemblance to bobbin-net making than to the weaving of calico or cloth; for the mesh is a peculiar kind of net-work. The method is applicable alike to cotton, worsted, and silk, as we see in the several kinds of stockings made. A poor clergyman, in the time of Queen Elizabeth, while looking at his wife knitting, formed the idea of a machine that would enable her to knit more rapidly;

and from this idea sprang the *frame-work knitting machine*, or *stocking-frame.* Chiefly by means of this machine, variously modified, cotton stockings are made in Nottinghamshire, worsted stockings in Leicestershire, and silk stockings in Derbyshire. Some of the machines are worked by steam-power, but most of them by hand. To whatever degree stockings and hosiery may vary in other ways, all have this quality in common—that the fabric is produced by a peculiar knotting or linking of a thread which constitutes both warp and weft, in a way that imparts both strength and elasticity; instead of being produced by the intersection of long and cross threads, as in woven goods.

How many pairs of stockings are made annually in the United Kingdom, no one knows; but it is an ascertained fact that more than a *million dozen* pairs of cotton stockings alone are annually exported, after supplying the home demand.

2. Flax and the Linen Manufacture.

We pass on to another of the great departments of manufacturing industry relating to clothing; viz., the culture of *flax*, and the processes for working it up into the various kinds of *linen* and other flaxen goods.

Flax Growing and Dressing.—*Flax*, which is in all probability older in use than cotton, although now so much less important, is obtained from a genus of plants called *linum*. It is not the fibre of the seed-pod, like cotton; it is the more stringy fibre of the stalk, when separated by steeping and other processes. The plant is simply a small shrub, with a stem from one to two feet high; this stem yields the fibre, while the seeds yield *linseed oil*. The Flemish farmers, who are the best flax growers, prepare the ground by careful manuring, and by a particular rotation of crops; the seed is sown broadcast, and is covered with a thin layer of earth. As soon as the young plants appear, women and children carefully weed them. The time of plucking is regulated according as the grower wishes for good and plentiful fibre, or good and plentiful oil. When ready, the plants are pulled up in small handfuls, laid on the ground to dry in fair weather, and packed into ridges till wanted.

Then, to obtain the flaxen fibre. The seed-ends of the plants are beaten out with a kind of bat, or else passed between the teeth of a sort of large comb; in either case the seeds are *rippled* or separated from the stems. Next comes the *steeping*. This is effected in many different ways; but the object in all is to dissolve a glutinous matter that fastens the outer bark or peel to the inner fibres, and which must be loosened before the fibres can be obtained. A slight fermentation takes place, which aids the process, and when this stage has been reached, the plants are carefully dried.

The operations of *breaking* and *scutching* separate the fibres from such other parts of the stem as are not required. Sometimes they are done by hand, sometimes by machinery; but in either case the *boon* (as the stem in this case is called) is thoroughly broken from end to end, to reduce all the woody substance to fragments; and then a wooden knife beats or scutches off all these fragments, leaving the fibres exposed. Next comes the *hackling* or *heckling*. The heckle is a square brush with long iron teeth. The heckle takes a handful of flax fibres by the middle, and draws them repeatedly through or between the teeth of the heckle: thereby clearing away all the bits of woody refuse, and laying the flax fibres straight and even.

FLAX THREAD AND YARN.—When the flax has been pulled, steeped, broken, scutched, and heckled, it is in a state fit for the spinner. In the great flax-mills of Yorkshire, the bundles or *heads* of flax, weighing a few pounds each, are first scutched or roughly combed at the ends, to remove some of the dust and dirt. The flax is again heckled to clear the surface of every fibre, and separate the fibres one from another. The flax intended for the finest lace and cambric is heckled six or eight times over, to increase its fineness and evenness.

The heckled flax is next *sorted*. Small portions are spread out on a table and examined, the fibres being separated into two or more groups according to their length and quality. Generally speaking, they are about ten inches long; but some exceed and others fall short of this length. After the sorting, those processes begin which have the effect of combining the fibres into a continuous thread. First comes *drawing*. The flax, placed upon a travelling apron, is drawn in between two rollers, until it presents the form of a soft ribbon called a *sliver*. The *carding-machine* then draws and cards and doubles this sliver over and over again, bringing it to a state of equal width and thickness in every part. All the good flax thus treated is called *line*; while the short, defective, or irregular fibres are collected to form *tow*, which is used for inferior purposes. The slivers of line are conveyed to *roving-machines*, where they are elongated and slightly twisted. All is now ready for the *spinning*. Cotton, as we have seen, is spun *dry*, but flax is spun *wet*, to make the thread fine and smooth; and if the water employed be warm, the improvement is still greater than if cold. Hence the spinning-machines for flax are complicated with the arrangements for wetting the fibres. The flax-roving, in its progress towards the bobbins and spindles of the spinning-machine, passes through troughs of water. In its wet state it gives forth a spray of minute drops; and the women and girls who attend the machines wear leathern pinafores, to shield themselves from its consequences.

The flax yarn produced by the above processes depends for its fineness on the original quality of the fibres, and on the carefulness with which the processes have been conducted. If intended for weaving, it is reeled into hanks and then made up into bundles. Three hundred yards form a *lea* or *lay*, six leas form a *rand*, and twelve rands (about twelve miles) form a *dozen*. The very finest yarn is sometimes mixed with silk, to weave into handkerchiefs, &c. If not intended for weaving, the yarn is further prepared for lace-making; or it is doubled and twisted into hard *sewing thread*.

LINEN AND CAMBRIC.—Flax is woven both by hand-loom and by power-loom. The different kinds of flaxen fabrics receive names depending partly on the uses to which they are applied, and partly on causes not easy to assign. *Linens*, *damasks*, *shirtings*, *sheetings*, *ducks*, *drills*, *table linens*, *checks*, *huckabacks*, *diapers*, *towelings*, *tickings*, *drabbets*, *dowlas*, *sailcloth*, *floor-cloth*, *canvas*—these are some of the different varieties. The north of Ireland, the West Riding of Yorkshire, and the part of Scotland between Dundee and Aberdeen, are the chief seats of these manufactures.

The manufacturing arrangements differ in different places. In some districts, manufacturers, as they are called, purchase flax-yarn from the spinners, and give it out to hand-loom weavers; these latter take it to their homes, weave it, and carry it back to their employers, who pay them so much per yard or piece for their labour. Some of the Irish hand-loom weavers act on a more precarious plan; they go to market to buy yarn, return home to weave it, go to market to sell the woven linen, and return home with their earnings or profits. More and more is the power-loom system acted on, which leads to the regular employment of weavers, at definite wages, in large factories.

Two hundred million pounds of flax are sometimes imported in one year, for manufacturing into linen goods. The home growth is but small.

3. Woollen and Worsted Goods.

Cotton and flax are of vegetable origin; but the clothing-materials now to come under notice are fibres derived from the animal kingdom. It will be seen, however, that the mode of treatment, though differing much in detail, depends on the same general conditions as those which have just engaged our attention.

Wool and Alpaca.—In all probability, wool was used as a material for clothing before either cotton or flax; seeing that the same sheep which yielded meat for food, yielded at the same time a woolly fleece susceptible of being spun into thread for weaving. All the wool and hair of all the varieties of sheep and goats are available for this purpose, but not equally well. It is found that a sheep which grows good mutton, grows coarse wool; and therefore the grazier has to decide how he will manage his sheep farm, according as he wishes to accommodate the spinner or the butcher. England produces mutton equal to any in the world; but English wool is becoming less and less fitted for the making of the best woollen cloth; and therefore we import largely of fine wool from other countries, chiefly Germany and Australia. The microscope shows that each fibre of wool has minute projections along its surface; these projections assist the fibres in *felting* or *fulling* together into woollen cloth.

When a sheep is of the proper size and age for the fleece to be sheared as wool, the animal is well washed in clear water, allowed two or three days to dry, and then sheared. The old wool separates naturally from the skin, being pushed away by the new; and at that time the shearing is best effected. The fleece varies from two to six or even eight pounds in weight, according to circumstances.

The animal called the *alpaca,* which yields a beautiful kind of wool or hair now largely manufactured, is a species of *llama* found in Peru and other parts of South America. It is something between a sheep and a goat, but nearer the former than the latter. The fibres are longer, softer, more lustrous, and more pliable than any ordinary sheep's wool. The manufacturers of Yorkshire began to use it about a quarter of a century ago, for making *alpaca cloth,* a woven material of much beauty, intermediate in character between stuff and silk; and from that time the trade has extended very rapidly. Attempts are now being made to rear the alpaca llama in Australia.

Woollen and Worsted Spinning.—In making woollen cloth, fine or coarse fibres are selected, according to the nature and value of the article to be produced; but the best *broadcloth* for men's garments can only be made from foreign wool, the English varieties being too coarse. English wool is, however, suited for making *stuffs*, *merinos*, *worsted stockings*, *blankets*, *flannel*, *carpets*, and *rugs*. The names *short*, *carding*, and *clothing* wool are given indifferently to that kind which is employed for making good woollen cloth; while the names *long*, *combing*, and *worsted* wool are applied to the other kind.

The preparing and spinning of the two kinds of wool vary in some of the details. In the management of *clothing* wool, the fibres are first *sorted* into different degrees of fineness, softness, strength, colour, cleanness, and weight. The wool is then *washed* or *scoured*, in hot soapy and alkaline water, to free it from the grease which always mixes with it in the fleece. When dried, it is *willowed* or disentangled by a revolving spiked machine, nearly in the same way as cotton. The wool is then *moated* or *picked* by hand to remove impurities; *oiled* with olive oil, beaten into the fibres by means of revolving staves; and *scribbled* in a machine provided with two sets of comb-teeth, which lay the fibres straight and parallel, in a soft downy layer. Then comes the process of *carding*, by which the downy layer is separated into narrow portions, forming soft round rolls of wool called *cardings;* those cardings are short; but they are speedily united end to end to form a long cord called a *slubbing;* and this slubbing is gradually attenuated to the state of a soft thick weak imperfect woollen thread. Finally, comes into operation the *spinning-machine*, which changes the slubbing into *yarn;* spindles and flyers, bobbins and rollers, rotate with great velocity, stretching the wool out by degrees, and spinning it as it stretches. When brought to the state of woollen yarn, it is sold to the broad-cloth weaver.

In the management of *worsted* wool, the processes differ slightly from those just noticed. The fibres vary from four to twelve inches in length. When the wool has been *sorted*, *washed*, and *dried*, it is *plucked;* that is, drawn between spiked rollers, to separate the fibres. The wool is then *oiled*, and *combed* between the heated teeth of a machine, to drive out the short and imperfect fibres, and straighten and smooth the rest. This done, any defect in the combing is remedied by the *breaking-frame*, in which other teeth still further separate and arrange the fibres. Next come into action the *drawing-frame*, to stretch and attenuate the flat layers of wool; the *roving-machine*, to bring it to the state of a thick soft cord; and the *spinning-machine*, to convert it into worsted yarn, or into the various kinds of worsted thread used in needle work and knitting. Worsted yarn for weaving is made up into hanks of five hundred and sixty yards each.

Woollen and Worsted Weaving.—The making of a piece of woollen cloth involves several remarkable processes. The woollen yarn is woven at the loom nearly in the same way as cotton or flax. If the woven material be *broadcloth*, for men's garments, it is made to pass through the following processes. It is *scoured*, or beaten and rubbed in soapy water, to remove grease and oil; *tented*, or stretched out by tenter-hooks, to dry in the open air; *dyed* (unless it be *wool-dyed*, before the spinning); *burled*, or freed from irregular threads and hairs; and *fulled*. This last is a singular operation. The cloth is folded up into a thick heap, and beaten violently for many hours with heavy wooden stocks or mallets, while plentifully sprinkled with soapy water. The fibres become hooked into each other by the projections on their surfaces, and entangled into a mass possessing great strength; the cloth is greatly thickened by this action, and, as a consequence, is rendered much narrower and shorter than before. The roughened surface of the cloth is next *raised* or *teazled*. Numerous thistle-heads or teazles, or numerous wire-teeth arranged into a kind of brush, are made to rub strongly against the cloth as it passes in front of them, and to raise up the ends of the fibres into a sort of *nap* or downy coating. To remove this nap, and to produce a pleasant smooth surface, are the objects of the *shearing* or *cutting* process, by which a complete though very thin layer is removed from the entire surface. For superfine broadcloth, the raising and shearing are repeated two or three times. After a few more processes, the cloth is packed for market.

If, instead of making fine broadcloth, a coarser fabric is to be produced, some of the above-named operations are omitted. If the goods belong to the class of worsteds or stuffs, there are no fulling or shearing processes. If there be a figured pattern, the arrangements of the loom are more complicated than for broadcloth. If cotton or silk, alpaca or mohair, is to be combined with the wool, the weaving and finishing processes are considerably varied. If blankets or flannels are to be made, a loose hairy surface is purposely produced. If worsted stockings are the object of manufacture, the worsted yarn is twisted round by a machine into a kind of netting or knitting, as in making cotton hosiery. By variations in all these ways, the multitude of different kinds of fabric is rendered very great. *Broadcloth, kerseymere, pilot-cloth, serge, frieze, blanketing, flannel, merino, cashmere, stuff, mousselin-de-laine (wool-muslin), baize, camlet, drugget, carpet, shalloon, bunting, waistcoating, tweeds, cheviots, worsted hosiery, fleecy hosiery*—all are made of wool, more or less mixed with cotton. The materials known as *bombazeen, poplin, challis*, and *Norwich crape*, are mixtures of wool and silk.

The very cheapest woollen goods contain *shoddy* and *mungo*. These strange names are given to fibres obtained by tearing up old woollen rags, tailors' cuttings, carpets, worsted stockings, blankets, flannel, &c.

If used by themselves, these old fibres would scarcely be strong enough to be spun and woven; but when mixed with new wool and with cotton they form a material for cheap woollen garments.

Taken altogether, it is believed that more than *two hundred million* pounds of wool, new and old, are worked up yearly into cloth in this country.

4. THE SILKWORM AND SILK GOODS.

The next fibrous substance which calls for our notice, although of animal origin like wool and alpaca, presents differences of an exceedingly interesting character. This substance is *silk*.

REARING THE SILKWORM.—That most beautiful of all fibrous materials for clothing, silk, is produced by a small insect of the genus *Bombyx*. The beginning of a silkworm's life is the very condition of making silk at all. The parent constructs a soft nest in which to deposit the eggs; this nest consists of silken filaments; and, so far as man has ever known, the insect has no other motive for making the nest. The substance of the silk exists in the body of the insect, as a glutinous gum; and she has the power of drawing it forth in a continuous filament. This filament is wound round and about in every direction, to form a hollow dwelling-place. After depositing her eggs, the silkworm changes her form, becomes a *chrysalis* or *pupa*, and then bursts forth from her prison as a beautiful light-winged moth. All these changes are exquisitely adjusted by the hand of Nature; but we are concerned with them here only so far as they relate to the production of silk.

In conducting this operation as a matter of trade, the silk-rearer makes all the necessary provision for the wants of the little insect. Temperature, moisture, and purity of air are attended to; and mulberry leaves are provided as the insect's favourite food. At the proper time, the little worker begins her labours, weaving around herself a silken nest, hard on the inside, but more flossy outside; it is formed from two filaments, elaborated from two orifices near the head of the insect. When completed, the nest or *cocoon* is an oval yellowish ball, about an inch and a half in the longest diameter; the average weight is about three grains, and the average length of filament about three hundred yards.

The question next arises, how to make this filament available for use? In Italy, where the silk-culture is carefully managed, the growers sell the cocoons to *silk-winders.* The poor insect is first killed by the heat of an oven; then the external *floss* silk is removed, to be afterwards spun into an inferior kind of silk goods; and the hard portion of the cocoon is reserved for other treatment. The cocoons are steeped in warm water, to soften a kind of gummy substance that glues the two filaments together. The winder presses a whisk of twigs upon several cocoons, and lifts a filament from each; these she passes through eyes in a winding-machine, and winds them off the cocoon, combining all the filaments into one thread, exquisitely thin and delicate. It is believed that *five hundred miles* of the original silky filament would barely weigh one pound. Only one twelfth of the weight of each cocoon is wound off: the remaining eleven twelfths consisting of the dead insect, floss silk, waste, and dirt.

The winding is continued until the silk of a large number of cocoons is combined into a thread long enough to form a *hank*, weighing a few ounces. These hanks constitute *raw* silk; and it is of such silk that every variety of silken goods is chiefly made.

Silken Goods.—Almost countless are the diversities of beautiful fabrics made of silk, by spinning, weaving, embroidery, and other processes. The *raw* silk has first to be converted into *thrown* silk, or silken threads thick and strong enough to be woven. If this thrown silk is to be used for silk gauze, it is called *dumb singles ;* if for ribbons and common silks, *thrown singles ;* if for the weft-threads of the best silk goods, *tram :* if for the warp-threads of the same goods, *organzine.* A *winding-machine* transfers the raw silk from the hanks, and winds it upon bobbins a few inches in length. A *cleaning-machine* draws the filament through a cleft in a thin piece of steel, clearing away all irregularities from the surface. A *twisting-machine* twists the silk round like a rope, rendering it thinner but harder. A *doubling-machine* increases the strength by combining two or more threads together, and again twisting them. And lastly, a *throwing-machine* compacts all the separate threads more completely together into a state fit for weaving or sewing. The thickest silken thread, for the best goods, has undergone two twistings; and these twistings, as in rope-making, are in opposite directions, to insure strength.

The weaver, after the silk has been scoured and dyed, takes it in hand. For *ribbons*, he uses a peculiar form of loom, which enables him to weave several at once. For *broad silks*, he uses a loom nearly like that employed in cotton-weaving. For *figured silks*, he employs an intricate and beautiful apparatus called the *Jacquard-machine*, attached to his loom; to cause the weft-threads so to interlace among the warp as to produce a pattern on the surface, in threads of different colours. For *Persian*, *sarcenet*, *Gros-de-Naples*, and *ducapes*, the silk is selected and woven in such a way as to present different degrees of softness and fulness. For *brocade* and *damask*, the weaver employs silk in rather large quantity, and weaves it with an elaborate pattern on the surface. For *satin*, he allows the warp-threads to come up very conspicuously to the surface, and gives them a gloss by the aid of heated cylinders. For *poplins*, *bombazeens*, and some other goods, the silk is, as we have said, mixed with wool. For *velvet*, the weft-threads are cut in a peculiar way after weaving, and are dressed up into a beautiful soft *nap* or *pile*. For *embroidered* silks, the material, after weaving, undergoes a kind of machine-needlework, by which a pattern in coloured silken thread is worked into the surface.

We import and work up about *ten million pounds* of silk annually, besides the finished silk goods brought from France and other countries.

5. Leather, Gutta-percha, and India-rubber.

Having thus gone rapidly through the chief matters relating to textile goods for clothing, we shall next notice the principal material for boots and shoes—*Leather*; comparing it at the same time with the two remarkable vegetable substances, *Gutta-percha* and *India-rubber*.

Leather and Tanning.—Leather, as we all know, is made from the hides and skins of oxen and other animals, by the process of *tanning*. To effect this, the tanner first removes the horns, and steeps, rubs, beats, unhairs, and scrapes the hides. The hides, after being steeped in an acid liquor to open the pores, are exposed for a long time to *tan* in a solution of oak bark, or some other astringent substance. Sometimes the hides are allowed to remain many months in tanks filled with this liquor; the bark being renewed from time to time, and the hides repeatedly turned and stirred. In one method, the tan is *forced* into the pores by various means. Usually, however, slow tanning is said to produce the best leather. When properly tanned, the hides are slowly dried, being rubbed and beaten frequently meanwhile.

The thinner hides, such as those of calves, sheep, and goats, are more usually called *skins*. If tanned with oak bark, they are exposed to its action during a much shorter time than hides ; but sometimes other tanning ingredients are used, such as *valonia*, *terra japonica*, *nut-galls*, *willow*, *sumach*, and a kind of bean-pod called *divi-divi*.

The leather for men's boots and shoes requires to be *curried*, to give it softness, smoothness, and pliancy. This currying consists in paring, rubbing, and scraping one or both surfaces. If for upper-leathers, the material (usually calf-skin) is stained black on one side. Thinner leather is prepared in various ways. Goat skins are tanned with sumach, and worked up into what is called *morocco* leather. Sheep skins prepared in a similar way produce *imitation morocco*. If the thin skins of sheep, lambs, and kids are treated in a particular way with alum, salt, and yolk of egg, they become *kid* leather. If the skin of deer, goats, and sheep are dressed in a certain manner with oil, they become *chamois* or *shamoy* leather. Beautiful machines are now in use, which will split up a sheepskin into two complete layers or thicknesses ; and it is often so managed that the best half is converted into imitation *kid* by alum and egg, while the inferior half is converted into *shamoy* (also called *wash* leather) by oil. *Russia* leather, *shagreen*, *japanned* leather, and *enamelled* leather differ not so much in the skin employed as in the mode of preparation.

Besides the animals already named, many others yield hides or skins that may be converted into leather; such as the rhinoceros, hippopotamus, wild bull, antelope, horse, dog, hog, rat, and seal. This variety leads to the production of the numerous kinds of leather necessary for boots and shoes, gloves, caps, saddles, harness, bookbinding whips, bags, aprons, carriage linings, chair-covers, straps, bands, &c

GUTTA-PERCHA.—This singular material is a fair substitute for leather in many cases, besides possessing other qualities to which leather can lay no claim. It was about the year 1842 that Europeans, settled in or trading to the East Indies, discovered that the Malays were acquainted with the use of a singularly tough material, obtained from the sap of a particular tree. This material was gutta-percha. The trees which yield it grow abundantly in the islands of the Indian Archipelago. The natives adopted a reckless way of cutting down the trees in order to obtain the sap; but they are now gradually accustoming themselves to a more economical method—they preserve the 'goose that lays the golden eggs.' The sap, circulating between the bark and the wood, is ready for gathering at a particular part of the year; it is allowed to flow out through incisions in the bark into vessels, where it thickens gradually; but before it is quite hard, the natives fashion it into large balls for convenience of carriage.

When the gutta-percha reaches England, it is passed through many processes to render it fit for use. It is cut into slices by a revolving knife, and thrown into hot water to get rid of the dirt and impurities; it is put, while in a partially softened state, into a rotating machine, where sharp spikes tear it to pieces with great violence. Being thus made clean and uniform, the gutta-percha is cut into blocks or slabs by a cutting-machine; or into sheets by passing between steel rollers; or into ribbons by slitting the sheet into narrow widths; or into rods or pipes by being forced through hot cylinders.

We mention gutta-percha in this place, because of its occasional use for boots and shoes; but it would be scarcely possible to enumerate the various other purposes to which this very useful substance is applied. These uses depend on its great toughness; the ease with which it may be pressed into moulds when softened by heat; the ease with which naphtha will dissolve and cement it; its remarkable properties of conducting sounds and *not* conducting electricity; its imperviousness to water; its power of resisting corrosive acids and alkalies; its capacity to bear a large amount of friction, hard usage, and frost; its freedom of attack from insects; its strength combined with flexibility; and the ease with which the surface receives adornment by painting, japanning, and gilding. On account of one or other of these valuable properties, gutta-percha has come largely into use for boot and shoe soles, cistern linings, drinking-cups, jars, inkstands, noiseless curtain-rings, card and pen trays, cord and line, working aprons, pipes and tubes for various purposes, casings for telegraphic wires, sponge-bags, stethoscopes, ear-trumpets, speaking-tubes, bandages, bottles and vessels for chemical liquids, buckets, mill-boards, valves, whips, medallions, brackets, cornices, buoys, powder-flasks, fishing-floats, life-boat linings, cricket-balls, fencing-sticks—and a host of other articles. The gutta-percha is first made into a block, slab, sheet, tube, or cord, and is then wrought into the above-named articles by various processes, of which cutting and stamping are the chief.

INDIA-RUBBER.—This substance, also known as *Caoutchouc*, resembles gutta-percha in many of its qualities. Both are gums that exude from trees; both solidify to a tough and elastic substance; both resist the action of water and of numerous chemicals; both convey sound well, and electricity scarcely at all. They differ however in many things, which lead to considerable varieties of application. Many trees in tropical regions yield this gum. The substance was known in Europe a century and a half ago, as *india-rubber*, on account of its singular property of rubbing out pencil-marks; but its more important uses have not been known to us till recent years. To obtain it as an article of commerce, the natives (chiefly in South America) pierce the trunk of the trees during the rainy season; a sap or juice slowly flows out, and solidifies in the open air. According to the substance on which it is received, so will it take the form of cakes, lumps, bottles, &c.

The two great properties of india-rubber that render it so invaluable in the arts are its *elasticity* and its *imperviousness to moisture.* If we look around us at all the articles made of this substance, we shall find that one or other of these two qualities is brought into requisition. Forty years ago, india-rubber began to be used as an elastic appendage to glove-wrists, waistcoat-backs, waist-belts, pockets, purses, trousers-straps, gaiter-straps, gaiters, riding belts, stays, patten-ties, shoe-ties, &c.—in the form of small slips or threads. A great advance was made when means were found for employing india-rubber threads as weft or warp, and weaving them up with other threads into an elastic web. The elastic sides for boots, now so prevalent, afford a good example of this kind of work; and every haberdasher or hosier's shop furnishes numerous others. The elasticity of the substance leads it also to be used for billiard-cushions, driving-bands, and countless other purposes.

The *waterproof* quality of india-rubber is perhaps still more valuable than the elasticity; and when the two are combined, the value is great indeed. As soon as it was found that india-rubber might be dissolved in oil of turpentine, it was at once seen that a waterproof varnish of great importance had been obtained. *Macintosh cloth*, for capes and cloaks, coats and leggings, is nothing more than two pieces of cotton or silk, cemented together by a varnish of india-rubber, and thus made waterproof. A long succession of experiments has shown to manufacturers that india-rubber, either as a solid or a cement for solids, is a material suitable for making undersheathing for ships, waterproof boots and shoes, tubes and pipes, gas-bags, fire-engine hose, life-boat coverings, life-preservers, cork-bed bags, floating mattresses, swimming-belts, pump-buckets and valves, bottle-stoppers, surgical tubes, and innumerable other articles. For nearly all these purposes, the india-rubber is brought to the state of large blocks, by tearing, kneading, and pressing; and then various mechanical processes transfer these blocks into the articles needed.

If sulphuric acid be skilfully mixed with india-rubber, it renders it better able to resist heat and cold, less clammy, and less sensitive to oil and grease on the surface. The substance thus made, called *vulcanite*, or *vulcanized india-rubber*, is now very largely employed in the arts. Besides being elastic and waterproof, it is durable and manageable to a greater degree than plain india-rubber.

VI.—Hats, Bonnets, Furs, Feathers, and Flowers.

Utterly impossible as it is, within the narrow limits of this volume, to describe all the numerous ingenious processes involved in the preparation of the materials for modern dress, we shall simply group together, in the last section of this chapter, a few details relative to *silk* and *beaver hats, straw plait* and *straw bonnets, furriery*, the dressing and arrangement of *feathers* for ornament, and *artificial flowers*.

BEAVER AND SILK HATS.—Although beaver hats are now almost out of fashion in England, still the art of making them remains amongst us, and may possibly recover favour by-and-by. The chief kinds of fur employed for this purpose are *beaver, nutria, hare*, and *rabbit*, the first especially. The pelt or skin of such animals has generally long hair as well as short fur; and the former, not having the property of *felting*, is removed by pulling or cutting, in order to get at the true fur. This fur is sheared off from the pelt by means of a peculiar knife; beaver fur, however, being more valuable than other kinds, is cropped from the pelt by the aid of a very beautiful machine, which not only removes all the fibres, but also separates them into three or four qualities. The four kinds above named are those which possess the best felting properties; but this is also possessed in a smaller degree by the furs of the mole, musquash, seal, otter, and other animals.

The making of a beaver or fur hat is a remarkable operation. The hat consists of a *body* and a *covering;* the former usually of wool, and the latter of fur. The wool is soaked, scoured, washed, dried, and carded. It is next *bowed*, or struck repeatedly with the string of a large bow applied in a peculiar way, to disentangle knots and spread out the fibre in a soft flocculent layer. A triangular piece of paper is then placed upon the wool, part of which is brought over the upper surface of it, and by a singular routine of pressing, bending, rubbing, coiling, and uncoiling, first dry and then wetted with an acid liquor, the wool is so worked up that all the fibres become matted or interlinked, forming a *felt* or continuous substance. The intervening paper prevents contact between the two layers. The paper being removed, the wool presents the appearance of a grey conical cap. This, when stiffened by gums and varnishes, is ready to receive the beaver covering. The beaver fur is worked about until it forms a thin soft layer; and this layer, by wetting, rolling, and rubbing, is made to adhere to the grey cap, until the two in effect form one; for the fibres of fur actually work their way between those of the wool. Then does the beavered cap pass through processes which convert it into a hat. It is worked gradually, while wet, on a wooden block, into the well-known hat-shape. After being dried in a hot room, its *nap* is raised by a sort of comb, and cropped by shears to the desired length. The beaver hat is finally dyed, lined, bound at the edges, and shaped according to the prevailing fashion of the day.

Those which are called *silk* hats are made in a wholly different way. The foundation is of calico, cork, mohair, whalebone, or any other light substance, shaped upon a block, and stiffened by waterproof varnishes. The covering is a silk plush applied to the surface of the foundation, and made to adhere to it by a hot iron, which softens the composition underneath. The so-called 'Paris' hats owe any little superiority which they may be supposed to possess, to the excellence of the silk plush made in France.

The *felt* hats, such as those lately called "wide-awakes," are made in the same way as the body or foundation of beaver hats, the fur covering being omitted.

STRAW-PLAIT AND STRAW BONNETS.—This neat and pretty material for hats and bonnets, has been known for nearly three centuries in Italy, from which country the English derived it. Italian straw is generally finer than English; and this is one reason why *leghorn* hats and bonnets, as they are called, are deemed superior to our own home make. Sometimes the whole straw is used; while at other times each straw is ingeniously split into four equal parts, which are flattened out before using. During the long war, early in the present century, when foreign straw hats and bonnets were not imported, the English straw-plaiters were very busy; but when peace was restored, Italian straw again came into fashion. By attention to the growth, preparation, and plaiting of the straw, however, the manufacture has again become a large one in this country, especially in Bedfordshire and Hertfordshire.

If a straw hat were picked to pieces and examined, it would be seen that the straws, whether whole or split, are plaited over and under each other, to form a kind of narrow flat ribbon. Such ribbons are called *plait*, and are sold at so much per dozen yards. In the country districts around Luton, Dunstable, and St. Albans, women and girls buy the straw, make it into plait, and take the plait to the weekly markets held in those three towns. The purchasers are manufacturers, who employ other persons to fashion the plait into hats and bonnets. This fashioning is effected by sewing the plaits together at the edges, and curling them round and round, until they are made to conform to the block by which the shape is given.

Straw admits of being both bleached and dyed; and this enables the makers to give great diversity to the hats and bonnets produced. There are also modes of combining the straw with lace, whalebone, and other materials, to the production of very elegant effects.

FURS, FEATHERS, AND FLOWERS.—These adjuncts to dress, the first useful as well as ornamental, the others ornamental only, deserve a few minutes of our attention.

Furs have just been noticed in connexion with the hat-manufacture; but their use is much more extensive and important for articles of what is called *furriery*. The principal fur-bearing animals are the *ermine, stoat, sable, marten, fox, nutria, otter, bear, beaver, racoon, badger, minx, lynx, musquash, hare, rabbit, squirrel, chinchilla,* and *seal*. North

America furnishes the chief part of the supply. All furs, so far as concerns their uses, may be grouped into *felted* furs and *dressed* furs; the former for beaver hats, the latter for furriery. The making-up of fur into a muff or boa is a very different operation from the application of the fur to a hat; because the fur does not require to be removed from the pelt, and because it does not need felting. The fur hunters are very careful in stripping, drying, and packing the peltry which they obtain, in order that the fur may not be loosened from its pelt by any putrefactive action. The furrier, when the furs reach his hands, finds it necessary to wash out a greasy substance from the pelt, and an oily moisture from the fur; which is effected by the aid of alum, bran, salt, soap, and soda. The alum employed in cleaning the pelt converts it into a kind of leather like inferior kid, and renders it more durable. The making-up of the dressed fur into garments, or portions of garments, is in many respects a kind of needlework, calling for much tact and taste. As the skins, and even different parts of the same skin, differ greatly in colour, much cutting and adjustment are necessary to produce either a uniformity of colour, or any prescribed diversity of tints; and the cutting, unless carefully managed, would lead to much waste of valuable material. An examination of the pelt or back of a piece of furriery, will render apparent a multiplicity of joinings, especially those in which small and cheap skins are used.

Considered as ornaments for the person, *feathers* are more or less in favour in most countries; their elegance of form and beauty of colour constitute their attraction for this purpose. *Ostrich* feathers are the chief kind employed. The male bird yields the finest feathers, especially from the back, the wing, and the tail; the smaller feathers from various parts of the body, varying from four to twelve inches in length, constitute *down*, black in the male, and grey in the female bird. In preparing ostrich feathers for use, the plumassier or feather-dresser scours them by washing in white soap and water, washes them in hot clean water, bleaches them by exposure to burning sulphur, and hangs them upon cords to dry. The fibres are separated by shaking; the ribs are scraped with a piece of glass, and the filaments with the edge of a blunt knife; and after a few more processes the feathers are ready to be applied to ornamental purposes. All other feathers are prepared nearly in the same way as those of the ostrich; and some are dyed of various colours.

The application of feathers to the making of *feather-beds* and of *quill-pens*, does not belong to our present subject; it may suffice to say that the processes of preparation are little other than cleaning and dressing.

The last ornamental appendages to dress, here to be noticed, are *artificial flowers;* singular examples of patient ingenuity. They are the result of a careful attention to the forms and colours of natural flowers, bud and leaves. *Silk, silkworms, cocoons, ribbon, shells, cambric, taffeta, feathers, whalebone, paper, velvet, wax, glass, thread, wire,* all are brought into requisition. Of course the mechanical processes depend on the nature of the substances employed. Generally speaking, however, the imitative petals and leaves are stamped out of cambric, by means of punches or dies of the proper shape. The colours depend partly on a previous dyeing, and partly on the application of water-colours to certain spots afterwards. Some of the pieces are embossed with veins by means of the stamping-presses; some are glazed by the application of a kind of varnish; and various other modes are adopted for imitating the beautiful surfaces of flowers and leaves. Beads and small pieces of wax are rendered available for imitating seeds and small fruits. Wax has been much employed within the last few years as the chief material in producing imitations of certain flowers, presenting a remarkably delicate transparency of effect.

Necessarily brief as these details have been, they will tend to show how extensive and complicated are the processes employed in working up the materials for ordinary dress—materials obtained almost wholly from the animal and vegetable kingdoms.

OUR DWELLINGS AND THEIR MATERIALS.

1. BUILDING-STONE, MASONRY, AND SLATING.

STONE FOR BUILDING.—QUARRYING AND MASONRY.—SLATES AND SLATING.

2. BRICKS, TILES, AND BRICKWORK.

BRICKS AND BRICKMAKING.—TILES AND TILEMAKING.—BRICKWORK OR BRICKLAYING.

3. LIME, MORTAR, CEMENT, AND PLASTERING.

LIME, SLAKED AND UNSLAKED.—CEMENT AND CONCRETE.—PLASTER AND PLASTERING.

4. TIMBER, CARPENTRY, AND CABINET-WORK.

TIMBER TREES.—SAW MILLS AND WOOD-WORKING.—CARPENTRY AND JOINERY.—FANCY WOODS AND CABINET-MAKING.

5. WALL AND FLOOR COVERINGS.

PAPER-HANGINGS.—CARPETS AND FLOOR-CLOTH.

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CHAPTER III.

OUR DWELLINGS AND THEIR MATERIALS.

It is useless to discuss which of two human wants, *clothing* or *shelter*, is the more urgent, the more eagerly demanding the time and attention of the busy workers in the world. Suffice it to say, that all above the level of the brute creation, with exceptions which are becoming fewer and fewer as civilization advances, require and obtain both. We have seen how large a portion of man's intelligence, industry, accumulated experience, labour, and capital is called into exercise in providing food and clothing for himself and others; and we shall now invite the reader's attention to the materials and processes concerned in the production of the dwellings and furniture which administer so greatly to the comfort of all around us.

1. Building-stone, Masonry, and Slating.

The excavating and earth-work necessary in laying the foundation for a house may be left to the observation of the reader; they are matters that need not be touched on here. We proceed at once to *masonry*, which, with *bricklaying* and *carpentry*, make up the three principal house-building trades.

STONE FOR BUILDING.—The kinds of stone used in building are numerous. *Bath* and *Portland limestone* are easily wrought, but are by degrees affected by the atmosphere, not only through its moisture, but also in consequence of the sulphureous and other particles that float about in it. *Derbyshire* and *Plymouth limestones* are harder, and resist for a longer period any destructive action. Various kinds of *sandstone* are used by builders and engineers instead of limestone, for some purposes; such as *millstone grit* and red sandstone. *Granite* is too hard, and *marble* too costly, to be used much in this country for building. Nearly all the kinds generally employed, belong either to the limestone or the sandstone series. *Isle of Wight limestone, Suffolk crag, Purbeck* and *Portland stone, Bath stone, magnesian limestone,* and *mountain limestone,* such as that of Derbyshire, are the chief examples of the limestone group used in building.

Perhaps the most remarkable inquiry ever made into the qualities of building-stone was that which bore relation to the re-building of the Houses of Parliament. While the plans for the new building were being prepared, a royal commission was appointed to investigate the qualities of the various kinds of stone used for building, in order that such a selection might be made as would best meet all the requirements. Some of the Commissioners visited the principal quarries; while the others made experiments on the specimens of stone obtained. The researches were limited to *freestones*, *sandstones*, and *limestones*.

Each kind of building-stone was found to have its own peculiar sources of decay, depending on the mode in which the particles are held together; and the question hence arose, which kind has the fewest disadvantages?

In our climate, stone exposed to the west and south wears away more rapidly than with an eastern or northern exposure, on account of the prevalent winds and rains. A kind of stone suitable for the plain parts of a building does not always suit for the carved ornaments. Numerous specimens of stone, collected by the Commissioners from various parts of the kingdom, were shaped into cubes; and these cubes were subjected to experiment, to determine their specific gravity, chemical composition, absorptive power, and power of bearing pressure, friction, heat, and cold. One kind was found to excel in one of these qualities, one in another, one in a third; but the sort which appeared to possess the best combination of properties was *magnesian limestone*, such as that of Bolsover in Derbyshire. The Commissioners described this stone as being heavy, strong, little absorbent of water, rich in tint, and beautiful in granular structure. The stone was purchased, and the building constructed. The result has been unfortunate. Even before the works are finished, the stone is already beginning to crumble! It is supposed that the vicinity of the Thames has something to do with this mortifying fact; but be the cause what it may, the fact is certain; and measures are being taken to coat the exterior with some kind of protective glassy varnish.

QUARRYING AND MASONRY.—The various kinds of stone are quarried much in the same way; except that more labour is necessarily required on the harder kinds. Some layers of stone are so near the surface that open cuttings suffice to reveal them; whereas others are deep down, and call for the removal of much superincumbent earth. The Egyptian quarries yield the granites and other hard stones employed in the marvellous works of architecture and sculpture in that country. The Greek and Italian quarries yield the marble of which the finest sculptures the world has seen were made. Our own country produces quarries of almost every kind of useful stone, especially those suited for ordinary building.

If the valuable stone lies at some distance below the surface, the quarrymen sink a shaft to get at it; but if it lies within the side of a hill, horizontal galleries are excavated. In working a large quarry of the first-named kind, the earth is first removed from the surface; then the inferior stone; and thus the good stone is reached. It is not often blasted with gunpowder, because it would be thereby too much broken up. It is separated into blocks by tools, aided by the *cleavage* planes, or parallel layers, existing in most stone. Thus wedges, a few inches apart, are driven into these natural divisions in such a way that slabs or blocks are riven off; one series of wedges determine the width, and another the thickness of the layer thus separated. If the stone be very hard, such as granite, and without any cleavage structure, holes are gradually made by means of heavy sharp instruments, and wedges are driven into the holes. If the natural strata of stone are vertical in the quarry, the rending into blocks and layers is much easier; and on this account some quarries are more profitable than others, as demanding less labour for disengaging the stone.

When the stone would be quite as useful in irregular masses as in squared blocks, the operations are greatly quickened by the application of gunpowder. Holes are bored in the rock to a considerable depth at certain places, gunpowder is introduced, and this powder is exploded by the aid of electricity. The explosion shakes down vast masses of stone. At Holyhead a breakwater is thus being formed. Holyhead mountain may be said to be travelling into the sea; for it supplies the stone which, year after year, is being thrown into the deep water of the harbour to form a breakwater. A similar operation is being pursued at Portland.

When, however, the stone is to be employed for building, this tearing and rupturing plan is not suitable. The quarrymen endeavour to obtain the stones in form approaching somewhat to blocks or slabs. This done, they roughly prepare them on the open ground above. A mallet and a *kevel* are the chief tools here employed. The kevel, sharp at one end and flat at the other, is worked over the whole surface by means of the mallet, to knock off projections and irregularities, and to bring the sides tolerably square.

The stonemason finishes the work by the aid of many different kinds of tools. If the stone is not very hard it can be cut by blades of iron wetted with sand and water. The chisel and mallet finish off the surfaces; a circular form can be produced by the lathe; or the surface can be ground down by the application of tools made of iron. According to the hardness of the stone, so is the amount of labour required.

In the trade of *stone-masonry*, the stones are fashioned by various means. Most of the surfaces are brought true by means of the *pointer*, a sharp chisel worked by a mallet; and the smoothing is mostly effected by rubbing two surfaces of stone against each other. Carved work in stone is executed by the same means as sculpture—a very careful application of tools all over the surface, preceded by accurate drawing, and corrected by frequent measurement. When stone is scarce and dear, buildings are frequently constructed of *ashlar-work*;

that is, a surface of stone applied to an inner substance of brick. To render this kind of work durable, some of the stones are let in at intervals to the whole depth of the brickwork. In buildings of solid stone, not only is adhesive cement applied between the stones, but short iron clamps are added to bind them; these clamps are inserted in holes bored to receive them, and are kept in their place by lead poured in while in a molten state.

SLATES AND SLATING.—*Slate* is stone, properly speaking; but it is placed in a separate group on account of its peculiar structure. It is *laminated*, that is, disposed in layers or plates, the interstices between which greatly facilitate its separation into thin pieces. Geologists believe that slate was at one time a sort of clay, which by intense pressure became converted into very hard stone; and that the slaty structure, the alternation of layers with cleavage-planes, was in some way produced by the pressure.

Colonel Pennant is the owner of the most valuable slate-quarry in the world, at a spot a few miles from Bangor, in North Wales, between that town and Snowdon. No less than two thousand persons are employed in working the slate. The whole face of one particular mountain is wrought into terraces, rising one above another. Each terrace forms a sort of landing-place for the workmen, who are enabled to quarry with much ease the slate of which the mountain consists, on account of its peculiar structure, which enables them to split it into slabs and thin laminæ. Various mechanical contrivances are adopted for expediting the processes. In some places, however, the only available mode of working is for half-a-dozen men to stand upon a platform, suspended from above by tackle, and separate the slate from the side of the mountain in masses, six or seven feet in length by two or three in width, and of a thickness depending on various circumstances. These masses are loosened chiefly by means of iron crowbars and sledge-hammers. The enormous quantity of two hundred and fifty tons of slate are thus excavated and lowered every day, at an average, at the Bangor works; and there is a prodigious amount of rubbish gradually accumulating at the foot of the mountain.

The most frequent employment for slate is as a substitute for tiles in roofing. The Bangor variety takes the lead for this purpose; after which come the kinds from Snowdon, Carnarvon, Westmoreland, Scotland, and Devonshire. The light-blue varieties are generally better than the dark-blue or the greenish. At Bangor, when the masses of slate have been conveyed to a convenient part of the works, they are wrought into form by various chipping and cutting tools. According as they are intended to be made into roofing slates, writing slates, cisterns, gravestones, rails, &c., so are they treated by the workmen.

When the roofing slates have been roughly shaped, they are sold to the slater in pieces of various sizes, which receive quaint names, such as *imperials*, *countesses*, *duchesses*, &c. When about to be used for roofing, they are laid upon battens on the roof. Holes are easily made by a small pick or pointed hammer; and through these holes flat-headed nails are driven to fasten the slates to the boarding underneath. The slates are laid side by side, and in tiers one above another; each tier overlaps the one which lies beneath it, the more effectually to keep out the rain. The over-lapping is such that every part of the roof is covered by two thicknesses of slate.

2. Bricks, Tiles, and Brickwork.

In some foreign countries, masonry is more important than brickwork, in relation to houses and other buildings. Such is not the case, however, in England. We are not largely supplied with quarries of good building-stone; whereas our supply of clay fit for making into bricks is practically inexhaustible.

Bricks and Brickmaking.—Some of the earliest buildings recorded in history were of brick. The walls of the famous city of Babylon were formed of this substance. The clay for making the bricks was obtained from the ditch which encompassed the city; it was moulded into form, then burned, and cemented into a wall by hot bitumen. The wall was of prodigious extent; two hundred feet high, thick enough to allow a chariot with four horses abreast to travel along the top, and long enough to be pierced with a hundred gates. The bricks (some of which are now to be seen at the British Museum) were of three different sizes; some were dried in the sun, others burned in a kiln. Many of the buildings were encased with finer bricks, laid and cemented with great nicety. The Egyptians used bricks very extensively, consisting of clay and chopped straw, and mostly dried in the sun. The Greeks employed bricks less abundantly than the Egyptians. The Romans were well acquainted with brickwork; their bricks resembled thick flat tiles, varying from eight to twenty-four inches in length. The ancient Persians made bricks both kiln-burned and sun-dried, and mixed chopped straw with them to render the clay adhesive.

The bricks used in England at the present day are sometimes made by machinery, but mostly by hand. Those of familiar size are about ten inches long, five broad, and three thick; but others for special purposes vary in size and shape. For making bricks, a particular kind of clay is selected. The soil is exposed to frost and wet during winter, to separate its particles, and enable them to combine better with ashes. In spring, a layer of ashes is laid on the clay, and the two are dug and mixed up together, in the proportion of about four of clay to one of ashes. Water is added; and after much stirring and raking, the mixture becomes a black streaky mass, which is kneaded and worked in a revolving apparatus called a *pug-mill.*

Bricks are made in wooden moulds, of which the bottom is loose from the sides. Two workmen aid each other. The *feeder* separates a piece of clay sufficient for one brick, sands it, and hands it to the *moulder*, who sands the mould, dashes the clay into it, strikes off the superfluous clay from the top by means of a straight stick, lifts off the sides of the mould, and leaves the newly-made brick lying upon the bottom. The bricks, as they are made, are one by one placed upon small boards, carried to a lattice-work frame, wheeled away, and deposited in the brick-field in long rows called *hacks.* The hacks are covered with straw, and so left until the bricks are dry. The next process is the *burning* or *firing.* The bricks are not usually placed in a furnace or kiln, but are built up into a *clamp* or nearly solid mass, with *breese* or sifted ashes at intervals, and firewood in small flues. The whole is so managed that, when kindled, the clamp maintains a kind of smouldering fire for nearly a month, by the end of which time the bricks are found to be properly burned.

For some purposes, bricks are kiln-baked instead of clamp-burned. Various names are given to different kinds. *Stock-bricks, place-bricks, clinkers,* and *turnovers*, depend for their difference on the comparative success or failure of the burning. *Marl stocks* contain a portion of lime; *Dutch clinkers* are small hard yellow bricks ; *coping-bricks* are used for the tops of walls ; *cogging-bricks* are applied to the indented work under copings ; *draining-bricks* are flat on one side and hollow on the other ; *fire-bricks* are made of a kind of clay suited to resist great heat ; *paving-bricks* are only half the ordinary thickness ; *feather-edged-bricks*, also thin, are occasionally used in wooden buildings.

TILES AND TILEMAKING.—So far as concerns plain roofing tiles, they too much resemble bricks to need separate description ; but there are other kinds of tiles, of which a few words must be said. Machinery is far more extensively used in making tiles than in making bricks. In some of the machines invented for this purpose, the clay is pressed into a number of moulds by rollers, as it comes out of the pug-mill ; and the tiles are delivered upon an endless band. In others, the clay is moulded or pressed into a long fillet or a trough, the proper breadth and thickness ; and the fillet is cut into tiles by descending wires. In others, the clay is forced by pressure through a hole of the proper sectional area, and is cut in pieces at regular intervals during its passage. By slight modifications of the apparatus, these and other machines would serve for making bricks as well as tiles.

The *roofing* tiles of the ancients were simply flat bricks, dried in the sun or baked by heat. Those of the present day are either *plane* tiles or *pantiles.* The plane tiles are about ten inches by six, and are quite flat; they have holes through which wooden pegs can be passed to fasten them to the woodwork beneath. The pantiles are larger, and are bent up in such a manner as to present concave channels for the trickling of water down the roof, thereby facilitating the carrying off of rain. One edge forms a sort of hollow beading that laps over the edge of the adjoining tile, and prevents the entrance of water beneath. *Drain tiles* are made arched, and are placed upon flat tiles called *soles*. It has become customary, however, to employ drain *pipes* instead of tiles; which pipes are largely made by machinery.

The ornamental *tesselated* tiles, used for the pavements of churches and other large buildings, consist of a mosaic of small square pieces. Clay of a particular kind is mixed up with colouring substances, formed into flat cakes, and divided into small cubes either by pressing or cutting. Then, when a pavement is to be made, these cubes are laid side by side, in any determinate order according to the colours, to form a pattern. They are cemented down upon a groundwork, and then constitute a flooring of a very durable kind. *Encaustic* tiles are also ornamental in their character, like the tesselated variety just described; but the decorative effect is produced by different means. Here each tile has in itself two or more colours, produced in a curious way. In the first place, a mould is prepared, obtained by casting in plaster from a clay model. If the tile is to display two colours, the mould has a device sunk about a quarter of an inch below the general level. Coloured clay, prepared to a particular degree of stiffness, is pressed into the mould, whereby a tile is obtained about an inch thick, with one part of its device sunk a quarter of an inch below the rest. When dried, the sunken portion is filled up with another kind of clay of a different colour, mixed to the consistence of paste or plaster, and applied with a trowel. When the surface has been scraped, smoothed, baked, and glazed, it presents to view a tile with an ornamental device in two colours, elegant and durable. Some of the nations of antiquity largely employed both tesselated and encaustic tiles for pavements; and tiles of similar kinds have lately come rather extensively into use in England.

BRICKWORK OR BRICKLAYING.—The laying of bricks seems very easy work to the bystanders; yet properly to lay fifteen hundred in a day (which a good workman will accomplish), requires much tact and experience, both in the adjustment and the cementing. Walls may be from half a brick to any number of bricks in thickness; a 'brick' being about nine inches, that is, the length of the brick when shrunk by burning. If bricks were laid simply one on another in regular rows, the length of every brick being parallel with the length of the wall, the wall would be deficient in strength; but by making them interlace, or cross, the length of some of them being in the direction of the thickness of the wall, much additional strength is given. This interlacing is called the *bond*. There are many different kinds, called *English bond*, *Flemish bond*, *herring-bone bond*, *garden-wall bond*, &c. The bricks which are laid lengthwise of the wall are called *headers;* those placed breadthwise are *stretchers;* and the manner in which the latter alternate with the former gives a character to the bond. One kind of bond is most easy to produce, another is strongest, another is most pleasing in appearance; and thus the bricklayer can adopt whichever kind best suits his purpose.

In building brick walls, the lower part or foundation is made broader than the upper, to afford better support. In some walls there are piers or buttresses at intervals, for the sake of strength; as, for instance, in lofty garden-walls, which are unprovided with ties or lateral supports of any other kind.

The mortar employed by bricklayers is made of lime and sand in certain proportions. The best is considered to be that which is made of newly-burned quicklime from grey limestone, and river sand. The quicklime is thrown on the ground, and water is applied enough to slake it; the sand is added, more water is poured on, and the mixture is well stirred to the proper consistency. If the ingredients be properly selected and proportioned, the mortar will harden by degrees to a kind of stone; but in the cheap houses, constructed by speculative builders, the mortar is so poor in quality as speedily to crumble away.

When the work of the bricklayer commences, he has at hand his *trowel*, *square*, *level*, and other tools; and a labourer is near to supply him with bricks and mortar, carried in that curious receptacle called a *hod*. The lowest layer of brick is placed upon the earth, upon a bed of concrete, or upon planking supported by piles, according to the quality of the soil and the excellence of the work; it is broad, and very level, to insure the verticality of the wall. The layers or courses above it gradually diminish in width, until that breadth is reached which will give the proper thickness of the wall generally. A string stretched between two pegs enables the bricklayer to lay the bricks in a straight line; the level enables him to maintain the upper surface horizontal; the square adjusts the corners of buildings or the ends of walls rectangularly; while the plumb-line determines the uprightness of the wall. Much nicety is needed in those parts of the work where interruptions to the plain line of wall occur; such as apertures for windows and doors, arches, buttresses or other projections, columns, pilasters, cornices, niches, and the like. In some of these, the aid of the carpenter is called for, to supply a framing of wood.

The viaducts belonging to the various railways often present beautiful examples of brickwork. The tunnel for the underground Metropolitan Railway, from Paddington to Farringdon-street, is distinguished for superior workmanship, although nearly hidden from view. The south part of the new Exhibition building at Brompton, in Cromwell Road, is one of the most important specimens of brickwork recently constructed. The use of *coloured* bricks—white, yellow, red, brown, and black—in church building, is becoming rather extensive, and is in many instances productive of beautiful effects.

The bricklayer adopts a peculiar system in measuring his work. The standard of measurement is supposed to be a wall a brick and a half or 14 inches thick; and a square piece of such wall, measuring about $16\frac{1}{2}$ feet on each side, is called a *rod* of brickwork. However the length, breadth, and thickness may vary, the rod always contains the same mass or quantity. Thus, a rod of brickwork, of whatever thickness, contains about 4500 ordinary bricks, and, with the mortar, weighs about 300 cwts.

3. Lime, Mortar, Cement, and Plastering.

We next notice certain earthy substances which have these peculiarities in common, in reference to their use in house-building: they are used *wet*, and they assume a stony hardness as they dry.

Lime, Slaked and Unslaked.—It is not easy to place a limit to the usefulness of *lime*, as a substance from which cements and concretes of various kinds are made. Our masons and bricklayers would equally be at a loss to give permanency to their walls without it. Lime occurs as a *carbonate* in marble, chalk, limestone, birds' eggs, and fish shells; as a *sulphate* in gypsum and other substances; and as a *phosphate* in most kinds of bone. One very familiar mode of obtaining lime is to take ordinary limestone, mix it with coal or some other fuel, and set fire to the fuel; by degrees the heat drives off all the carbonic acid from the lime, leaving the latter in the state called *quicklime*.

In the practical operations of a lime-kiln, as a matter of trade, various modes are adopted. Sometimes the kiln is merely a conical hole in the ground, with a contrivance for getting at the lime at the bottom; sometimes it is a structure, having the shape of an inverted cone, or nearly that of an egg; some are cylindrical, others square. The selection of the kind of limestone, and the form of the kiln, determine the quickness and completeness with which the carbonic acid is driven off. The limestone is broken up into pieces, and is placed in alternate layers with fuel. Some kilns are so constructed as never to be emptied and never extinguished for a whole year together; new materials are thrown in at the top as fast as quicklime is drawn out at the bottom. According as coal, coke, furze, or peat is employed as fuel, so do the operations vary a little in detail.

Thus, then, is *quicklime* or *caustic* lime produced. It is useful for many purposes in this state; but to the builder and the civil engineer it is more serviceable as *slaked* lime. When quicklime is sprinkled with water, a strange change takes place; the lime is absolutely thirsty for water; it drinks up a great deal, and yet remains dry at the surface; it becomes hot, hisses, cracks, swells, and falls to powder. By various modes of conducting this process, slaked lime is produced of diverse qualities, applicable to different purposes.

Cement and Concrete.—In almost all the varieties of these useful substances, lime plays an important part. Slaked lime, also called *hydrate* of lime, when mixed with sand or gravel, forms many kinds of mortar, plaster, cement, and concrete, according to the proportions of the ingredients, the mode of mixing, and the addition of other substances. If the sand is coarse, like gravel, the mixture becomes *concrete;* if the lime is accompanied by clay, the mixture obtains the name of *hydraulic cement*, and is fitted for use under water. Lime gives to the mixture the character of limestone, sand that of sandstone, and clay that of brick; insomuch that different properties are secured by various ratios in the ingredients.

The peculiar way in which some of the mixtures harden under water has led to the introduction of many kinds of cement and artificial stone, some of which have been patented. Parker's *Roman cement* is a well-known variety. Within a certain limit, this cement will harden under water the more quickly according to the ratio of clay combined with the lime. The calcining or burning of the limestone for cement-lime requires to be more carefully conducted than for mortar-lime. In some places the natural stone dug or quarried contains all the necessary ingredients for making good water-resisting cement. *Portland cement*, on the other hand, is made from an artificial mixture of clay and burnt chalk. When employed as a cement between large blocks of stone for building or engineering purposes, it becomes almost as strong as the stone itself.

Certain kinds of cement are made with gypsum or sulphate of lime, instead of common or carbonate of lime, and are applied to numerous purposes in the arts. It is to this class that the very useful substance *plaster of Paris* belongs, so valuable on account of the facility with which it can be cast into moulds.

PLASTER AND PLASTERING.—The department of house-building which devolves upon the *plasterer* is the laying of a coat of plaster upon brickwork or woodwork. The substance used is not exactly mortar, such as is employed to cement bricks; nor is it the kind selected by stonemasons; it contains no sand, being made principally of lime. If applied to the surface of brickwork, the roughness of that surface enables the plaster to hold or cling firmly; but if applied to wood, as in the ceiling and walls of ordinary rooms, a rough layer is necessary before the application of the fine plaster; this rougher material contains cow-hair mixed with the lime, to impart a more cohesive action.

Considering the mode in which the plaster of rooms is applied to wooden laths, it is remarkable that the retention should be so complete as it is. These laths are made of deal, split or sawn into various sizes. Supposing a ceiling to be under process, the first substances acted upon are the joists under the flooring of the roof above. Laths are nailed up to those joists, in parallel rows and nearly close together. This done, the plasterer takes a small square tray or board in his left hand, receives from a labourer a supply of coarse plaster, and applies it to the laths by means of a flat square wooden trowel. Some of the plaster passes in between the laths, and by that means facilitates the cohesion of the entire mass. A long straight-edged piece of wood is scraped against the wet plaster, to make it even and regular. When this prepared surface is ready, a thin layer of finer plaster is applied, with more care as to quantity, distribution, and smoothness.

Some of the mouldings for the cornices of rooms are made of solid plaster, by the aid of moulding-pieces of various kinds. If of large size, however, such masses would be likely to fall down by their own weight. To prevent this, it is customary to fix up properly shaped brackets or projecting-pieces at intervals, to nail laths up against these brackets, and to apply the plaster to the laths. The plaster ornaments in the centre of ceilings, and some of those at the junction of walls and ceilings, are made by casting in a mould.

up-and-down motion is given. The log of wood is placed horizontally in a frame so adjusted that it can travel from end to end; that is, the log can advance up to the saws as fast as the latter can effect the cutting. A still more complete kind is the *circular* saw, sometimes nearly twenty feet in diameter. This saw is made of a number of thin pieces of steel ingeniously adjusted; it rotates on its axis with great rapidity, and the wood is driven up against its edge to be cut.

Besides saws of various kinds, numerous machines of most ingenious construction are now used for the cutting and shaping of wood. *Planing*, *dowelling*, *dovetailing*, *grooving*, *tenoning*, *moulding*, *rebating*, and other carpentering processes, are in the present day effected very rapidly by machines specially invented for those purposes, and with greater accuracy than by hand.

In such undertakings as the Great Exhibition building at Brompton, it would be impossible to execute the work in the stipulated time or at the stipulated price were not the aid of machinery obtained in shaping and preparing the wood. Where flooring is estimated by the *acre*, and sash bars by the *mile*, the necessity for mechanical aid becomes apparent.

Not only is the timber-work of buildings now prepared by machinery; but even such trifling articles as *firewood* and *lucifer-matches* are cut by steam-worked mechanism of a highly-finished and elaborate kind, such as can only be rendered profitable by an enormous demand. There are machines now at work which will cut and shape *millions* of lucifer splints in a day.

Carpentry and Joinery.—The work of the carpenter comprises a multitude of details, in the shaping and fitting of the pieces of wood to which his attention is directed. Sometimes his work requires him to join thin pieces together to obtain the desired strength. This is done by *scarfing*. The ends of the two pieces are partially cut through, in such a way that each may fit into the other without increasing the width or thickness at that part. The mode of giving additional strength to a long beam, without altering its dimensions, is *trussing*. This consists in cutting away certain parts of the beam, and letting in bars, rods, or plates of iron, in such directions as to add to the strength without much increasing the weight. One mode of joining two timbers crosswise is by the *tenon* and *mortice*, producing a joint strong and not unsightly. A mortice is a hole cut into the side of a beam; a tenon is one end of another beam so shaped as to fit the mortice. Another mode is by the *dovetail;* where the tenon is made to spread out wider at the end, like a dove's tail, and the mortice or hole is made of corresponding shape.

All these are matters which the carpenter must understand; and also those processes which are necessary for making panels, doors, windows, &c.

Technically, there is a difference between a carpenter and a joiner; the former shapes and fixes all the larger timbers for a house; whereas the latter makes the doors, windows, staircases, &c. Both use the same kinds of tools, differing only in fineness and accuracy. *Planes* are employed in great variety, partly to shape and partly to smooth the wood; they consist of sharp steel tools inserted in stout wooden frames. *Saws* have already been noticed, as the most indispensable tools in wood-working. *Chisels* are required in many shapes, either used with a mallet, or pressed by the hand. *Gouges* afford means for working out hollow places in wood. *Gimlets* enable the carpenter or joiner to make holes for screws; and *brad-awls* for nails. *Augers* make larger holes; and *centre-bits* are employed for making holes of certain definite shapes. Screws and nails, hammers and pincers, screw-drivers, rules, levels, squares, plummets—all aid the labours of these handicraftsmen.

One adjunct indispensable to the joiner is *glue*. However skilful his mechanical joinings may be, his work could not be completed without the aid of a cement which will unite pieces of wood. Such a cement is glue, made by boiling down the refuse of skins, hides, tendons, horns, and hoofs. The gelatine contained in these substances is extracted by boiling, and cooled down into flat cakes; these are afterwards melted and liquefied for use.

FANCY-WOODS AND CABINET-MAKING.—If we suppose a house to be built, and about to be furnished, we then meet with a different selection of woods; for beauty of appearance is here more sought than great strength and durability. *Mahogany* is the most useful of all the fancy furniture woods; it would be one of the best even if it were not beautiful in appearance; for it is very durable, and can be obtained in pieces of enormous size. The common kind is called *Honduras* mahogany; the *Spanish*, more pleasing in colour and grain, is reserved for the best work. *Walnut-wood*, once much in fashion for good furniture, has been almost superseded by mahogany. *Lance-wood*, although not much used for furniture, is applicable to many special purposes on account of its lightness, strength, and elasticity. *Ebony* is one of the darkest, dearest, and most durable of woods; but being costly, it is used only in small pieces, and generally as a veneer. *Rosewood* is used chiefly as a veneer, but in larger pieces than ebony. *King-wood*, of a dark chocolate colour, veined with fine black lines; *zebra-wood*, with a colour and markings which have suggested its name; *beef-wood*, hard, heavy, and pale red; *tulip-wood*, hard, and clouded with red and yellow; *satin-wood*, yellow and glossy; *maple-wood*, light in colour, and very elegantly diversified with a twisted grain; *sandal-wood*, light brown, with a golden wavy grain; *iron-wood*, dark in colour, and nearly as hard as ebony—these are among the chief kinds of fancy wood employed by the cabinet-maker.

The cutting-up of these valuable woods into *veneers*, or thin slices, is a curious process. The employment of such veneers is a mask or deception; for the wood which does *not* meet the eye is cheap and inferior; but like many other masks, it has grown to be a custom of our age. Various modes have been adopted in past times of slicing up valuable woods into veneers; but the plan generally adopted at present is to employ circular saws of large diameter, so nicely adjusted as to separate logs of wood into parallel layers of remarkable thinness and regularity.

The labours of the *cabinet-maker* almost tell their own tale. He is a worker in wood, who avails himself, to a greater or less extent, of all the appliances noticed in this section. He has not much to do with the rough tools employed by the carpenter; but he is familiar with all those used by the joiner, and with more besides. He must know how to *veneer*, to *inlay*, and to *polish*. The veneer is fastened down to the wood beneath by means of glue, applied hot to the warmed surfaces of the two pieces. This is a process requiring much nicety where the surfaces are curved. Inlaying is an adjustment of small pieces, usually veneer, in such way as to produce a pleasing pattern by the differences in the colour and grain of the wood. When the veneered or inlaid surface is dry, it is scraped and smoothed, and finally rendered glossy by a varnish or polish made of sundry gums and spirits.

5. Wall and Floor Covering.

So countless are now the conveniences and adornments of rooms, especially in the houses of the wealthy, that a mere enumeration of them would be beyond the limits of this work. Of those made of *wood*, the section just finished will afford some idea; of those made of *textile* material, such as hangings and curtains, the details given in the sections relating to cotton, wool, and worsted manufactures will suffice. The *glass* for the windows and the mirrors, as well as the *paint* for the walls, &c., will be noticed in the chapter relating to mineral manufactures; while the *lead* for the plumber, the *iron* and *brass* for the furnishing ironmonger, and the *gold* for the gilder, will claim attention in the chapter relating to metal manufactures. The *paper-hanging* for the walls, and the *oil-cloth* and *carpets* for the floor, may conveniently be noticed in this section.

Paper-hangings.—The days of *tapestry* are gone. We do not now, even in the houses of the wealthy, see the walls of rooms covered with an elaborate textile material prepared by the delicate fingers of ladies; or if such be ever done in these times, it is as a curiosity or as a labour of love. The regular use of tapestry died away in the middle ages. To that succeeded the practice of *panelling*—covering the walls with well-made panels of oak or walnut or some other kind of wood, and allowing the wood to remain in its bare unpainted state: depending for its beauty on the colour, the grain, and the polish. A later stage was that of making the panelling with common wood, and trusting to oil-paint as a means of imparting beauty to it. A still more superficial plan was that of *stencilling*, or imparting a coloured pattern to the surface of a plastered wall, by brushing a liquid paint through holes in a stencil-plate placed flat against it: the holes in the plate being cut according to some definite pattern.

At what date the neat, cheap, and effective contrivance of *paper-hangings* was brought into use, is not exactly known; but it is supposed to have been almost two centuries ago. The paper is called *hangings*, only because it superseded the tapestry hangings of earlier days; for it is in reality pasted, not hung. The removal of the excise duty has rendered paper-hangings so cheap, that they are now to be seen in the houses of all except the very humblest classes, imparting a clean and wholesome appearance, though not always in good taste as to colour and pattern.

Paper-hangings are painted on one surface, not stained through the whole substance. Different modes are adopted of attaining this end. One, formerly much practised, but regarded as too slow and expensive at the present day, consists in engraving the outlines of the pattern on a wooden block, printing this outline on the paper, and filling up the details of the pattern with a pencil or small brush. A second method is that of *stencilling*, just noticed. A third consists in engraving as many blocks as there are colours in the pattern, wetting each block with its own particular colour, and pressing them down on the paper in succession—in such way that each colour shall keep clear from the spots covered by any of the other colours. A fourth plan consists in employing engraved cylinders instead of blocks, as many as there are colours, and applying them nearly as in calico-printing.

The colours employed consist of pounded whiting, mixed with mineral paints, and liquefied by means of melted size. In the block method, the paper, in pieces twelve yards long, is laid down on a bench, and painted all over with some one uniform ground colour. After this, the colours of the pattern are separately applied. Each colour is spread with a brush on a frame covered with leather or flannel; the block, laid face downward upon it, takes up a thin layer, which is at once applied to the paper; and so on with all the colours in succession.

By various manipulations, paper-hangings of very diverse kinds are produced. *Satin* papers, *flock* papers, *striped* papers, *blended* papers, *bronze* papers, *washable* or *varnished* papers, are among these varieties.

Carpets and Floor-cloth.—What paper-hangings are to the *walls* of our rooms, floor-cloth is to the *floor*, a cheap substitute for something more costly, and a neat substitute for something more coarse and clumsy. In ages long gone by, the mansions of the wealthy and high-born exhibited floors made of polished oak, in which the several pieces of wood were disposed in an artistic or ornamental form, constituting *parquetry*. In those same times, the room-floors of humbler dwellings were too often bare earth; sometimes brick or tile; sometimes bare boards of the commonest kind; and sometimes strewed with rushes. Even the great hall of the baronial mansion was often, on festive occasions, thus strewed with rushes. When, or on what occasion, a *woven* material was first employed among us as a floor-covering, is not known; but there seems reason to believe that the precursor of the modern carpet and oil-cloth was a coarse kind of drugget, warm and neat, but in no sense beautiful. Even down to the middle of the last century, carpets were very little used in England.

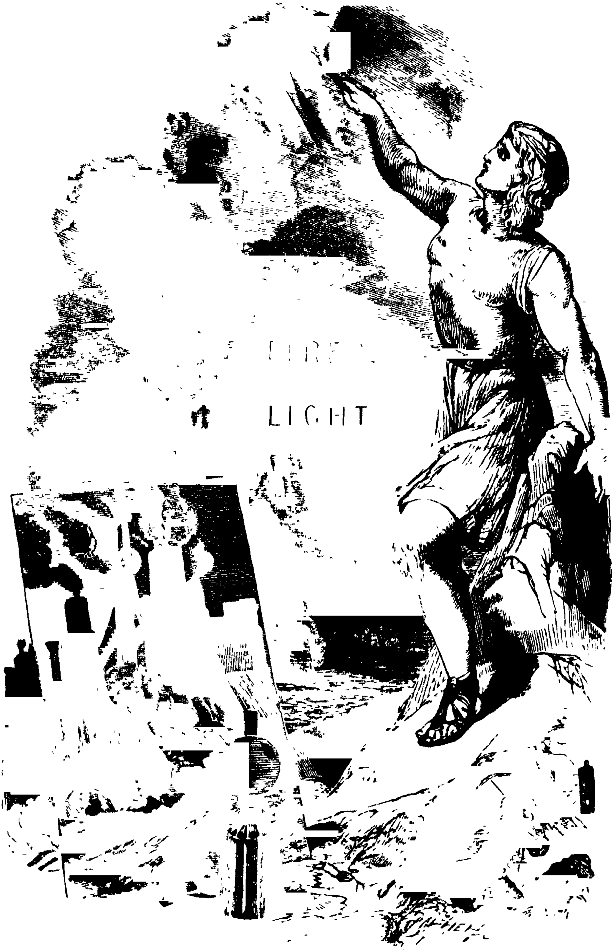
At the present day, the carpet trade is a very important one. At Halifax, at Kidderminster, and in certain parts of Scotland, the manufacture is conducted on a large scale. The names *Scotch*, *Wilton*, *Kidderminster*, *Axminster*, *Brussels*, *Venetian*, *&c.*, as applied to carpets, at first denoted particular kinds made at the places thus named; but though the kinds remain, and with them the names, many of the places have almost ceased to produce carpets. Of the processes of manufacture, it is not necessary to say much, in addition to the details given in a former chapter relating to worsted goods. A carpet has to be spun and woven, just as a piece of cloth, but with certain modifications, depending on the use to which the substance is to be applied. Carpets are thicker than any kinds of cloth; and although their surface exhibits only wool, there is flax incorporated with most kinds, for strength and for cheapness. The weaving is of a peculiar character, to enable different layers of warp-thread to interlace well among the weft. In some kinds the surface is soft and plushy: this effect is produced by cutting some of the woven threads in the same way as in making velvet.

The useful and often beautiful substance, *floor-cloth*, is, as we have said, an advantageous substitute for carpet under certain circumstances. The cloth of which it consists is sometimes of hemp, but more generally of flax; and it is woven, chiefly in and near Dundee, to the enormous width of four, six, or even eight yards. The bales of canvas, when woven, are cut into pieces of convenient length. The pieces are stretched vertically in a frame, almost as tightly as the parchment of a drum. Workmen, standing on ranges of scaffolding in front of the canvas, then apply hot size to it, and rub it well with pumice-stone, to smooth away the asperities, and partially fill up the pores. When dry, the canvas receives a groundwork of colour laid on with a kind of trowel, the paint being almost without turpentine, and much thicker than that employed by house-painters. This is for the *back* of the canvas or floor-cloth. The *front* or face is then sized, rubbed with pumice, and coated with paint many times over, to produce a proper degree of solidity and smoothness.

Then comes the device or pattern. This is cut or engraved upon blocks, one for each colour; and the blocks adjust or "register" with each other just as in calico-printing or in paper-staining. The canvas is spread out upon a long table. Each block is taken in turn, and is dipped face downwards upon a cushion previously wetted with paint of the proper colour. A layer of paint is thus taken up, and is transferred to the prepared canvas, as in printing. Varied as are the patterns of the best kinds of floor-cloth, the processes are nothing more than a repetition of those here described. The colours are applied one by one, and fall into their proper places; the engraving of the blocks and the skill of the workman being directed to this end.

From the cottage of the workman to the palace of the Queen, stone, brick, mortar, cement, wood, tiles, slates, and woven materials are used in the modes just briefly described The principles of application are the same in all; the details only vary.

OUR SUPPLY OF FIRE AND LIGHT.



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CHAPTER IV.

OUR SUPPLY OF FIRE AND LIGHT.

Few persons would imagine, until attention had been paid to the matter, how large a portion of industrial labour and skill is involved in the production of artificial *Fire* and *Light*. The indispensable necessity we have for those aids, in our daily life, is almost kept out of mind by the very familiarity of the subject; we seldom conceive ourselves to be without them, and therefore can hardly realize the possible intensity of the privation. It is only the poor, in a severe winter, who are entitled to speak on this matter. *Coal, coke, charcoal, peat, artificial fuel, sulphur matches, congreve matches, gas, lamp oil, tallow, candles, palm oil, bitumen, petroleum, paraffine*—these will show how wide is the range of commerce and industry conceived in the production of fire and light.

1. Light-producing Contrivances.

Before we can understand how light and heat are communicated from one substance to another, we must pay attention to the modes of producing them, in the first instance, from substances which are at once opaque and cold.

THE TINDER-BOX.—How to produce a light, both *as* a light and as a means of producing fire, is one of the earliest problems which man set himself to answer. Friction we know to be one of the means of producing heat; and of friction primitive nations mostly avail themselves for this purpose. Two pieces of wood may be so rubbed together as to produce smoke, and then flame; and this mode is much adopted by wandering tribes. A blacksmith, hammering one cold piece of iron with another, and with no magic save that which resides in his own lusty arm, can produce a red heat which will easily kindle sulphur and some other substances. In these instances we have wood against wood, iron against iron; but mankind could not long have been acquainted with the use of metals without observing that, when a hard piece of stone is struck obliquely against a hard piece of iron or steel, sparks are struck off—small particles of metal made red hot by the effect of the hard blow. These red-hot particles, if allowed to fall upon charred linen, will heat it to such a degree as to kindle sulphur. Thus we have the philosophy of the *flint and steel*, the *tinder-box*, the *brimstone match*.

Then, when chemical science had made advances, it became known that flame would result from the contact of many different substances; and the ingenuity of man was directed to the adoption of some methodby which these substances could be brought to use. Some philosophers thought the *compression of air* might be rendered available for producing a light; it can certainly so be applied; but the apparatus is too troublesome to be conveniently used. The science of the matter is simple enough. Air becoming heated when compressed, it is possible so to place a piece of *German tinder* in the bottom of a small piston, that when the piston is forced into a tube closed at the lower end, it so heats the air by compression as to kindle the tinder sufficiently to inflame a brimstone match. But this method, and others useful to scientific men in some of their experiments, are too elaborate for every-day life.

Phosphorus, when placed between the folds of a bit of paper, and rubbed to and fro, will heat sufficiently to kindle a sulphur match. Again, phosphorus, when treated in a particular way, forms an oxide which will readily kindle sulphur. This suggested the *phosphorus lights* and *phosphorus boxes*, so well known thirty or forty years ago. Some one made the discovery that if alum, sugar, and flour be combined, the mixture has a tendency to take fire on exposure to the air; and this fact was rendered available by a contrivance called Homberg's *pyrophorus*. When it became known that chlorate of potash, mixed with a little sugar, kindles into flame on contact with sulphuric acid, *chlorate matches* were produced. Matches were first dipped in melted sulphur, then in chlorate of potash; a bit of asbestos was soaked in sulphuric acid and put into a bottle; and then, by pressing the end of one of the matches upon the asbestos, light was produced. A modification of this arrangement, called the *promethean*, lived its little day, and then gave way to something cheaper.

LUCIFERS AND CONGREVES.—A lucifer match, trifling as it may appear, is one of the triumphs of civilization. Although it may not sell for the hundredth part of a farthing it is still a great achievement —not possible until steam engines had been rendered available for the sawing and cutting of wood, and chemical science had developed the properties of many new substances.

Our present lucifer and congreve matches grew out of the various contrivances just noticed. Chemists and practical men made themselves acquainted with the properties of sulphur, phosphorus, chlorate of potash, sulphuric acid, sulphuret of antimony, charcoal, and other substances, in relation to each other and to heat; and the result is that we have now matches that require nothing but slight friction against a bit of sand paper to produce a light. The making of these invaluable little implements involves three branches—the forming of the splints, the tipping with chemical composition, and the making of the boxes. The splints or matches are made of the best deal, as being cheapest in the end, on account of the facility of working. The severance of a large plank into these tiny bits is a work of surprising ingenuity and celerity. Circular saws cut up the planks into blocks three or four inches long. Each block is then cut into slices by a machine which presents fifty or more lancet-shaped points in a row, and at a distance apart equal to the intended thickness of the splints. At the same time a long blade, acting in another direction, cuts a pile of these slices into splints, such as we are familiar with in every-day life. All this is very surprising to look at; for the machinery is so beautiful as to create wonder that profit can be derived from its use upon such humble articles; but the truth is, it works with such rapidity that the pennyworths of produce mount up to a formidable sum. One machine will cut sixty thousand well-made splints per *minute!* Some splints are round or cylindrical; they receive their shape by being forced through small holes in a steel plate. The Germans can make these round splints, and sell them wholesale at the rate of three or four thousand for a farthing.

The tipping of the splints with composition is a chemical affair. The ends of a bundle of splints are dipped in melted sulphur; and then, after drying, into a hot liquid composition of phosphorus and other substances. This is dangerous work; for the slightest mistake in the order of proceeding, or in the handling of the apparatus, might speedily set the whole building in flames. Cigar *fusees,* made of soft cardboard steeped in nitre, belong to the same family as lucifers and congreves, etnas and vesuvians, with certain variations in the composition employed.

Lucifer-boxes are another marvel of cheapness. Some are made of tin, with a hinged cover; some are turned in wood; but the kind now most generally used in England is a flat box inclosed in a case. For these boxes, the wood is brought to the state of a shaving by means of a peculiar machine; it is cut up into strips, and these strips are glued into form with surprising quickness.

2. Coal and Collieries.

That the substances available to us as sources of light and heat are numerous, every one knows. Where trees are scarce and coal unknown, as in the sandy plains of the East, dried *camel's dung* is often used for fuel. Where vegetation occurs, dried *leaves* are an occasional source of heat. Where forests are abundant, *wood* is the most generally known of all kinds of fuel. Where *coal* is plentiful, as in England, timber trees are appropriated to other purposes than fuel, and coal is used in its stead. When heat is wanted without flame, man avails himself of *charcoal* made from wood, or *coke* made from coal. Where peat-bogs are extensive, as in Ireland, the *peat* is rendered serviceable as fuel. Lastly, wherever *tallow*, *fat*, *oil*, *spirit*, *resin*, or *turpentine* are easily obtainable, there may we expect light and heat to be at our disposal. We shall now, therefore, treat of these matters.

Coal and Coal-fields.—England unquestionably owes much of her greatness to the vast stores of coal which lie beneath the surface. Were it not for this coal, our iron and other manufactures, our steam engines and machines, our railways and iron ships, would never have risen to their present pitch of excellence. Nor would our dwellings be warmed so comfortably, or lighted so cheerfully, were this bounteous supply wanting.

Coal is of vegetable origin; supposed to have been formed by the long-continued action of heat, moisture, and pressure on vast masses of vegetable substance. Such is really all that our scientific men know on the subject. Some coal, such as the Welsh *steam* coal or anthracite, consists of little else than carbon, in a very dense state; while other kinds, such as Staffordshire *Cannel* coal, are rich in bitumen, on which our gas-lighting mainly depends.

No one has yet measured the quantity of coal still in store in our country. It is pretty certain that the supply will last us for thousands of years, let the population of these islands increase as rapidly as it may. Coal underlies the surface in isolated patches; each patch constitutes a *coal-field;* and each coal-field comprises many beds of coal separated by earthy or stony strata. The principal coal-fields are the following:—Northumberland and Durham; North Yorkshire; South Yorkshire; Nottingham and Derby; Staffordshire; Lancashire; Whitehaven; Leicestershire; Warwickshire; Coalbrook Dale; West of England; Forest of Dean; Anglesea;

South Wales; and the centre and south-west of Scotland. Ireland has very little coal; and this is one cause for the backward state of that country in commercial matters. Each of these isolated coal-fields had probably its own geological history of submerged forests; but of that history we know nothing.

The several coal-fields differ much in the number, thickness, and quality of the beds of coal. The chief kinds are the *caking*, the *cannel*, and the *stone* coal, differing mainly in the proportion of bitumen combined with the carbon. All the coal-beds, and all the strata interposed between them, form collectively *coal-measures;* and these, with certain thick layers of limestone and sandstone beneath them, constitute a *coal-formation.* Some of the beds are very near the surface; others are reached by digging down to a depth of nearly two thousand feet; some are so deep as hardly to pay for working; while a few run out to a distance under the sea. Most of them are a little inclined from the horizontal. Two or three of the English coal-measures have as many as a hundred alternations of coal, clay-slate, and sandstone. The thickness of the seams of coal varies from one inch to fifty feet. When the seam is not thick enough for a man to creep into the space left by its excavation, the coal-mining ceases to be profitable at that spot. When the coal-measures include among their strata valuable beds of iron ore, iron-works are pretty sure to spring up at that spot; seeing that the ore, and the coal to smelt it, are found near together.

Some mines, such as those of Northumberland and Durham, occur so near the sea as to afford great facilities for the shipment of coal to other places. No less than three million tons a year are shipped to London from the banks of the Tyne, Wear, and Tees; besides another million or more brought by railway from other districts.

Colliers and Coal-mining.—In commencing a colliery, a perpendicular shaft is generally dug in the first instance; deep enough to cut through several seams of coal with the intervening layers of stone and earth. This shaft, usually circular, is from six to ten feet in diameter. As each bed or seam of coal is reached, side passages are dug from the shaft into or through the coal itself; as high as the thickness of the seam, and ten to fourteen feet wide. These passages are called *bords;* the earth above is the *roof,* and that beneath the *thill.* Other but smaller passages, called *headways*, are dug at right angles to the bord, and other bords at right angles to those headways; until at length the seam of coal is intersected by a chequer-work of avenues, eight or ten yards apart, mostly large enough to permit men and horses to work in them. Lower and lower, as the shaft descends, each seam is treated in this way. The shafts serve many purposes; for the miners ascend and descend by means of them; the coal is brought up them; the water which accumulates in the mine is pumped up them; and the fresh air to ventilate the mine is sent down them. Steam-engines are now used in nearly all our coal-mines, to assist in these various labours, which become very formidable when the mine is deep, or much flooded with water, or much vitiated by inflammable gases. In the best mines, the miners are raised and lowered by steam-power; but in too many instances the ascent and descent are made laboriously by means of ladders —a sad waste of muscular power, and an equally sad disregard of human comfort.

The miners work in the bords and headings, digging away the coal on either side. At first the open passages bear but a small ratio to the untouched coal; but by degrees the coal is dug away, and there is more empty space than solid substance. In fact, all the coal is removed, except so much as is necessary to form pillars or piers for supporting the roof above. In some places timber props are erected, instead of leaving coal pillars. The miners, in excavating the coal, cut fissures at the top, bottom, and sides of a cubical mass, and introduce a charge of gunpowder in a hole bored at a particular spot. The exploding of this powder loosens a mass of perhaps fifty or a hundred tons; and the miner's operations are thus greatly facilitated, his pick and shovel being then his chief tools. The coal, as dug, is shovelled into baskets, or tub-shaped boxes called *corves*. Tramways are laid down in the various passages; and horses, men, or boys, are employed to drag small low carriages on which the corves are placed. Women and girls used to be employed at this work; but the Legislature has put a stop to such a degrading system. When arrived at the shaft, the corves are lifted to the surface by steam-power. The pitmen carry lighted candles in front of their caps; but if the air of the mine be vitiated with inflammable gases, wire-gauze *safety-lamps* are used instead, to prevent explosions. The dreadful accident at the Hartley Colliery, in January, 1862, by which two hundred and twenty human lives were sacrificed, illustrated some of the many perils to which coal-miners are exposed.

When drawn up to the surface, the coal is then generally *screened;* that is, it is made to fall upon a kind of sieve, which separates the lumps from the powder. The powder is sold at a low price to manufacturers; while the lumps command a higher price as house-coal. All the important coal-mines in Great Britain are now connected, by railway, either with sea-ports or with the great railway stations, whereby the facility of transport is greatly increased. At Hartlepool, as one among the best recent examples, railways converge from every part of Durham county, bringing coal from the rich mines; and these railways are so connected with *staiths,* or elevated platforms, that ships in the harbours can receive their ladings of coal with extraordinary ease and rapidity. Other railways from other pits transfer coal to the care of railway companies instead of to shipowners; and thus a healthy competition is maintained in the supply of coal to our busy centres of population.

3. Coke, Charcoal, Peat, and Artificial Fuel.

We here group together four kinds of fuel which bear a certain relation to coal, but are not coal in its ordinary state.

Coke and Charcoal.—*Coke* is coal deprived of nearly all its hydrogen or flame-producing element, but retaining the carbon or heat-giving portion. At gas-works, coal is converted into coke in order to obtain gas from it; the coke being regarded as a residue, to be disposed of according to the best market that offers. For locomotive engines, and for certain processes in the arts, coke is better suited than coal; and thus coal is coked, in such instances, for the sake of the coke rather than of the gas.

There are many ways of making coke. If a heap of coal were closely covered in with earth, except small openings to permit the escape of gases, and were set on fire, it would be converted into a kind of coke; because the gases would be driven off, while the carbonaceous portion would not be fed with a sufficiency of air to burn away. Where the process, however, is required to be carried on in a more complete way, *coke-ovens* are built. Each of these ovens has an opening at the top, at which to put in the coal; and another near the bottom of one side for the removal of the coke. At some of the large iron-works, and at the great railway depôts, several flat-roofed coke-ovens are ranged in a row, with a railway running along the top, in such a way that trucks laden with coal may conveniently travel along the whole range, and deposit their contents in the ovens. Another railway, laid on the ground in front of the ovens, affords similar facilities for carrying away the coke when made. The burning is allowed to be very fierce at first, to get rid of the coarser smoke and most of the gases; but the oven is nearly closed by degrees, and merely a close heat maintained.

Good coke has something of a crystalline structure, and is much harder than coal. About one fourth of the weight is driven off during making; but the bulk is increased nearly in the same ratio; for coke, though harder than coal, is more porous, and on that account lighter.

If *coke* is a kind of coal-charcoal, so is *charcoal* a kind of wood-coke. Such is the relation between them. Charcoal consists of wood burned with very little access of air. It is made on a large scale by building up billets of wood into a heap, covering them with turf and sand, and setting fire to them through several holes left near the bottom of the pile. Orifices are left, only just sufficient to permit the escape of gases. When the burning is finished, the charcoal, or residue, is little else than carbon. For making fine charcoal, used in gunpowder works, the wood is burned in iron cylinders instead of in heaps; this enables the charcoal-burner to regulate the process more accurately. The densest charcoal gives out most heat.

Peat and Artificial Fuel.—Rich as Great Britain is in coal, Ireland is perhaps still richer in *peat*, if we could only find the means of rendering this peat valuable; but this useful application is yet but limited. There are three million acres of peat bog in that country; and the thickness is estimated to be such that the whole of the bogs contain the enormous quantity of *four thousand million tons* of peat. This substance consists of roots and fibres in various stages of decomposition; sometimes almost like wood, at others approaching nearer to the state of earth or mould. None of it is coaly in structure, though it is conjectured that the same kind of agency may have been concerned in the formation of peat and coal. Some specimens are solid and tolerably hard; some flow like a paste or thick liquid. All the woody portion is available for producing heat. In the treatment of Irish bogs, the peat is sometimes dug up and removed, chiefly to render the ground beneath fit for agriculture; while in other cases the use of the peat itself is the chief object. In Holland, peat is largely used for fuel. The peat there is a kind of mud at the bottom of lakes and ponds. It is dredged up, and is spread to the depth of six inches over a level piece of ground. When the water has drained off, men press the peat by means of flat boards fastened to their feet; and, thus consolidated, it is cut by spades into convenient square pieces. These pieces, when dry, form a fairly good fuel, giving out great heat, or producing charcoal when burned in close ovens. Irish peat may be treated in a similar way; or the more solid kinds may be dried at once without any need for draining. It is known that naphtha, paraffine, fixed oil, volatile oil, and ammonia may be obtained from peat by distillation; and hopes are entertained that the Irish bogs may one day be profitably rendered available as a source of these substances.

Many of the kinds of *artificial fuel,* brought into use within the last few years, contain peat as one of their ingredients. One of the Irish Steam Packet Companies employs fuel made in the following way. The peat, after being dug up, is heavily pressed by iron rollers, drained of its moisture by a hydraulic press, dried, and converted into a kind of coke or charcoal in an oven. Then, to make the artificial fuel, this coke is ground to powder, and mixed with melted pitch and resin to the state of a paste, which is at once cast into moulds, and made into brick-shaped blocks. There is, however, great difficulty in drying most of the Irish peat into fuel, on account of the large quantity of water it contains. *Oram's patent fuel* comprises the screenings from coal pits, mixed with various kinds of earthy and bituminous matter. *Williams's patent fuel* presents the forms of an artificial coal, an artificial coke, a charcoal harder than wood charcoal, or a dense peat fuel, according to the mode in which it is prepared. *Bethel's patent fuel* consists of small coal, coke dust, cinder siftings, and pitch or coal-tar. *Warlich's patent fuel,* made of materials similar to the above, is especially intended for marine steam-engine furnaces. Trinidad pitch mixed with wood shavings make a kind of fuel useful when combined with coal for furnaces.

4. Gas-making and Street-lighting.

Hitherto we have treated of certain solid substances, bought and sold as materials for producing light and heat in our dwellings. But now we come to a most singular material, which the buyer can neither feel nor see, but which he has ample means of knowing is both light-producing and heat-producing.

Gas-making.—One of the greatest advancements ever made in mechanical and chemical art, was that of substituting invisible gas for liquid oil or solid tallow as a source of light. It is not easy for us to realize, at the present day, the state of things when the streets of towns were either not lighted at all, or were lighted with oil lamps troublesome to trim, and expensive to maintain; when shops could not be well lighted but at a large outlay; and when no one thought of a light for dwelling-rooms that would be ready at all times, and in any desired quantity.

The philosophy of gas-making is very simple. If, for instance, we put a piece of coal into the bowl of a tobacco-pipe, cover it up with clay, and immerse it in the fire, a stream of gas will rush out from the small end of the tube which may be kindled into a flame. This is gas-lighting; and the problem is, how best to effect this operation on a large scale. In 1792, Mr. Murdoch, a Cornish engineer, was the first person to light a house with coal-gas. In 1798, Messrs. Boulton and Watt lighted their factory at Birmingham by similar means. In 1807, Mr. Winsor first began to light public streets by gas. In 1810, the first gas company was formed—the *Chartered Company*, still existing. Since those years gas has been introduced into the capitals and most of the chief towns of Europe and America.

The making of coal-gas requires a large array of apparatus. The gas is made in *retorts*, usually iron vessels, but sometimes of tile or fire-brick. Several retorts are so placed near each other, as to be heated by one furnace. When the retorts are red hot, a door is opened at one end of each, and coal thrown in—a coal rich in gaseous or bituminous matter. The door being then closed, the coal in the retort is decomposed by the heat to which it is subjected. Carburetted hydrogen and other gases ascend through a tube called the *stand-pipe*, which rises from each retort, and bends down at the top so as to dip into a larger pipe, called the *hydraulic main*. This main is half full of water. The gases deposit a kind of liquid tar in the water, and then pass through several *condensers*, *washers*, and *purifiers*, where they are brought into contact with various purifying chemical substances.

When the gas is brought to as great a degree of purity as is attainable, it consists of little other than carbon and hydrogen, or *carburetted hydrogen.* It must be stored in large quantities, ready for the sudden and great demand in the evening. The gas passes through a large meter, or measuring apparatus, into a *gas-holder* or *gasometer* ; which is an immense iron vessel, sliding up and down like a telescope, closed at the top, and dipping into a thin stratum of water at the bottom. This gas-holder is nearly filled during the day, and nearly emptied during the hours of evening and night.

Gas-lighting.—Many years ago an opinion was entertained that ready-made gas could be carried to houses and buildings in closed metal cans, to be used in whatever rooms or shops might be chosen; and a *Portable Gas Company* was formed to make the necessary arrangements. Although the plan was quite practicable, it was not found to be either safe or profitable, and was abandoned.

The system now adopted is to imitate the arrangements for water-supply. A vast store of gas is collected in one spot; large mains run under the principal streets from the gas-works; small pipes ramify from these mains to the chief streets; while smaller pipes carry the gas into buildings, and up the pillars of street-lamps. The system is wonderful in its completeness. Were it not for the frequent breaking up of roads by rival companies, it would leave little to desire. The gas-holder, as the heart or centre of the system, must necessarily be very large; and each gas-work has generally several. The gas-holder has weights, so placed that the top can press down upon the gas, and condense it a little: this causes the gas to run out, when the proper valves are open, with sufficient force to permeate all the miles of main and pipe beneath the surface of the street. An apparatus called a *governor* regulates the amount of this pressure, according to the requirements of each district at particular hours of the day.

All the larger gas-pipes are made of cast iron, and the smaller of wrought. The service pipes, which bring the gas into houses and buildings, are made of various metals, according to circumstances. Some of the larger mains will, under average pressure, allow the vast quantity of one hundred thousand cubic feet of gas to pass through them in an hour.

In the early days of gas-lighting, the consumers paid the companies so much per *flame* or *jet;* but now they pay so much a cubic foot—an arrangement much more satisfactory to both parties. The quantity is determined by *gas-meters,* placed between the mains and the service pipes. The gas passes through a sort of box, where it turns an index hand, or kind of clock-work, which shows how many cubic feet have thus passed through between any two periods of unlocking the meter. The customer is thus charged for neither more nor less than the exact quantity of gas which he has consumed, and is neither interfered with concerning the number of jets burned, nor the number of hours of burning.

The burners for gas-lights exhibit much ingenuity of arrangement, and often beauty of appearance. To lessen the quantity of smoke; to carry off readily such smoke as is made; to increase the brightness of the light on particular sides; to make rings of jets shoot out laterally, as a means of lighting churches and other large buildings—these are some of the objects which have led to great improvements in the form of burners.

5. Tallow, Palm Oil, and Candles.

In relation to light-producing rather than heat-producing, that little familiar friend, a *candle*, presents much that is curious and worthy of our attention, both in the material employed and the processes adopted.

Tallow.—Melt down the fat of an ox or sheep, and you obtain *tallow*. This is a simple way of stating the case; but in the practical management of the tallow trade, many points have to be considered. Butchers' meat brings so high a price in England, that as little fat as possible is thrown aside for the melter; and consequently large importations of tallow are necessary from abroad, to supply our soap and candle makers. In some countries, Russia and Australia especially, it is found profitable to rear cattle expressly for their tallow and hides, disregarding the quality of the meat, which in such case is sold at a very low price.

When the fat of English cattle is to be converted into tallow, it is sold by the butcher to the *renderer*. It is chopped into small pieces, and boiled in water. Most of the fat melts out of the membranous cells which enclose it, and floats on the surface of the water, whence it is removed by skimming. The membrane is taken out of the water, put into porous bags, and submitted to powerful pressure, by which the remainder of the oily fat is expelled. The nearly dry membrane forms the substance called *greaves*, on which some kind of domestic animals are fattened. The fat, when strained and otherwise purified, constitutes tallow, which is always solid in our climate.

The Russians, who sell us *a million hundred-weights* of tallow every year, obtain it mostly from the southern parts of the empire, where there are cattle farms of vast extent. There are *salgans*, or tallow-factories, connected with these farms. The owners buy lean cattle by hundreds or thousands at a time, at a very low price, and fatten them.

If the fattening has proceeded satisfactorily, the cattle are driven to the salgans towards the close of the season. These salgans are spacious court-yards, surrounded by slaughter-houses, boiling-houses, and other buildings. The cattle, when killed, are skinned; and a little flesh is cut off, good enough to be sold as butchers' meat in the neighbouring markets; but it is very poor in quality, and commands only a low price. The intestines are given as food to swine. All the rest of the carcase, bones included, is cut up into manageable pieces, and thrown into large caldrons, each of which will contain from ten to twenty carcases of oxen. The mass is heated only so far as to allow all the fat to melt out of the membrane, and to float upon water put into the caldron. The fat is skimmed off with large ladles, and poured into casks; the portion that runs off first, is the best in quality. The Russian merchants who buy the tallow from these establishments, cause the contents of every cask to be examined, and the tallow to be assorted into various kinds, according to whiteness, hardness, and other desirable qualities. Soap-tallow may be greasy and yellow; but candle-tallow should be hard and white.

Palm Oil.—This substance is becoming every year more and more important, as an ingredient in the manufacture of soap and candles. Not only is it valuable in this way, but it encourages trade with African tribes, who, without the incentive afforded by national commerce, are too apt to capture and sell each other into slavery. It has been well said, "Every cargo of palm oil, bought with our manufactures, does more to impede the traffic in slaves than a host of treaties and protocols with European states." There can be no question that if commerce be an aid to civilization, and if civilization would tend to lessen the selling, by barbarians, of each other to American slave-dealers, the encouragement of a trade in palm oil with the Africans, would work in the right direction, however slowly. We already purchase nearly *a hundred million pounds* of palm oil yearly from these sable cultivators.

The palm oil is obtained in greatest abundance from one particular species of palm-tree growing chiefly in the regions near the west coast of Africa. The oil exists in the fruit, as in the case of olive oil. The fruit is about the size and shape of a pigeon's egg, with an outer fleshy covering of a golden yellow colour, and is full of oil. The pulp, after being bruised in mortars, is steeped in boiling water; a yellowish oil separates, which with very little further preparation becomes palm oil. It is liquid in the hot climate of Africa; but when it reaches England the consistence is almost equal to that of butter.

CANDLES AND CANDLE-MAKING.—If we dip a rush into melted fat of any kind, and allow the fat to dry, we practically make a candle, call it what we may. All candle-making is only an advance on this primitive method. In fact, country people frequently make candles in this simple way; and *rush-lights*, by their very name, suggest the nature of their origin.

A common *dip* or *store* candle consists of a wick of cotton thread thickly coated with tallow. In a small way, threads of cotton may be doubled to produce a wick of the requisite thickness; but in manufacturing on a large-scale, quicker and more effective means are adopted. Loosely-spun threads are twisted into a soft cord or roving, in number depending on the thickness of the candle to be made. By the aid of a simple apparatus, these rovings are quickly cut off into pieces, doubled round a stick called a *broach*, and slightly twisted in the doubling; each piece forms a wick for one candle; and the broach is speedily laden with many such, nearly close together.

In making candles by hand, the maker is provided with a cistern or vessel of melted tallow, kept liquid by a fire underneath. He takes three broaches, holding them at the end by his two hands, and dips all the wicks into the tallow; this he repeats three times, and then passes the lower ends of all the wicks over a sloping board, to remove the superfluous tallow. The broaches, containing the wicks for perhaps six pounds of candles, are then hung up to dry. Three other broaches are treated in a similar way; then three others; and so on. When all the wicks are dry, after this first treatment, they undergo a second in a similar manner; until at length the successive coatings of tallow have brought the candles to the required thickness. Practice enables the dipper to judge how many dippings are necessary to produce 'sixes' 'eights,' 'twelves,' or any other kind, denoted by the number that go to a pound.

In making candles on a larger scale, twenty or thirty wicks are hung on each broach; twenty or thirty broaches are placed side by side in a frame; and twenty or thirty of these frames are ranged symmetrically around a vertical axis; in such a way that there may be twenty or thirty thousand wicks all hanging in the same machine at one time. Each frame of broaches can be conveniently lowered into the tallow, raised again, and turned aside to make room for another. The operations are in this way so much expedited, that one man and a boy can make thirty thousand dip candles in a day.

Some candles are made by *moulding* instead of *dipping*. Pewter moulds are provided, one for each candle, and several such moulds are ranged in a row. Ingenious means are adopted for stretching wicks along the axes of the moulds, one in each; and for pouring the melted tallow in such a way that the proper quantity, and no more, shall flow into each mould. A very beautiful machine is employed for cutting the wicks, stretching them in the moulds, and fulfilling the remaining operations, in an amazingly short space of time.

Many substances are employed, besides tallow, as ingredients for candles. One is *palm oil*, lately noticed. Another is *wax*, requiring more care in its preparation. Another is *composite* or *composition*, the mixed character of which is denoted by its name. A new substance called *paraffine*, obtained from coal-tar, is now made into candles of great beauty and excellence. Price's Patent Candle-works, at Vauxhall and elsewhere, are the largest in the world; the quantity made there annually is enormous; and great improvements are frequently introduced by the use of new substances, or new compounds of substances already known. The candles which require no snuffing have slender wires twisted in with the cotton of the wick; when burning, the top of the wick turns outwards, in such a way as to enable the oxygen of the air to consume the charred substance, which it cannot do when in the middle of the flame.

6. Lamps, and the Fuel to Feed them.

We next come to *liquid* materials for producing light and heat. There are many such; among which may be included *whale oil* and *colza oil;* and certain liquids which partake of the character of spirit rather than oil, such as *camphine*, *benzole*, *petroleum*, &c.

Whale Fishery and Whale Oil. — Although many other kinds of fish oil are used to feed lamps, whale oil is the chief. There are many species of the gigantic creature from which this oil is obtained. The common *Greenland* whale often reaches sixty feet in length by forty in circumference, and weighs the enormous quantity of seventy tons. The *South Sea* whale differs from the Greenland whale in many particulars, among others in containing the singular substance called *spermaceti*. The Greenland whales are captured by the crews of vessels of three or four hundred tons burden, sent out by various countries of northern Europe. The fishing season is in the summer months, from May to September; but as whales are now becoming scarce in the Northern Ocean, the trade is more precarious than in former times. Although *whalebone* (a kind of fringy substitute for teeth) is always valuable for its great toughness elasticity, the oil is regarded as the chief object for which the dangers of the whale fishery are braved. The oil is contained in the *blubber*, the fat of the animal lying immediately under the skin. This blubber varies in colour from yellowish-white to red, but is usually of a salmon tint, and from eight to twenty inches thick.

The Greenland whale-ships have usually crews of forty to fifty men each, divided into classes according to the duties they undertake to perform. As the men's earnings depend on the profits of the voyage, the contract among them partakes rather of partnership than of hiring. The apparatus is considerable. There must be six or seven boats, besides a large supply of lances, harpoons, ropes, lines, anchors, grapnels, &c. The attack on the whale is made from the boats, not from the ship. When the boats' crews succeed in approaching a whale (which is often very difficult), the harpooner buries a harpoon in the huge animal. The whale plunges at once down into deep water. All the boats' crews are speedily at hand, to avert if possible numerous accidents which are likely to occur at that time. If all disasters are escaped by the men, the whale, exhausted by violent struggles, and pierced by several harpoons, is dragged to the side of the ship, by means of the ropes attached to those weapons. When dead, it floats on the surface of the water, and is then more easily managed.

In the early days of the northern whale fishery, the blubber was boiled down in a small establishment at Spitzbergen, to obtain the oil; but for nearly two centuries another plan has been followed. The process of *flensing* is first necessary. The dead animal being lashed to the side of the ship, the men cut off all the blubber, divide it into small pieces, and throw it into the ship's hold. The flesh or meat of the whale, lying beneath the blubber, is of no value to the whalers; the whalebone is cut out, and the rest of the bulky carcase allowed to sink or float away. When a time of leisure arrives, the crew clean the pieces of blubber, cut away the useless portions, and pack all the rest into casks. When the ship arrives at Hull, or any other whaling port, the blubber is boiled down into oil. As four tons of blubber will yield three tuns of oil, the produce from a large whale is very considerable. The casks are taken to a boiling-house, and the blubber emptied into large wooden cisterns, from whence it passes into a copper boiler. The blubber is heated, kept boiling for a short time, and constantly stirred. The melted oil flows into coolers, from which the solid refuse is removed, partly as a scum and partly as a sediment, to be sold for manure. The oil, when quite cold, is transferred to casks for the market.

The *Sperm* or *South Sea* whale, in addition to oil, yields the peculiar substance *spermaceti*. This is an oily fluid contained in a cavity in the head, from half a tun to a tun in quantity. When poured out of the cavity, and exposed to the air, the spermaceti dries into a yellowish-white solid. When brought to England and purified, it is chiefly employed in making sperm candles.

COLZA AND OTHER OILS.—The number of seeds that yield oil is very considerable, and all the oil so yielded is available as a food for lamps. Some kinds, however, are better suited than others for this purpose. So far as concerns the process of obtaining the oil, all the seeds are pretty much alike. We speak here of seed-oils; but it is necessary to bear in mind that oil is also obtainable from the fleshy pulp that surrounds certain seeds, from the kernels of many fruits, and occasionally from the roots and bark. In countries of less commercial and manufacturing ingenuity than England, the people avail themselves of such oil-producing plants as come most readily to hand. In many parts of the South of Europe, *nut-oil* is produced by pressure from hazel nuts and walnuts. In the same region much *olive oil* is also procured, by a very simple process. The olives are crushed, beneath rollers or edge millstones, into a pulp, which is then pressed to yield its oil: the oil is afterwards purified in various ways, according to the purposes to which it is to be applied. *Almond oil* is obtained by shaking almond kernels in a bag, so as to rub off the brown skins, and then grinding and pressing them.

The two vegetable oils best known in England as sources of illumination are *palm oil* and *colza oil.* Palm oil has been noticed in connection with the candle manufacture. Colza oil will be best described in connexion with another and more important kind of seed oil.

Linseed oil would doubtless be used for lamps, were not a more profitable use found for it in painting and other arts, and that colza oil is preferable for illumination. Linseed oil is obtained from the same plant as flax for linen. When cultivated mainly for oil, the plants are pulled at a certain season, laid out to dry, and *rippled*. The pods and seeds combed out by the rippling are dried in the sunshine, threshed to separate the husks or pods, and stored up for use as *linseed*. If they have been so prepared as to be fit for sowing, they are usually called *flax seed*. A common screw-press could not supply sufficient power to squeeze the oil out of the seeds; it requires a *wedge press* or a *hydraulic press* to effect this. In using the wedge-press, the seeds are placed in bags, which are subjected to intense pressure by driving in wedges above and below them. In the hydraulic press, the pressure is more gradual but more intense than in the wedge-press. The seeds are first crushed between two rollers, then ground beneath an edge-stone, then heated, then put into bags; the bags are placed in a hydraulic press, and the oil expelled, leaving the remainder of the seed in the form of *oilcake*, valuable as a food for cattle.

Colza oil is a variety of *rape oil*, obtained nearly in the same way as linseed oil. Hemp-seed is to hemp-fibre what linseed is to flax-fibre; but colza-seed, or cole-seed, bears a different relation, because this variety of the plant is seldom cultivated for the sake of its fibre. When the colza-seed, in the proper condition for yielding oil, is gathered, the drying, crushing, and pressing are conducted nearly in the way just described. As colza-seed contains a much larger percentage of oil than linseed, one reason is presented why colza oil can be obtained more cheaply than linseed oil.

CAMPHINE, PARAFFINE, &c. — We must briefly describe certain peculiar substances which are used either in a liquid form as substitute for oil, or in a solid form as substitutes for tallow.

Naphtha is a general name for the more fluid and transparent portion of *asphalte*, *bitumen*, *petroleum*, and *tar*, separated from the other ingredients by chemical processes. However produced, it is always fitted to be used for artificial illumination. *Petroleum* is one of many kinds of bitumen due to some long-continued action on masses of vegetable matter. Deposits of bitumen are met with in many parts of the world. There is a close mutual connexion between bitumen, asphaltum, and tar, both as to the vegetable origin, and to their light-giving properties. From many varieties of them, liquids and gases can be obtained possessing the illuminating and heating qualities in great purity. One particular kind, *petroleum*, has a multitude of other names—*Rangoon tar*, *mineral tar*, *rock oil*, *black naphtha*, *liquid pitch*, *liquid bitumen*, *fluid asphalte*, &c. This remarkable substance is found near Rangoon, in the Birman empire. If wells are dug in that region to a depth of about sixty feet, a kind of greasy liquid, of a brownish-green colour, slowly oozes through the surrounding soil, and accumulates at the bottom of the well. Vast stores of this rock oil or well oil have recently been discovered in America, and are giving rise to a very extensive branch of commerce; the rock oil is equally available as a fuel for lamps and a material for gas-making.

Vegetable tar is chiefly produced from the roots of pine-trees, in northern Europe and North America. The roots are burned somewhat in the same way as wood to make charcoal, or coal to make coke; the resin contained in them becomes converted into liquid tar. When this tar is heated in retorts *pitch* remains behind, in the form of a hard black resin. The substances driven off from the tar in this process are inflammable, such as naphtha and paraffine. The *coal-tar*, formerly noticed as being produced in making gas, when subjected to certain chemical processes, yields various other inflammable matters, such as *coal naphtha, coal oil, pitch, benzole, paraffine,* and *naphthaline. Paraffine* is one of the few solid substances belonging to this remarkable family. It is obtainable from all the different kinds of tar by chemical processes, and when obtained presents itself as a white crystalline solid, something like spermaceti. This substance is now used for making the most beautiful of all kinds of candles.

Camphine is one among many inflammable substances obtained by chemical means from *turpentine*, which is itself inflammable. All kinds of turpentine consist of the sap of trees, obtained while the sap is still living. When distilled, the solid residue left in the still is resin, while the portion that flows out is *oil*, or *spirit of turpentine;* and when this oil or spirit is further purified it becomes *camphine*, a very vivid, but somewhat dangerous food for lamps.

This chapter will suffice to convey some general idea of what is really a very large subject. If any observant reader were to watch the operations of manufacturers, in reference to the management of *Heat*, he would see that countless inventions have been introduced, and untiring ingenuity exercised, to economize the heat-giving substances. The boilers and furnaces for steam engines are always undergoing improvements to this end; as are also the flues and chimneys of factories. Sheffield is constantly sending forth new forms of polished grates not simply for their beauty, but also in the hope of economizing the coal by which our bright open fires are maintained. Wolverhampton and other towns are working with the same object in view, in the construction of those ingenious kitchen ranges, cooking apparatus, and close stoves which now meet our view in all directions. Many thousands of pounds have been spent, many ingenious brains exercised, many patents obtained, and many laws passed, to achieve an object which, if attained, would be a double benefit to all: viz., the *consumption* or *prevention of smoke.* Smoke is good coal in the state of vapour; it will burn if properly fed with fresh air; and when burned it gives forth light and heat just in the same way as other coal. Vexing it is to know that thousands of tons are thus uselessly given off into the air every year: and we can thus well understand how strong is the motive for producing effective smoke-preventing contrivances. The object is partly attained; if it could be wholly so, we should save coal, maintain the air in a state of greater purity, and conduce to the cleanliness of all the objects around us.

METALS AND METAL MANUFACTURES.

1. IRON, STEEL, AND CUTLERY.

IRON MINES AND SMELTING.—THE FOUNDRY AND THE FORGE.—STEEL AND CUTLERY.—IRON AND IRON GOODS.

2. COPPER, ZINC, AND BRASS.

COPPER MINES AND SMELTING.—COPPER MANUFACTURES.—ZINC AND BRASS.

3. TIN, LEAD, AND MIXED METALS.

TIN MINING AND SMELTING.—TIN PLATE AND TIN WARE.—LEAD MINING AND MANUFACTURES.—MIXED METALS.

4. GOLD, SILVER, AND MONEY-MAKING.

GOLD AND SILVER MINING AND REFINING.—GOLD AND SILVER WORKING.—THE MINT AND MONEY-MAKING.

5. QUICKSILVER AND ELECTRO-METALLURGY.

MERCURY AND QUICKSILVERING.—ELECTRO-PLATE AND ELECTROTYPE.

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CHAPTER V.

METALS AND METAL MANUFACTURES.

It is not expedient in the remainder of this volume to adhere to a classification of the multifarious objects around us in relation merely to *uses*. We could group them in this way so far as concerns the chief articles of *food*, *clothing*, *buildings*, *fire*, and *artificial lighting*; but this plan will quite fail us when we come to articles of *metal* generally, because the number of their uses or applications wholly baffles all calculation. Let us rather take each of the principal metals in turn, and trace the chief processes by which it is brought into useful forms.

I. Iron, Steel, and Cutlery.

No better beginning can be made than with those two invaluable substances, *Steel* and *Iron*, which bear so remarkable a relation to each other, and which, in *Cutlery* and other manufactures, play so important a part in our daily life.

Iron Mines and Smelting.—This most valuable of all metals is never found in pure masses; it is always combined with some other substances, from which it must be separated before it can be applied practically. The metal is usually combined with oxygen, carbonic acid, or sulphur, or two out of these three. The kinds most serviceable to iron manufacturers are the oxides and the carbonates of iron, familiarly known as *ironstone*. Beds of this ironstone occur in various parts of the United Kingdom, especially in the south-west of Scotland, South Wales, and South Staffordshire and its neighbourhood. These beds lie at various depths, and are mostly near a series of coal seams.

To get the iron out of the ironstone is the work of the *smelter*. Smelting consists in expelling, by means of heat, most of the oxygen, carbonic acid, and other impurities. Much fuel being wanted for this purpose it is a great advantage to find coal so near the ironstone. In the more important works the iron owners are also coal owners. Miners, descending through shafts to the levels of the several strata, extricate the ironstone by means of gunpowder and tools, and send it up to the surface; the coal is brought to the surface in nearly the same way; and *limestone*, which is generally used to aid the smelting, is brought from the nearest quarries. The ironstone or ore, a dull-looking stone, of a greyish or brownish colour, is thrown into a kiln and exposed to a fierce peat; this *roasts* or *calcines* the ore, by driving off the water, sulphur, and arsenic which it generally contains.

Then the *smelting* or *blast furnace* comes into use. This is a brick structure, sometimes fifty feet in height, hollow in the inside, and open at the top for the materials to be thrown in. These materials—calcined ironstone, coal, and limestone—are supplied in certain proportions. Being exposed to heat at the bottom the coal catches fire, and melts the iron out of the ore, the lime acting as a flux. The heat would not be sufficient, however, if left to itself; it must be urged to a greater intensity by what may be called 'blowing the fire.' Near the lower part of the furnace are small openings, through which the nozzles or *tuyeres* of a blowing machine are introduced; and a powerful steam-engine sends a blast of air with great force into the midst of the burning mass. This is an important aid even when the air is cold, but when used as a *hot* blast the effects are far more striking.

In the course of about twelve hours fifty tons or more of ingredients have experienced the full effect of the intense heat. The coal has nearly all burned away, and has gone off in flame and smoke; the lime has entered into new chemical combinations; while the iron in the ore, becoming separated from the other ingredients, and being heavier than them, falls to a receptacle at the bottom of the furnace, called the *hearth*. At the proper time an opening is made by the removal of a clay stopper, and the molten iron, perhaps five or six tons in all, runs like a liquid fire out at the hole, and flows into grooves or pits made in the sandy floor of the smelt-house. The smelters give the absurd names of *sow* and *pigs* to the larger channel and the smaller ones which branch out of it; and hence the origin of *pig-iron* as a designation for the pieces cast in the smaller channels. The remaining contents of the furnace form cinder or *slag*, slightly useful in some of the arts. In an average state of trade a blast furnace is never cold or empty so long as it remains in good repair; the filling and emptying, burning and blowing, go on by day and night for months or years together, giving a very lurid appearance to the smelting districts.

THE FOUNDRY AND THE FORGE.—The pigs of iron prepared in the blast furnace are of various qualities, according to the kind of ironstone, the kind and quality of fuel, the temperature of the blast, and other circumstances. They are divided chiefly into two groups, *foundry* iron and *forge* iron—the former containing much carbon, and useful for castings; the latter almost free from carbon, and preferable for forging. Carbon renders the iron more fluid when melted, and consequently more suitable for founding or casting into moulds.

Forge iron is subjected to processes which deprive it of the greater part of whatever carbon and oxygen it may contain, to fit it for service as *wrought* iron. It is first *refined*. To effect this, the pigs of iron are thrown into a *refinery* or refining furnace, which is so constructed as to enable a very intense heat to be produced. The iron, when completely melted, is allowed to flow into long flat moulds kept cold by water underneath. Coke is the fuel usually employed in this process. The refined iron, being very brittle, is easily broken into pieces with hammers. The iron is next made tough by the *puddling* process. In the *puddling furnace* the metal, when melted, is stirred about for a considerable period, by bars of iron frequently exchanged as they become heated; the molten mass gives off gaseous bodies of various kinds, and becomes viscid enough to be made up into large lumps called *balls* or *blooms.*

Something escapes from the iron during the refining; something more during the puddling; and now something further has to be got rid of. The blooms are taken from the puddling-furnace to be *shingled;* that is, they receive several heavy blows from a ponderous machine called a *shingling hammer*. This treatment gives to the blooms an oblong shape, and presses a quantity of dross out of them. The blooms are then rolled; that is, they are passed between immense iron grooved rollers, many times in succession, the grooves being selected smaller and smaller as the operation proceeds. This brings them to the state of *malleable bar iron.* To render these bars suitable for manufacturing purposes, they are cut into pieces while red hot, and piled up in a furnace called the *balling-furnace;* each pile, when at a white heat, is passed between rollers, which bring them to the state of *bar* iron, *rod* iron, or *sheet* iron, according to the method of rolling.

Foundry iron is unlike forge iron in many particulars. After having undergone refining in a separate furnace, it is in a state fit for use in castings of the usual kind. Most specimens of cast iron are made either in sand moulds, or in sand linings to brick moulds. In making the enormous cylinders which are now used for some kinds of steam-engines, and for many other purposes in civil engineering, there are both a *core* and a *cope* built up, the former concentric within the latter. The size of the cylinder, both in diameter and in thickness of metal, is determined by the exterior diameter of the core and the interior diameter of the cope. Molten iron, poured into the annular space between the core and the cope, produces the cylinder, which by suitable means is extricated from its prison-house. Most iron castings of large size are produced in some such way as this. For articles next in size, moulds are formed in a layer of sand on the earthen floor of the casting-house. Still smaller articles may be cast in moulds on a bench. In every case, the moulds are so formed, in one or more pieces, as to permit the castings to be easily removed from them. Clay instead of sand, or a mixture of the two, is sometimes used for the moulds.

STEEL AND CUTLERY.—Steel and iron are so nearly allied, that it is not always easy to say where the one ends and the other begins. Steel always contains more carbon than wrought iron, but less than cast iron; and therefore the properties depend, in all probability, chiefly on the mode in which the carbon combines with the metal. But be this as it may, the process of making steel consists mainly in adding a little carbon to that which wrought iron already contains.

Very good iron is necessary for making steel. At Sheffield, the makers chiefly use Swedish and Russian iron—more expensive than English, but possessing qualities better suited for the purpose. The bars selected by the steel maker are technically known by the trade-marks stamped upon them—such as *hoop L*, *double bullet*, *C & Crown*, *D & Crown*, &c. The bars are first cut up into shorter pieces, by means of powerful shears. A flat narrow *converting furnace* is prepared, about twelve feet in length. On the floor of this furnace is placed a layer of pounded charcoal, to the thickness of about an inch; then a layer of bars; then another layer of charcoal, covered by another layer of bars—and so on, until the furnace is quite filled, leaving space only for a thick layer of ferruginous earth placed over all. The furnace, containing perhaps twenty tons of such bars, is then closed, and a fierce heat maintained for several days. The iron absorbs the carbon, or draws it in some way into its substance; and this absorption depends in degrees on the thickness of the layers of charcoal, which differ according as the steel is to be used for springs, cutlery, files, edge tools or other purposes.

The bars, when taken out of the furnace, are in the state called *blistered steel.* This steel is used for many common purposes without undergoing further preparation; but for all finer purposes its quality must be improved. The bars are broken into short pieces, and heated and hammered over and over again, to form *shear steel,* used for a large number of articles of medium quality. Still finer is *cast steel;* made by breaking up blistered steel into pieces, exposing it to a very intense heat in crucibles in a *wind furnace,* pouring it into moulds, and hammering or *tilting* and rolling these ingots into the shape of bars, rods, sheets, &c.

Many varieties of steel of recent invention, such as *Bessemer* steel, *Uchatius* steel, &c., differ from ordinary steel, not so much in the actual composition as in the processes of making. If the reader traces all the operations in converting a piece of iron ore into a piece of the finest cast steel, he will see that many roastings, meltings, and refinings occur, involving the consumption of a large amount both of time and of fuel. The new kinds of steel are the result of attempts to lessen the number of these furnace operations, and consequently to lessen the expense.

The countless articles of cutlery and steel-goods are made by processes of *hammering, rolling, casting, stamping, grinding,* and *polishing.* In hammering, the steel is sometimes used red hot, and in other cases cold. In rolling, there is a like diversity as to temperature, and also to the forms into which the steel is brought. In casting, small furnaces and small moulds are mostly used; seeing that there are seldom large castings in steel. In stamping, the steel is in the form of a sheet, and is pressed between a die and a counter-die. In grinding, the surfaces of steel goods are held against revolving grindstones, until enough of the surface is rubbed away to render the steel level and smooth. In polishing, the steel is wrought up to a beautiful surface by means of small revolving wheels covered with leather, emery, and other substances. Table knives and forks, pen and pocket knives, lancets, razors, scissors, and other articles of cutlery; fenders, polished grates, fire furniture, snuffers, and other articles of furniture; needles, thimbles, hoops, stay-busks, buckles, steel buttons and rosettes, and other articles connected more or less with dress; saws, files, shears, plane-irons, axes, adzes, hatchets, and other cutting tools; swords, bayonets, cutlasses, spears, daggers, and other cutting weapons; small steel instruments connected with science and the more delicate arts; large steel instruments connected with engineering and the rougher arts—all are produced by combining some or other of the processes here noticed.

Iron and Iron Goods.—If it be difficult to enumerate the chief articles made of steel, the difficulty becomes still greater in reference to iron. No civilized being can look around him without seeing iron confronting him in one or other of its useful forms.

Let any average English family put this matter to the test. In dress the articles of iron are few and small, such as buttons, buckles, boot nails, bonnet-wires, &c. But suppose the housewife to think a little how the daily meals are prepared. There are the coffee-mill and the coffee-pot, the iron saucepan and the iron kettle, the tin saucepan and the tin kettle (for though called tin, they have only a tin covering to an iron substance), the kitchen range and fire-irons, the fender and the roasting apparatus, the (tinned-iron) dish covers and roasting screen, the iron skewers and hooks, the tea trays and knife trays, and a whole array of useful articles. Then the housemaid, whether or not she be mistress as well as servant, has her own familiar knowledge of implements and vessels made of iron. At the street door are the railings and the scraper, the knocker and the bell wires; at all the doors are locks or latches, and on some of them bolts and bars; at the windows are fastenings and weights; the floors are fastened down, and partitions are fastened up, with iron nails. And then, when our supposed family go out, they have iron within sight or within touch everywhere—knick-knacks of iron in their umbrellas and parasols; iron in the cabs and omnibuses in which they ride; iron railways, and iron in the locomotives and carriages that run on them; iron in the steamers and anchors in the river; iron in the bridges over the river; iron turnstiles to check the money-takers at some of those bridges; iron corner posts and railings, iron lamp-posts and letter-pillars, in the streets; iron gas and water pipes beneath the feet. Let the father of this supposed family read the details of wars and sieges; he learns about iron guns and mortars, iron shot and shell, iron musket and rifle barrels, iron batteries, iron-plated war ships. Or let him go to the busy haunts of commerce. There he finds iron warehouses and sheds, iron-roofed buildings, iron cranes and windlasses, iron doors and shutters, iron safes and strong rooms. Let all the members of the family, old and young, male and female, follow their usual routine of business or pleasure, or both, throughout the day; they will find that in scarcely a single action do they fail to make use of iron, in some one or other of its multifarious forms.

What has just been said concerning steel applies more or less to iron also; that is, the metal is brought into usable form by one or more of the processes of hammering, rolling, casting, stamping, grinding, polishing; or sometimes by those of wire drawing, welding, and certain others. It must be borne in mind, however, that iron is generally worked in larger masses than steel, while it is less sedulously brought up to a highly-polished surface; hence the processes of hammering, rolling, and casting, are more important in reference to iron than to steel. The hammering, such as in forging anchors and engine-shafts, is sometimes effected by steam-hammers of gigantic power. The rolling requires rollers cf great size and strength, to enable the workmen to produce iron plates, and bars, and rails of various kinds. The castings are prodigious, weighing sometimes many tons in one mass. And then there are working-machines equally remarkable for their form and their accuracy of movement, employed in fashioning pieces of iron for various purposes; such as shearing-machines, for cutting up thick plates of iron as easily as if they were made of pasteboard; punching-machines, for making rivet-holes with equal ease through the same plates; riveting-machines, in which the steam-engine does the work of a hammer; drilling and slotting machines, to make holes of various shapes and sizes in iron; planing-machines, to bring surfaces to a true level; turning and screw-cutting machines, to give cylindrical forms to iron—all these are instructive examples of the working of iron, and of the employment of this metal in the machines and tools by which the working is effected.

2. Copper, Zinc, and Brass.

We now invite the reader's attention to *copper* and *zinc*, together with the valuable metal, *brass*, formed by their union.

Copper Mines and Smelting.—Copper, like most other metals, is generally found in combination with other substances, as an ore. In most cases it occurs in combination with oxygen, sulphur, iron, sulphuric acid, carbonic acid, and phosphoric acid. The kind with which we are most familiar in England is a compound of copper, iron, and sulphur, called *yellow copper ore*, or *copper pyrites*. This ore is found very extensively in Cornwall, Devonshire, and Anglesea.

The mining of the ore is an operation differing but little from the mining of iron and other minerals. The beds or veins lie at various depths below the surface. To get at them, the miner digs shafts, adits, levels, galleries, and other passages—vertical, horizontal, and inclined. By the aid of gunpowder and the pick, he loosens the ore from the strata of rocks that surround it; by steam-power he raises it to the surface; by pumps he drains away the water which must otherwise flood the mine and stop the working; and by ladders he ascends to and descends from his work.

The ore, when brought up to the surface, requires a more elaborate series of operations than would suffice for iron, because the necessity for purity is greater. The processes comprise various repetitions of roasting, calcining, melting, and refining. We may here remark, as a curious fact in the economy of manufactures, that nearly all the Cornish copper ore is smelted in South Wales. It is found, on striking a balance of advantages, more convenient to take the ore to the coals than the coals to the ore. The copper works near Swansea are large and fine establishments; but unfortunately they are day by day ruining the vegetation in the neighbourhood, by means of certain poisonous fumes given off from the furnaces.

The first thing done is to calcine the ore. Three or four tons are distributed over the brick floor of a furnace, where a brisk heat brings the ore to the state of a blackish crumbling mass, driving off any sulphur and sulphuric acid that may have been in combination. The black mass is then put into a smelting furnace, where it is brought to a molten state; it is well stirred, to make the metallic portion sink beneath the earthy impurities. More and more calcined ore is added and similarly treated, until the furnace contains as much as it can well hold. A tap or vent is opened, through which the metal flows into a vessel of cold water, where it sinks in a granulated state, deprived of a great part of its iron and its earthy matter. In this state, called *coarse metal,* it contains fourfold as much pure copper as the original ore. Again is the substance calcined, and again melted; a third time calcined and a third time melted, to get rid more completely of the impurities. From *coarse metal* it becomes *fine metal,* and then *coarse copper.* The pigs, or masses of this coarse copper, are thrown into a roasting furnace, and exposed to a degree of heat which brings them to the state of *blistered copper.* Another and final process is *refining.* It will thus be seen that seven or eight firings or heatings, managed with much precaution, are necessary to extricate the pure copper from the ore.

Copper Manufactures.—If manufactured articles in copper are neither so numerous nor so valuable as those in iron, they are in general more beautiful to the eye, and subserve purposes which no other metal can answer equally well. Copper takes a very high polish; it is malleable both when hot and cold; it may be beaten out into very thin leaves, and drawn out into very thin wire; and this wire, with two or three exceptions, is stronger than any other of equal thickness. Copper is very sonorous, and is a good component in sound-producing instruments. It conducts heat well, and is therefore good for boilers and cooling vessels. It conducts electricity well, and is therefore good for the wires of electric telegraphs. In pure dry air it does not readily tarnish. It requires such a high temperature to melt it, that it is safe over all but very intense fires. Lastly, it combines readily with zinc, tin, and other metals, thereby producing alloys very valuable in the arts.

For the chief manufacturing purposes, copper is generally bought in the form of flat cakes, about eighteen inches long by twelve wide, weighing about ninety pounds each. These are heated in small ovens called *muffles*, to the temperature of a bright red heat, and are then passed repeatedly between strong iron rollers. The rollers are brought closer and closer together, until the cake is lengthened fivefold, and diminished in thickness in equal proportion. The plates of copper thus produced are cut into pieces called *blanks*, which are heated in the muffle, and rolled out till twice as long as broad.

Several times are the heating and rolling repeated, until the metal is brought to the state of *sheet* copper.

The singular tendency of copper to yield to hammering without breaking is one of the most valuable of its manufacturing qualities. A copper vessel of six feet diameter is sometimes made in an extraordinary way. The copper is first cast into a mass resembling in shape a double-convex lens, like the object-glass of a telescope. The mass is hammered all over with great force, especially near the centre, by which the thickness is gradually rendered equable, and the edges made to curl up all round; until at length, a hemispherical vessel is produced. Iron would not bear any such operation as this. Multitudes of smaller vessels are produced by modifications of the same process.

Copper receives a great increase of density and toughness by *planishing*, which is only hammering under another name. Copper vessels are beaten all over with large smooth-faced hammers, to produce this effect; and these hammer-marks are to be seen on most of them.

Hammering, rolling, casting, drawing, stamping, —these, or some among them, are the processes by which copper is wrought up into form. Tea-kettles and tea urns, saucepans, coal scoops, copper fittings for ships and for steam-engines, copper sheathings for ships, copper coin and medals, copper buttons and ornaments—all, large and small, depend for their shape on such operations, aided by the mechanical processes of riveting, filing, polishing, &c. Copper pipes and tubes are made in a great variety of ways, depending chiefly on the malleability of the metal.

Zinc and Brass.—We are more familiar with *zinc* as a component of *brass* than as a separate metal: nevertheless, zinc manufactures are every year increasing in importance. Zinc does not occur in the native state. There are two ores, *calamine* and *blende*, the one a carbonate and the other a sulphuret of the metal, from which the supply is chiefly obtained. It is a peculiar process to drive off the carbonic acid and sulphur from these ores, by means of heat, in suitable furnaces. The ore, after calcination, is mixed with charcoal and put into a crucible; the zinc, separated by heat from the other ingredients, passes as a gas through a tube into a vessel of cold water, where it condenses into the metallic form.

There are properties in zinc which render it rather difficult to work. It is almost too hard to be filed; and is too brittle to be rolled into sheets at ordinary temperatures. Zinc is, however, very valuable in the arts. It is whitish and lustrous; it resists both air and moisture as well as common temperatures; it may be rolled into sheets and drawn into wire when heated to a certain point; and it is more fusible, for small castings, than copper. It is now largely employed for roofing, terrace coverings, chimney-pots, water-pipes, cistern linings, pails and buckets, and other purposes in which sheet-metal is available. It is not often employed in bulky masses, like iron or copper.

But the chief employment of zinc, perhaps, is in making *brass*, which is a compound of zinc and copper. To produce it, molten copper is poured into large ladles or colanders pierced with small holes; the copper passes through the holes in drops, and falls into a vessel of water beneath. If the water be hot, the copper solidifies into roundish drops like rain drops, which obtain the name of *bean-shot* copper; but if cold, the drops assume a ragged appearance, which earns for them the name of *feathered-shot* copper; and each of these has its own special uses.

As it was not until comparatively modern times that zinc began to be known as a simple metal, the ancients had no mode of making brass by mixing zinc at once with copper; but they obtained the same end in a different way. Calamine, copper, and charcoal were put together into a furnace; the carbonic acid of the calamine was driven off, and the zinc then combined with the copper to form brass. The moderns could make brass by simply combining the two metals; but they prefer to adopt a modification of the old process. The calamine is first broken into small pieces, and roasted in a reverberating furnace, to give off moisture and carbonic acid. It is mixed with bean-shot copper and powdered charcoal, and put into earthen crucibles. When melted, the compound is poured into long flat granite moulds, producing slabs or cakes of brass. By changing the proportions of ingredients and the details of process, *latten*, *tombac*, *pinchbeck*, *Muntz's metal*, and other mixed metals, are produced instead of brass. Sometimes blende or sulphuret of zinc is used instead of calamine; in which case it is necessary first to drive off the sulphur by roasting.

The usefulness of brass is indicated by the facts that this metal is harder, more fusible, and more sonorous than copper; that it turns well in the lathe, to produce highly-polished and durable instruments; that it draws out into excellent wire for pins; that it may be beaten out into thin leaves of *Dutch metal* or *Dutch gold*; and that for all kinds of articles, useful or ornamental, made by casting, it is more manageable than copper.

3. Tin, Lead, and Mixed Metals.

A very interesting group is formed by the soft metals *tin* and *lead*, and mixtures in which one or both take part: such as *nickel silver*, *tin-plate*, *solder*, *pewter*, *albata*, *German silver*, *Britannia metal*, *tutenag*, *bronze*, *bell-metal*, *speculum-metal*, *gun-metal*, *type-metal*, *fusible-metal*, &c.

Tin Mining and Smelting.—This valuable metal has been known from very early times, and has always been applied to peculiar uses on account of the properties it possesses. When pure, tin is one of the most silvery white of all metals. It is so malleable, that it may be reduced to the state of *tin-foil* less than a thousandth of an inch in thickness. It bears exposure to the air without much deterioration. It is very flexible, and may be bent to any shape without returning to its previous form. It melts at a lower temperature than almost any other metal, and thus assists in producing *fusible metal* by mixture with certain other kinds.

Nearly all the tin obtained in Cornwall and other parts of the world is derived from veins of *tin-stone*, an oxide of tin combined with various other metals; or from lumps of *stream tin*, which is an almost pure oxide. In Cornwall and Devon, the veins of tin-stone lie at various depths below the surface, and are reached by vertical shafts and horizontal galleries. When brought to the surface, the ore is *dressed*, that is, subjected to processes which drive off most of the early impurities mechanically mixed with it. The lumps are first broken with hammers into small pieces, and useless bits of sparry stone thrown aside. The ore is next *crushed* beneath rollers; then *jigged* or sifted in water to separate the tin-stone from the refuse; then *stamped* and *washed* in various ways, until everything is driven off that can be removed by mechanical means.

Next ensue the operations necessary for separating such impurities as are chemically combined with the tin. The crushed and washed ore is calcined in furnaces, to get rid of arsenical and other vapours. It is then mixed with culm, or powdered anthracite, and put into another furnace; heat is gradually applied, and various impurities are thereby expelled. Most of these substances may be skimmed off as a dross; and the molten tin is allowed to flow out of the furnace into a vessel. By degrees, all the iron, copper, arsenic, tungsten, sulphur, and other substances are driven off by the action of a refining furnace; and the refined tin is cast in granite moulds into blocks weighing about three hundred weight each. This is called *block-tin.* For producing the finest kind, stream tin is employed instead of tin-stone, and charcoal instead of culm. The stream tin is melted, refined, and cast into blocks; and these blocks being again melted, the metal is granulated by being allowed to fall from a height into cold water. Thus is produced *grain-tin.*

Everything connected with the tin trade of Cornwall is remarkable. The Prince of Wales, as Duke of Cornwall, is a sort of lord over most of the tin mines, and derives an annual revenue from some of them. Almost all the working operations are conducted by companies, who lease certain plots of ground for a certain number of years. They pay the landowner, not a definite money rental, but a per-centage on the value of all the tin ore they bring up to the surface. If the ore be deficient either in quantity or quality, the landowner as well as the company has to put up with smaller profits. The working-miners themselves have a partnership interest, as well as the shareholders of the company; for they undertake the digging and dressing of the ore at a rate that will depend on the proportion of pure tin contained in it; and therefore they, as well as all else concerned, are interested in discovering the probable quality of all the ore lying hidden beneath. This system develops the sagacity and observant powers of the miners.

It may here be added, that while all the Devon and Cornwall copper is smelted in South Wales, all the tin is smelted in those counties themselves. The same ships that carry copper ore to the copper works in one direction, often bring back coal to the tin works in the other.

TIN-PLATE AND TIN-WARE.—It is a curious fact in the tin manufacture, that most of the metal is used, not by itself, but as a covering to another metal. *Tin-plate* or *tinned-iron*, of which our kettles and saucepans are so largely made, is sheet-iron coated on both surfaces with tin: coated so firmly, too, although thinly, as to be remarkably durable. The tin renders iron culinary vessels neater to look at and to handle, easier to keep clean, less likely to affect the contents of the vessels, and less likely to be affected by those contents. The tin is applied as a liquid, a process rendered possible by the comparatively low temperature at which it melts.

In making tin-plate, the best sheet iron is employed, smelted with charcoal instead of coal or coke, and rolled to a high degree of toughness and strength. The plates, usually cut to the size of about thirteen inches by ten, are cleansed from rust or oxide by washing with an acid liquor, heating in an oven, pickling with another acid liquor, rubbing with hemp and sand, washing in pure water, and other processes. A mixture of block and grain tin is then melted in iron pots, and a little grease put on the top. The plates of sheet-iron, steeped for an hour in melted grease, are immersed in the molten tin, and become coated with it on both surfaces. The grease keeps the surfaces of the iron free from contact with the oxygen of the air, which would otherwise interfere with the union of the two metals. Certain finishing processes bring the two to an equable, smooth, and bright condition on the surfaces of the plates. Sometimes, instead of tinning plates of iron, and making vessels of them, iron vessels are tinned on the inner surface; here the molten tin is poured into the vessel, and worked about by a piece of cloth or hemp. Bridle bits, stirrups, nails, tacks, pins, and other small articles are easily coated with a brilliant white metal by thus dipping them into molten tin.

The working up of tin-plate into culinary vessels is a simple operation, but one calling for much dexterity. Large shears fixed to a bench, smaller shears held in the hand, hammers, mallets, steel heads, wooden blocks, swages, soldering irons—these are the chief tools. The tin-plate is cut by shears, and is easily brought to a definite form by beating with mallets on a properly shaped block; different pieces are united by soldering, and the hammer and swage finish up the work. Much tin-plate ware is made by stamping between dies; and the articles so stamped are often further ornamented by lacquering, painting, or japanning, or by receiving that beautiful appearance called *moiré metallique*, so much admired a few years ago.

Tin, as we have said, is used uncombined with other metals, but not extensively. One use is in making *tin-foil*, for placing at the backs of mirrors. This is produced by rolling out tin to a state of remarkable thinness.

LEAD MINING AND MANUFACTURES.—This metal very rarely occurs in nature in a pure state. It is obtained almost wholly from ores, such as *galena, native massicot*, and *native minium*. If we enumerate the properties of lead we shall appreciate the reasons why this metal is so much valued in the arts. Lead is soft enough to be easily bent; it is tough and strong in sheets, if not rolled to too great thinness; at common temperatures it is only acted upon slowly by the air; it is easily malleable, insomuch that a few blows with a mallet will close up a leaden pipe or bend a piece of sheet lead into any form. The ease with which sheets of lead can be cut, flattened down, bent, and soldered, have caused this metal to be extensively used for roofing, terrace-coverings, and cisterns; while it is perhaps the most generally useful of all metals for small water pipes.

Most English lead is obtained from galena, or sulphuret of lead, found in Derbyshire, Devonshire, Cornwall, and North Wales. The mineral occurs in beds or veins, and usually includes a small percentage of silver, with other but less valuable substances. The mineral is mined and brought to the surface in the same way as most other ores. When brought to the lead works, the ore is crushed and washed to get rid of such impurities as can be removed by mechanical means. The galena is then thrown into a furnace; the sulphur burns off; various earthy matters rise to the surface as a scum; the lead sinks in a molten state, and is ladled into iron moulds to make *pig-lead.*

Very delicate means are adopted for separating what little silver there may be in the lead. It may be as low a proportion as one ounce to the ton, or as high as a hundred ounces. The refiners have ascertained that it is worth while to undertake this work of separation if the silver exceeds three ounces to the ton. The pig-lead is melted and crystallized, melted and crystallized, over and over again, getting rid of portions of lead each time in the form of crystals, and leaving the silver behind. The remaining lead thus becomes richer and richer in silver, until it contains two or three hundred ounces to the ton. The silver is finally separated from the lead by another process, and the lead is brought back to the state of pig-lead by re-melting. There is a lead-mine owner in Derbyshire who possesses a complete and valuable service of plate, the silver of which was derived in this way from the lead in his own mine.

Lead is applied chiefly in the form of sheets to the more useful purposes for which it is fitted. To make *sheet-lead* the pigs are melted in large cauldrons, and poured out upon a cast-iron table covered with sand. Ledges at the sides of the table, and a long straight rod or roller, enable the workmen to spread out the lead in a sheet of definite thickness. More usually, however, at the present day, the lead is cast into the form of a large block, or cake, six or seven feet square, and weighing several tons; this block is drawn several hundred times between powerful iron rollers, by which it is thinned to any desired degree, and drawn out to a length of three or four hundred feet. Sheet lead produced in this way is called *milled* lead.

Lead *pipes* are made in a singular way. The lead is first cast into a short but very thick cylinder; the cylinder is then drawn by intense steam power through a series of holes in steel dies, the holes, being in a series, becoming smaller and smaller as the operation proceeds. The lead stretches out in proportion to the degree in which the external diameter is reduced. The inner diameter or bore remains constant, by means of an iron rod kept inserted in it.

Lead is useful for many minor purposes; among which is that of fastening iron rails into masonry. This is easily managed on account of the low temperature at which lead melts allowing it to be easily poured from ladles into holes prepared for its reception.

Mixed Metals.—The mixed metals, in most of which either copper or tin is an ingredient, are both numerous and useful. Sometimes the mixed metal possesses qualities intermediate between those of the components; while in other cases new qualities are developed, and thus manufacturers are provided with metals possessing certain properties in any desired degree. We have already noticed *brass*, *latten*, *tombac*, *pinchbeck*, *Muntz's metal*, *Dutch metal*, &c., formed by various mixtures of copper and zinc; and a rapid glance will now be taken at a number of other mixed metals highly useful in the arts.

Bronze is a combination of about nine parts of copper with one of tin; it is harder and more fusible than copper, and is on that account much valued in certain branches of manufacture. Statues are cast in bronze more frequently than in any other metal; and England is now receiving an exchange of pence, halfpence, and farthings in bronze for others in copper. *Bell-metal* is formed of four parts of copper with one of tin; it is more sonorous, giving a louder and more musical sound when struck, than any other metal. *Speculum-metal*, for making the reflectors of telescopes and microscopes, consists of about two parts of copper to one of tin. Notwithstanding that the reddish metal copper is in twofold proportion to the white metal tin, this compound presents an exquisitely white reflecting surface when polished. *Gun-metal* is a mixture of copper and tin, not differing very much from bronze. *Tutenag*, of which the Chinese make their loud-sounding *gongs*, is a compound of copper, zinc, nickel, and iron; it is silvery white, very sonorous, and takes a fine polish. *Cymbal-metal* is something between bell-metal and gong-metal. *German silver*, now used largely as a substitute for real silver, is nearly like tutenag in composition, but without iron. *Albata* is another silvery-white metal, made chiefly of zinc and tin. *Nickel silver* is another, containing nickel as one of the components. *Britannia-metal* is made of tin, antimony, copper, and brass, mixed in certain proportions; it is brilliant, white, light, cheap, and worked with great facility, and is largely used at Sheffield and Birmingham for making tea and coffee pots, candlesticks, and other articles. The four mixed metals, last named, are very extensively used in the arts as substitutes for the more costly metal, silver.

Numerous as are the mixed metals noticed above, there are still others worthy of notice. *Solder* is a general name for any metal which, used in a molten state, serves as a cement for other metals in a solid state. Thus, *hard brass solder* is made of brass and zinc; *soft brass solder* contains also a little tin; *copper solder*, made of copper and zinc, is softer than either of the above two; *pewter solder* consists of five parts of lead, one of tin, and one of bismuth, and melts at a comparatively low heat; while *plumbers' solder* consists of equal parts of lead and tin. *Pewter*, largely used for beer measures, consists of about four parts tin to one of lead, with sometimes a little antimony and copper; although easily bent, it will bear much rough usage without breaking; and on this account it was formerly often used for plates and dishes. *Type-metal*, for making the small types used by printers, is not always alike in composition; but lead is invariably the chief component. The other metals are chiefly tin, antimony, or bismuth, or two out of these three. Bismuth has a curious effect on the mixture; it is one of the few metals that expand in cooling; and this property enables it to fill up the deep corners of the type-moulds, thereby rendering the types clear and sharp. *Fusible-metal* is a common name for any kind that melts at a very low temperature; one variety consists of five parts of bismuth, three of lead, and two of tin; this melts at as low a temperature as that of boiling water. One particular mixture melts at even a lower temperature than this; and it is a familiar puzzle or trick to give a visitor a tea-spoon made of such metal; the spoon melts in the tea, if the latter be very hot. There are certain qualities which render some of the fusible metals fitted for making stereotype plates, and also for the blocks employed in calico-printing. *Safety-valve* or *plug-metal*, of reddish metal copper is in twofold proportion to the white metal tin, this compound presents an exquisitely white reflecting surface when polished. *Gun-metal* is a mixture of copper and tin, not differing very much from bronze. *Tutenag*, of which the Chinese make their loud-sounding *gongs*, is a compound of copper, zinc, nickel, and iron; it is silvery white, very sonorous, and takes a fine polish. *Cymbal-metal* is something between bell-metal and gong-metal. *German silver*, now used largely as a substitute for real silver, is nearly like tutenag in composition, but without iron. *Albata* is another silvery-white metal, made chiefly of zinc and tin. *Nickel silver* is another, containing nickel as one of the components. *Britannia-metal* is made of tin, antimony, copper, and brass, mixed in certain proportions; it is brilliant, white, light, cheap, and worked with great facility, and is largely used at Sheffield and Birmingham for making tea and coffee pots, candlesticks, and other articles. The four mixed metals, last named, are very extensively used in the arts as substitutes for the more costly metal, silver.

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4. Gold, Silver, and Money-making.

All the metals hitherto noticed are small in value compared with the two which are now to engage attention, *gold* and *silver*.

Gold and Silver Mining and Refining.—The most precious of all the metals, as the world calls it, is met with in various countries underground, but nowhere in large masses. It is usually small in quantity in any one place, and combined with many other substances. Some years ago, South America was the chief storehouse for gold; next ranked Siberia; but in later years California and Australia have taken the lead. Sometimes nuggets or small pieces are picked up, nearly pure, varying in weight from a fraction of an ounce up to many pounds. At other times the gold is found in small grains, mixed with the sand and mud of rivers. Sometimes, again, it is combined with quartz, in a crystalline form, and in proportions that vary within very wide limits. The gold-diggers, now at work so largely in California and Australia, seek for gold chiefly near rivers. They wash the river sand, or dig into rocks, according to the indications that may be presented. If they are poor, ignorant men, they dig and search without much system, and experience many periods of privation between their moments of good fortune; but if many work together, and invest a little money in labour-saving machinery, their chances of success become much more considerable. At the diggings are agents of bankers and bullion-dealers, ready to purchase all the gold and gold ore, at a price depending on the ratio of pure gold contained in each specimen.

The ore containing gold is crushed, ground, washed, and otherwise treated, to separate all earthy matters from it. Any baser metals that may be in combination are removed chiefly by the aid of quicksilver, which, when heated, helps to carry off those metals, and leave the gold behind. When thus separated, the gold may be cast into blocks or ingots; and these may be rolled into plates, stamped into coin, beaten into leaves, or drawn into wire, with great facility. Gold is so malleable, that it may be reduced by hammering to one 250,000th part of an inch in thickness. It is so ductile, that one grain may be drawn out into five hundred feet of wire. It is so little affected by external agents, that it suffers scarcely any change from air or moisture. It has just that degree of softness which enables it to be stamped easily without wearing very rapidly when stamped. These properties, together with its splendid colour, and the high polish which it takes, render it universally admired.

A companion 'precious metal,' *silver*, is found in various parts of the world; but it has not, like gold, been marked by a great increase of discovery within any recent period. The silver mines maintain pretty nearly a steady uniformity in number and productiveness, taking one with another; although there are fluctuations in richness in each particular mine. Sometimes a mass weighing five or six hundred pounds, nearly pure, will be found; but the pure specimens are few in number, and generally small in size. The silver ores of Mexico and South America, which are the kinds best known to us, mostly contain sulphur, antimony, or muriatic acid. Some of the veins are a hundred or a hundred and fifty feet in width, and have been worked to an extent of eight or ten miles. These ores are seldom rich. Taking an average of all in Mexico, it is found that one hundred pounds of ore contain barely four ounces of silver. Sometimes, as in the rich mine of Copiapo, ore is met with in which more than half the weight is pure silver; but to counterbalance this, there are other mines in which one thousand pounds of ore contain only two ounces of the precious metal. According to the components of the ore, so do the processes vary for extracting the silver. The ore is crushed and ground, roasted and washed, melted and stirred; the ingredients, one by one, are separated by skimming, subsiding, or volatizing; and refining, by means of quicksilver, carries off the last remaining metallic impurity. All these processes, as also those for gold, resemble in principle those described in former sections connected with the coarser metals; the chief difference being, that they are more carefully conducted.

GOLD AND SILVER WORKING.—Scarcely is it possible to enumerate all the uses to which these two beautiful metals are applied. We can only glance at the principal among them.

For making *gold-leaf*, the gold is brought, by means of flatting mills, to the state of a thin ribbon. This ribbon is cut up into pieces about an inch square; and the pieces, by repeated blows with heavy hammers (which are kept from touching the gold by the intervention of leaves of goldbeaters' skin), are spread out gradually in length and breadth. The gold is reduced to less than one 250,000th of an inch in thickness. Though so exquisitely thin, the gold is unbroken, and can be applied to various kinds of gilding. *Silver-leaf* is prepared by means of hammers in a similar way, but cannot be brought to so great a degree of thinness. *Gold and silver wire*, for numerous purposes in the arts, is made by preparing a cylindrical rod of the precious metal, and dragging this rod forcibly through a series of holes; the holes are graduated in size; so that the rod becomes converted into a thick wire, and this into wire of any required degree of thinness. For making *gold lace*, wire, made in the way just described, is flattened by a highly-finished steel rolling mill, and twisted round a thread of silk; the compound thread, thus made, is finally woven or twisted into a kind of lace or braid. *Silver lace* is made in a way nearly similar.

In making *gold and silver plate*, such as presentation salvers, racing cups and vases, and table services for state occasions, most of the mechanical processes already more than once noticed—casting, rolling, cutting, hammering, tube-drawing, stamping, pressing, soldering, and the like—are employed. The chief difference is, that these processes are conducted more delicately, both in extent and in manner, on account of the great value of the gold and silver operated upon. Burnishing, chasing, and engraving, are other processes by which the work is brought to a finished state. For making *gold and silver coin*, operations are conducted of so curious a kind, as to deserve a little separate attention presently. For *gilding* picture and mirror frames, and other articles of ornamental character, the gold is used in the form of leaf. The surface on which the gold-leaf is to be laid, whether of wood, papier-maché, carton-pierre, or composition, is prepared in a particular way for its reception, by layers of gold-size and other substances; and the gold, when applied, is finished by burnishing and other processes. *Silvering* is a similar application of silver leaf, but is not so much employed. For *gilding buttons*, and other small metallic articles of use and ornament, the gold is first combined with quicksilver into a paste; the paste is applied with a brush to the articles, which are first prepared for its reception by aquafortis; and then a carefully applied heat, driving off the quicksilver, leaves the gold behind it as an extremely thin but adherent film, which may be further improved by burnishing. This is often called *water-gilding*, but the name is an inappropriate one. The costly articles of *silver-gilt* work are made by preparing the article in solid silver, and then applying a surface of pure gold by the so-called process of water-gilding. Another mode of applying a thin layer of gold or silver, by electric action, will come separately under notice shortly. *Plating*, or *silver-plating*, is a mode of making ornamental goods, in which a common metal acts as a foundation or basis for a surface of silver. In the first place, a thin plate of silver is placed upon a thick plate of copper, albata, or some other metal; the two are rolled together to any required degree of thinness; the silver is thinned as well as the baser metal, until it is at length only a mere film. Out of the sheet of compound metal thus prepared, candlesticks, dish-covers, and other articles are made, by various mechanical processes.

THE MINT AND MONEY-MAKING.—The coining of money takes rank among the most delicate kinds of working in metal; so numerous are the precautions to insure excellence in quality and accuracy in quantity. The Mint, on Tower Hill, contains an array of beautiful machinery for these purposes.

Let us take one particular coin, a sovereign, as an example of the mode of making all. The die-sinker or engraver prepares two engravings, to represent the devices on the two sides of a sovereign; they are engraved on small pieces of soft steel, which are afterwards hardened. Each of these engravings constitutes what is called a *matrix*, which, by immense pressure, is made to produce a *mould* in a soft piece of steel; the matrix is hardened; by pressure a copy is obtained from it in soft steel; and this copy, when hardened, is used as a die to stamp the coin. The same matrix will produce a great number of dies in this way.

The gold requires much preparation before it is fitted for stamping. It is sent from the refiner's to the Mint, in bars or ingots worth about 700*l.* each. The gold is assayed, or tried, and brought to the exact state (slightly alloyed with silver and copper) called *sterling*. Several ingots are melted, and cast into a long flat golden bar worth nearly 5000*l.* This bar is passed many times between highly-polished steel rollers; then cut into pieces; then annealed in an oven; then rolled again—and so on, until it is reduced to the form of a long broad ribbon, exactly as thick as a sovereign. The most rigid precautions are taken to insure equality of thickness. The ribbon of gold is then cut into *blanks*, small circular pieces containing exactly the quantity necessary for one sovereign each. Several powerful presses are employed for this purpose; boys place the ribbons of gold in the machines, and shift them after each cut; while punches are brought down with force enough to stamp out the blanks. In busy times, as many as two hundred thousand sovereign-blanks are punched out in a day, at the Mint. All the scrap, called *scissel*, or cuttings, is sent back to the furnace and re-melted.

There come now into operation several weighing machines of exquisite construction. Piles of blanks are fed into the machine; these separate themselves into three groups, and fall into three boxes, according as they are *heavy*, *medium*, or *light*. They weigh themselves, rather than are weighed. The heavy and light blanks are cast aside to be re-melted; the medium blanks, which generally comprise forty-nine out of every fifty, are reserved for coining. Another machine then takes each of these proper or medium blanks, and, by a peculiar movement, rolls the edge smooth and circular, and makes it project slightly on each surface. Then they are heated in a fire, cooled in water, cleansed with dilute sulphuric acid, and dried with hot beechwood sawdust.

Now comes the stamping. The die is placed on a firm stand or basis; and the counter-die is held fast in a moveable frame over it. Blanks are fed into the machine through a tube, and fall upon the die one by one. Directly a blank thus takes its position, the counter-die, acted upon by steam power, comes down upon it with great force, and both sides receive the impress at one time. Not only so, but the *milling*, or series of little lines and hollows at the edge, is produced by the same action.

Half sovereigns are made in a similar way; so are the various kinds of *silver* coins, with minor changes in the routine of processes. Generally speaking, *copper* coins have been made for the Government by private firms at Birmingham; and so are the hard, small, light, neat, bronze coins now used instead of copper.

5. Quicksilver and Electro-metallurgy.

There are many metals too scarce or too unimportant to claim notice in this little work; but one, *mercury* or *quicksilver*, must not be passed over unheeded. And there is one peculiar mode of working in metal—*electrotyping* or *electro-metallurgy*—that equally deserves description.

Mercury and Quicksilvering.—Mercury is one of the most remarkable of all metals. It is the only one that is liquid at ordinary temperatures; and it is unquestionably the most brilliant of all colourless liquids. Its mode of extraction is remarkable, as is everything else relating to it. Most of the supply is obtained from Almaden in Spain, and Idria in Carniola. The ore that contains it is chiefly *cinnabar*, or sulphuret of mercury. The mines at Almaden, about fifty miles from Madrid, are the most extensive of the kind in the world. They are worked in part by convicts, who remain only three hours a day underground, on account of the unhealthiness of the employment. The cinnabar is a stony substance, which is treated much like other metallic ores. The proportion of pure mercury varies from three to ten ounces in a pound of ore. The mines belong to the Spanish Government, who make all the arrangements for working them. There are twelve large ovens for smelting the ore, named after the twelve apostles.

The quicksilver mines of Idria, though less valuable, are no less remarkable than those of Almaden. The miners descend to a depth of nearly eight hundred feet, by a staircase cut in the rocks. The mining operations are conducted in galleries, where the cinnabar is found in veins from two to six inches in thickness. It is of a dull-red colour, and is sufficiently soft to be wrought easily with the pickaxe.

When the mercury is to be obtained from the ore, the ore is broken, sifted, and crushed. This crushed ore is thrown into furnaces, with iron, lime, or some other agent, and heated; the agent combines with and carries off the sulphur, leaving the mercury in a state of vapour. This vapour passes off into another vessel, and cools down to a liquid state. When purified by filtration, it is packed either in sheepskin bags or in iron bottles. This beautiful metal is more than thirteen times as heavy as water; it does not pass into vapour until heated up to 650° F.; nor does it freeze down into a solid until the intense cold of 40° below zero, or 72° below the freezing point of water, is reached.

One of the chief uses of mercury is for amalgamation. When gold or silver is combined with other substances in ores, mercury is a valuable agent for separating it. The precious metals have a strong affinity for mercury. When heat is properly applied to them, they quit the other ingredients of the ore to combine with the mercury, forming what is called an *amalgam ;* and when this amalgam is again exposed to heat, the mercury goes off in vapour, leaving the gold or silver behind.

Another remarkable employment of mercury is for *silvering looking-glasses.* The term is not a proper one, for there is no silver employed; it would be more correct to say *quicksilvering.* In this process, a sheet of thin tin-foil is spread out on a very smooth flat stone; it is flooded all over with mercury; the glass is laid upon it in such a way as to expel air-bubbles; and heavy weights are laid on the glass. The weights press out all the superfluous mercury; and the remainder combines with the foil to form an *amalgam,* or mixed metal of mercury and tin, which adheres with sufficient firmness to the glass.

In making barometers and thermometers, no other liquid is so useful as mercury, which expands and contracts readily, and remains in a liquid state at all except very high and very low temperatures. The filling of the slender glass tubes with mercury is a very delicate art; and it is a singular fact, in relation to the distribution of trades, that this art is practised in England almost exclusively by Italians.

ELECTRO-PLATE AND ELECTROTYPE.—The application of electricity to the production of beautifully pure, thin, and uniform films of metal, is one of the most remarkable recent inventions in manufactures. It is literally true that a cup or salver of copper or some other cheap metal may be put into a vessel of cold liquid, and taken out soon afterwards covered with a layer of absolutely pure gold; and that this layer by longer immersion in the liquid, might be made so thick as to constitute a cup or salver strong enough for use even when separated from the supporting metal.

If a galvanic current be made to pass through a metallic solution, the metal becomes separated, and deposited atom by atom on any surface suitable for its reception. According as the metal is gold, silver, or copper, for instance, so must there be selected a particular kind of liquid to hold it in chemical combination and so also is there a particular substance selected to form the surface on which the deposition is to take place. Cyanide of gold and potassium, cyanide of silver and potassium, sulphate of copper—these are some among many salts which are held in a diluted state in the vessels. The substances on which the deposition takes place may be of almost any kind—metal, wood, wax, plaster, paper, bits of lace, or even leaves, buds, twigs, or fruit. But in every case the surface requires to be prepared with some substance which has a particular chemical and mechanical relation to the deposited metal; black lead and phosphorus are two of the substances thus employed.

If we take one of the best specimens of Elkington's electro-plate, we shall find that its manufacture involves a large number of processes. The artist sketches a design. The modeller makes a model from this design, in wax or composition. The moulder casts a lead mould from the model. The pattern-maker produces a brass cast or pattern from the leaden mould. This pattern represents in form and proportion the article to be made; and as it is formed of strong metal, which will serve as the basis for any number of copies, the original model may be broken up. A sand-mould is made from the pattern; and a cast is obtained from this mould in a peculiar white metal bearing some resemblance to silver.

The white metal basis for an article in electro-plate may either be prepared by these elaborate processes, or by the mechanical operation of stamping, rolling, hammering, swaging, embossing, &c., according to its form. In either case, when ready, it is immersed in a chemical solution of gold or silver, and a galvanic current sent through the liquid. The precious metal separates from the other constituents, and settles on the white metal in an exquisitely thin film, which may be thickened to any required degree. A plate of the precious metal, whichever of the two kinds it may be, is hung in the liquid, to feed the latter as it becomes impoverished.

When properly conducted, the process leaves a permanent deposit of one metal on the surface of another; and thus electro-plate of great beauty is produced at a cheap rate. Sometimes the operation is employed, not for saving valuable metal, but for faithfully copying devices engraved on metal plates. Thus are produced fac-similes of engraved pictures and maps, engraved printing-cylinders, stamped coins and medals, and numerous other works of use and ornament, under the designation of *electrotype*.

Many other metals might engage a little of our attention on account of their curious properties. Scientific chemists have detected and separated about fifty metals altogether, without reckoning those which consist of alloys or mixtures of two metals; but only a few of them (chiefly those described in this chapter) have been brought practically into use by man; and three-fourths of the number have never been seen but by the eyes of scientific inquirers. Iron, copper, zinc, tin, lead, gold, silver, mercury—these eight, with mixed metals formed by combinations of two or more of them, are those wherewith our workshops and our every-day operations are mostly concerned. It is true that there are other metals which form the bases or groundwork of the invaluable substances salt, soda, potash, clay, lime, &c.; but these are not known in the metallic form to one person in one thousand: we are told that they exist, on evidence which is trustworthy, but few of us know of their existence from the evidence of our own senses. In considering the subject of metals generally, it is impossible not to be struck with the fact that the most *precious* metals, so called, are far from being really the most precious to man. It is a grand fact that our colonies in Australia and America contain gold which is every year enriching those countries; but how insignificant this wealth becomes when we compare it with the iron of England! The gold we could dispense with; but how about the iron? Place a lump of gold and a lump of iron before a rude dweller in the plains and forests, unprovided with the means of effecting an exchange or barter with more civilized nations; or let all the gold and all the iron be in imagination swept away from England, compelling us to begin over again our social existence as a nation—the relative merits of the two metals would soon be made apparent.

MINERALS AND CHEMICALS.

1. GEMS AND PRECIOUS STONES.

GEM-CUTTING AND LAPIDARY WORK.

2. POTTERY, PORCELAIN, AND EARTHENWARE.

POTTERY AND EARTHENWARE. — DECORATED WARE AND PORCELAIN.

3. GLASS AND ITS MANUFACTURE.

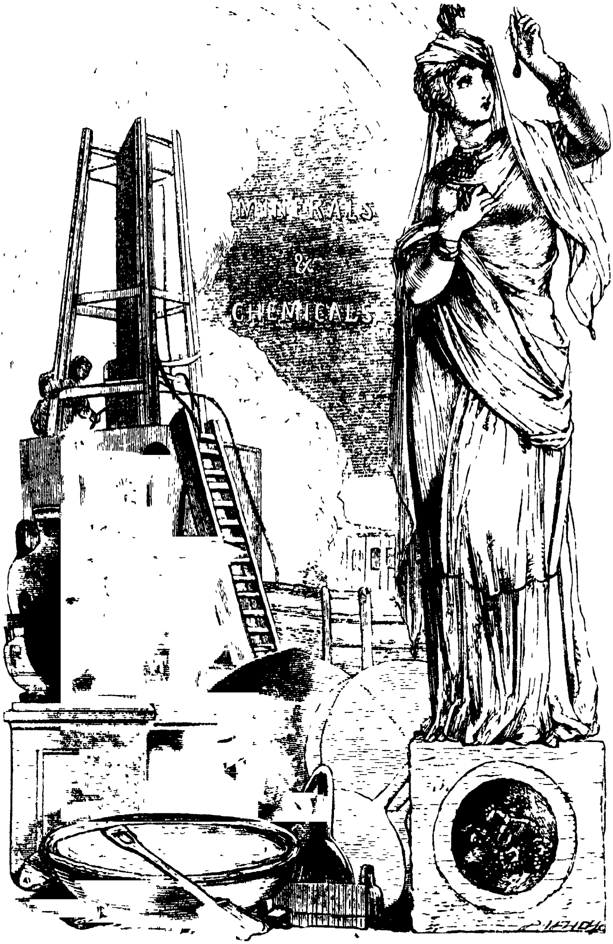
FLINT GLASS OR CRYSTAL.—WINDOW, PLATE, AND BOTTLE GLASS.

4. ACIDS, ALKALIES, AND OTHER CHEMICALS.

COMMON OR TABLE SALT—SODA.—POTASH.—SOAP MANUFACTURE.—SULPHUR OR BRIMSTONE.—SULPHURIC ACID OR OIL OF VITRIOL.—NITRIC ACID OR AQUAFORTIS.—SALTPETRE OR NITRE.—GUNPOWDER.—GUN-COTTON.—ALUM AND ALUMINIUM.

5. PAINTS, COLOURS, AND DYES.

ANIMAL DYES AND COLOURS.—VEGETABLE DYES AND COLOURS.—MINERAL DYES AND COLOURS.



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CHAPTER VI.

MINERALS AND CHEMICALS.

This chapter will pass in review a number of substances, and processes relating to them, which belong especially to the group of *minerals* and *chemicals*. Many materials have already been noticed, such as *stone*, *slate*, *lime*, *cement*, *mortar*, *concrete*, *plaster*, *clay*, *bricks*, *tiles*, *coal*, and *coke*, which take rank among minerals; and many others which, in the mode of their production and their mutual action, are chemicals. There are, however, certain others that will afford an ample reward to those who study them—such as *gems* and *precious* stones; *pottery* and *porcelain*, *glass*, *salt*, *soda* and *potash*, *soap*, *sulphur*, and *sulphuric acid*, *aquafortis*, *saltpetre*, *gunpowder*, *alum* and *aluminium*, *dyes*, and *colouring drugs*.

1. Gems and Precious Stones.

What are *gems*? It is nothing but the fancy or liking of men that determines which stone shall be called a gem or a precious stone. If one stone appears to us more beautiful than another, it is a precious or highly-prized stone *to us;* and if it be very rare and costly, we call it a gem. For the sake of convenience, however, certain natural stones are, by general consent, placed in the list of gems; partly on account of their beautiful colours, partly for their extreme hardness, and partly in relation to the exquisite polish which they take. The hardest of these are chiefly the *diamond, sapphire, chrysoberyl, ruby,* and *zircon.* The next in hardness are the *agate, amethyst, aquamarine, bloodstone, carnelian, carbuncle, cat's-eye, chalcedony, chrysolite, chrysoprase, crystal, emerald, garnet, jade, jasper, lapis-lazuli, onyx, opal, sardonyx,* and *topaz.* The softer kinds, such as *alabaster, coral, jet, malachite, satinstone,* &c., are not usually called precious stones, although they rank among articles of ornament.

GEM-CUTTING AND LAPIDARY WORK.—All gems and precious stones are met with naturally, occurring with other fragments of stone under various circumstances. The *diamond* is the most valuable of all known substances, and is at the same time the hardest. Few things in chemistry are more remarkable than the identity of composition between carbon or charcoal and diamond. The diamond is absolutely pure carbon, in a crystalline form. Formerly, the supply came chiefly from Golconda, in the East Indies; but at present most of the diamonds are brought from Brazil. They occur as rough pebbles, and do not present much beauty of appearance until they have passed through the hands of the diamond-workers. These workers are ranked in classes, according as they are skilled in cutting, splitting, sawing, or polishing these valuable gems. Diamonds may be split by a sharp blow from a peculiar knife, applied in a particular direction. They may be sawn in two, by a saw made of fine brass wire: particles of diamond powder, moistened with olive-oil, serve the place of teeth to the saw. They may be cut to make *facets*, or small flat surfaces, all over them, by a slow process of grinding with diamond-powder. And they may be polished, by the patient application of certain polishing substances. Thus have been prepared those diamonds which have acquired notoriety—such as the *Pitt* or *Regent diamond*, the *Pigott diamond*, the *Austrian Royal diamond*, the *Nassuck diamond*, the *Grand Russian diamond*, and the world-renowned *Koh-i-noor*, or 'mountain of light,' now the property of Queen Victoria.

All the other gems are of less value and brilliancy than the diamond; but many of them have nevertheless been objects of attraction from a very early period of the world's history. The *sapphire*, next in hardness to the diamond, varies in all shades of blue, from deep indigo up to nearly white. It is found in Pegu, Ceylon, and a few other places, mostly in the sand of rivers. The deep-blue specimens are most valued, especially those that have a star-like radiancy, and are called *asterias*. The *ruby* is nearly as hard as the sapphire, and varies in tint from purple, through crimson and rose-colour, up to pinkish-white; it is brought chiefly from Ceylon, Pegu, Sweden, and Mount Vesuvius. The *hyacinth* varies in colour from orange-red to whitish-yellow, and is found in various parts of the East. The *topaz* is a beautiful gem, generally of a yellow colour; the largest known, in the Museum of Natural History at Paris, weighs four ounces. The *emerald* is not so hard as most other gems; but its beautiful grass-green colour makes it an object of great admiration. The *beryl* or *aquamarine* is very similar to the emerald, except in colour, which is blue. The *garnet* is a rich blood-red gem; the *amethyst*, a kind of rock crystal, has a beautiful violet colour; and the *chrysoprase*, an apple-green tint. The *carnelian* and the *chalcedony* differ only in their colour; the former is orange, yellow, or red; while the latter varies from white to light-blue. The chalcedony, when varied in tint in a peculiar way, becomes the *onyx* or the *sardonyx*, much used for engraving into *cameos*. *Opal* is a gem remarkable for that peculiar kind of lustre called from it *opalescence*.

All these gems, and others of less importance, are cut, ground, and polished by the lapidary. He employs chiefly a *mill-plate* or *mill-wheel*, revolving rapidly on a vertical axis. This mill-wheel is made of copper, lead, or hard wood, according to the hardness of the gem to be ground; and it is wetted either with diamond powder and olive-oil, or with emery and water. The gem is cemented to the end of a short rod, and applied to the upper surface of the mill-wheel, which grinds it away by friction. In this way the facets or little flat surfaces of gems are produced. Some gems are split before grinding, to make a greater show with a given quantity. The polishing is effected in the same way as the grinding, excepting that the wheels and the frictional powder are of finer texture.

2. Pottery, Porcelain, and Earthenware.

Perhaps the most generally useful of all the applications of earthy substances, in their soft or plastic state, is that which is so well known to us by the names given in the above heading.

Pottery and Earthenware.—Clay, when moist, can easily be moulded into form; when baked in an oven, it becomes hard and durable; and when coated with a liquid which turns vitreous under the action of fire, it becomes glossy, clean, and well fitted to resist corrosive action.

In making *coarse red ware,* such as garden pots and red pans, a common kind of clay will suffice. For *brown stoneware,* such as water-jugs, washing-pans, &c., a finer clay is needed, that will harden almost to the consistence of stone. For *earthenware,* such as the blue and white dinner and tea services now so extensively used, the clay requires the addition of some kind of stone or flint. For the finest *porcelain* or *china-ware,* the clay and stone require to be selected with great care, and to be used in due proportion.

Let us take an earthenware tea-cup as an example. Clay of a particular kind, obtained from Devon, Cornwall, and Dorset, is found better than any other in England for this purpose; it is whitish, smooth, and pure, and bakes well. At the pottery works in Staffordshire or elsewhere, the clay is brought to a creamy state with water. Flint or flinty stone is burned in a kiln, crumbled into pieces by suddenly plunging in cold water, ground to powder in a mill, washed to a very pure state, and mixed with the pulp or clay-cream. The mixture, called *slip*, after being agitated and sifted, is evaporated until brought to the state of a soft clay. This clay, after a few more processes, is in a fit state for making into earthenware.

The *throwing* of a tea-cup or other vessel, by means of the *potter's wheel*, is a curious operation. This wheel is a small circular stand, made to rotate horizontally by means of a winch handle and band. A piece of prepared clay, large enough to make the vessel, is laid upon the stand, and made to rotate with it. The potter, wetting his hands and applying them to the clay, works it about in various ways; raising it up, pressing it down, hollowing it on the inside, fashioning it on the outside; until, without the aid of any tools, he has brought it to the proper shape. When about half dry, the vessel is turned in a lathe, to give it a true and smooth shape, and to produce rims, rings, &c. If, like a jug, the vessel requires a lip, a slight pressure produces one; or else a piece of clay is stuck on at a place made vacant to receive it. If, like a tea-cup, it requires a handle, a small slip of clay is moulded to the form and stuck on, liquid clay being used as a cement. Sometimes the spouts and handles are very ornate, in which case they are pressed in moulds; but for common articles these appendages are made and fixed with wonderful quickness.

When the tea-cup or other vessel, fully formed and turned, leaves the hands of the maker, it is laid aside to dry. After this it is baked in an oven. In order to make the best use of a large fire, many newly-made articles of earthenware are put into large oval cases called *seggars*, and the oven is nearly filled with several such. Here the ware remains about two days and nights, exposed to a fierce heat, which bakes the clay to the state of a fine stone. If the clay and flint have been selected with care, the ware comes out perfectly white. It is, however, dull or unglazed, in the state called *biscuit;* and this biscuit requires to be glazed before it will be fit for use. The glaze is a liquid, usually made of litharge and flint reduced to a powder and mixed with water to the consistence of cream. The ware is dipped in this cream, and then put into a glaze-oven; here the heat converts the liquid into a true glass, which imparts both beauty and usefulness to the ware.

Decorated Ware and Porcelain.—The earthenware cup just described is supposed to be plain and white, without any adornment whatever. In practice, however, such plain ware bears but a small proportion to that which receives some sort of beautifying, by means either of ornament or of colour.

Some kinds of ware, such as plates and saucers, shallow in proportion to their width, are made by pressing clay upon a mould; and according as the mould bears devices of foliage, flowers, &c., so would the ware be ornamented. A kind called *dipped ware* has rings and ornaments produced on the surface by means of liquid coloured clay. Articles of more complicated shape than can be produced by throwing or pressing, are made of creamy clay poured into plaster moulds, and carefully solidified by drying.

But the *blue printed* ware is that for which England has become celebrated all over the world. No other country produces anything like so large a quantity of this kind, or so cheap in relation to its excellence. Let us suppose a blue dinner-plate to be under preparation. A designer in the first place prepares a pattern. An engraver next engraves this upon copper or steel, possibly aided in so doing by the electrotyping process. The printer then takes impressions from the plate, on very thin but tough paper, with an ink formed of peculiar metallic colours mixed with oil. This impression, cut out with scissors nearly to the shape, is laid upon the dinner-plate while in the biscuit or unglazed state, and rubbed well down with a wad of flannel. By subsequent dipping in water, and a slight rubbing, all the paper is rubbed off, leaving the ink or paint on the ware. The heat of a kiln drives off the oil, and develops the blue colour of the device. A process of glazing then finishes all.

Porcelain or *china-ware*, as we lately observed, requires a more careful selection both of materials and of processes than earthenware. Calcined flint, calcined bone, Cornish stone, and Cornish clay, are the ingredients generally employed. The calcining, grinding, mixing, liquefying, evaporating, and kneading, are all most carefully conducted, to produce a plastic mixture of great whiteness, smoothness, and uniformity. The porcelain vessels are made in a way that may be inferred from the foregoing descriptions. The *thrower* produces the greater number of them, by means of the potter's wheel. If throwing will not suffice, turning, pressing, and moulding are resorted to.

The *painting* and *gilding* of porcelain are delicate arts. The paints are composed of metallic oxides, mixed to a proper state with essential oils; while the gold is brought to the state of a paint or solution. The paint is laid on with small camel-hair brushes or pencils, and the painters must all be men of taste—some having a knowledge of flowers, some of foliage, and so forth. Some kinds of porcelain are painted all over in one uniform colour, with or without coloured devices. Gold is applied just like paint, with a brush. When done, none of the colours appear bright, nor does the gold present a metallic appearance. The magic change is brought about by heat. The ware, when painted and gilt, is put into an *enamel kiln*, where it is heated just sufficiently to dissipate the oil, and cause the metallic colours to combine with the porcelain; then it is, and then only, that the colours display themselves.

The painting and gilding are effected after the baking and glazing. Nothing now remains but to *burnish* the golden portion of the adornments; this is done with pieces of very hard and smooth stone, such as agate.

3. Glass and its Manufacture.

This beautiful substance has been known from very early times, and has been highly valued wherever known. It is one of the few products of man's industry which are at once solid, colourless, and transparent. The usefulness of glass as a material for windows is evident; but the smoothness and clearness of the substance, as well as its power of bearing the action of a large number of chemical liquids, render it invaluable as a material for vessels; while its great reflective brilliancy, when silvered or rather quicksilvered on one surface, points to its fitness for looking-glasses or mirrors. The chief kinds are known by the names *flint*, *crown*, *sheet*, *plate*, and *bottle* glass.

Flint Glass or Crystal.—Any kind of hard stone, melted with any kind of alkali, will produce glass. *Flint* is the most available and generally useful of the kinds of stone employed, and *soda* or *potash* the most usual alkali. Of certain metallic oxides, used to impart additional good qualities to glass, the oxide of lead is the chief. These three substances, therefore, may be regarded as types of all those employed in glass-making. Sea sand is nearly pure flint, and is a material highly valued by glass manufacturers: especially the kinds obtained from the Norfolk coast and from Alum Bay in the Isle of Wight.

Flint glass is the kind of which tumblers, goblets, wine-glasses, decanters, &c., are made; as well as numerous articles of decorative furniture and fittings. It is made usually from sea sand, carbonate of potash, and oxide of lead; with minute additions of manganese and arsenic to increase the colourless transparency of the glass. The sand is first carefully washed, to rid it of all impurities, and then dried in an oven. The carbonate of potash is in like manner cleansed, till brought to the state of fine grains. The oxide of lead is used to assist the melting of the other ingredients, and to render the glass more heavy and massive, more lustrous and brilliant, more ductile for working, and better fitted to bear alternations of heat and cold.

The melting-pots employed in glass-making are made of Stourbridge clay, and will contain nearly a ton weight of materials. Several such pots are ranged circularly in a large furnace; and when brought to a white heat, they are filled with a granular mixture of sand, alkali, and oxide. After many hours, the mixture arrives at the state of a golden liquid, or rather golden paste. And now the working begins. A workman thrusts the end of an iron tube into the molten glass, takes up a portion, and blows through the tube. The mass of glass expands in the inside, and becomes hollow. It is the blower's business to take up just so much glass as will make the article needed; but the mode in which he makes an elegant vessel out of the crude soft lump, is not easily described. He whirls the tube and the mass of glass round in the air; blows through the tube; rolls the glass on an iron plate; shapes the article with small tools; cuts off superfluous portions with scissors; blows and rolls again and again—until a goblet or other vessel is produced, with a dexterity very striking to a looker-on. Sometimes, for particular articles, the glass requires to be pressed against a pattern; sometimes to be pressed or cast in a mould; its peculiar pasty or putty-like state enables it to adapt itself readily to all such processes. This condition also enables it to be drawn out into tubes for thermometers and barometers.

All flint glass articles require to be annealed by slow heating and slow cooling, to fit them for use. Many of them afterwards receive those adornments which earn for them the designation of *cut* glass.

The surface of the glass is ground away at certain parts, according to the taste of the workman, by means of small revolving wheels of cast iron, wrought iron, Yorkshire stone, willow wood, and other substances; and additional beauty is secured by allowing some parts to be dull or ground, and other parts polished.

WINDOW, PLATE, AND BOTTLE GLASS.—*Crown* glass, or common *window* glass, contains sand or flint, like flint glass; but lime is used instead of oxide of lead, and soda generally instead of potash. Crown glass is made in a still more singular way than flint glass. The workman dips the end of an iron tube into the molten glass, and takes up a quantity. By a little swinging and rolling, and a great deal of blowing and rotating, he brings several pounds of paste-like fiery glass to a hollow globular form. This globe is flattened a little, then opened at one point, and then rotated until it flashes out into a flat circular sheet—one of the most surprising processes in the whole range of the mechanical arts. This sheet, at a proper stage of the operation, is detached, and placed in an annealing oven, where it acquires a durability necessary for its future usefulness.

There is, nevertheless, something very wasteful about this so-called crown glass. Each sheet or *table*, as it is termed, being circular, cannot be cut up into four-sided pieces, without leaving many curved fragments; and there being a thick part or *knot* in the middle, further waste results. To obviate this double source of waste was the chief reason for making *sheet* glass, which is now coming rapidly into use. There are processes not less beautiful and remarkable than those already described. The workman takes up, on the end of his iron tube, a large mass of glass, and whirls it about in an extraordinary way. He swings it round in a vertical circle, blows into it, swings it again, rolls it, until at length it protrudes beyond the end of the tube, as a cylinder, perhaps four feet long by ten inches in diameter. This cylinder is easily opened at the two ends and detached from the tube. A hot iron wire severs it in a line from end to end; and the cylinder by careful heating and rubbing, opens out into a square sheet, flat, but slightly wrinkled on the surface. Much larger panes can in this way be obtained than from crown glass. The two Crystal Palaces, at Hyde Park and Sydenham, and the new Exhibition building at Brompton, were glazed with sheet glass made in this way.

Plate glass, for looking-glasses and mirrors, for large shop-windows, and for glazing large and valuable engravings, is made in a wholly different manner. It is cast, not in a mould, but on a flat surface; this surface is a carefully-prepared plate of iron, of very large dimensions, provided with apparatus for tilting it to any desired angle, and placed on wheels; The materials are selected and prepared with especial care, because any defects become very conspicuous when plate glass is silvered on one side. The molten glass is ladled out of the furnace and examined, in small portions, with a view to the removal of impurities and defective portions. When the molten mass is in a proper state, an iron vessel, called a *cuvette*, is placed in the furnace, brought to a white heat, and filled with molten glass by means of ladles. The cuvette is taken out, and tilted in such a way that the whole of the golden lava (as the glass appears), is poured out upon the surface of the iron table. A heavy polished iron roller, resting on ledges, brings the layer to an equable thickness. As soon as the glass has become solid by partial cooling, it is dexterously slid into an annealing oven; and when annealed, it is ground and polished, by means of sand, ground flint, emery powder, cloth polishers, and polishing paste. It is a precarious and expensive manufacture, for no one can tell until the plate of glass is finally polished, how many or what kind of defects it will present, or how much of its value will be deducted on account of such defects.

Bottle glass is of so common a kind as to need little description; yet it is commercially one of the most important of all, on account of the immense quantity made. Common wine and beer bottles are not purposely made *green;* this colour results from the coarseness of the ingredients employed. The sand and alkali are the cheapest obtainable. In making a bottle, the mass of molten glass, at the end of the tube, is inserted in an iron mould, which gives the external form; while the hollowness is produced by blowing through the tube. White glass chemical bottles, though requiring more nicety in the ingredients and the processes, are made nearly in the same way.

4. Acids, Alkalies, and other Chemicals.

We shall here group a number of acids, alkalies, and other chemical substances, together with certain manufactured articles produced from them. It can at best only be a selection from a vast list; it will include *salt*, *soda*, *potash*, *sulphur*, *sulphuric acid*, *aquafortis*, *saltpetre*, *gunpowder*, *gun cotton*, *alum*, and *soap*.

Common or Table Salt.—If there be one substance more than another, of which the cheapness hides from us the inestimable value, it is *salt*. This substance is absolutely necessary to us, for rendering food digestible and palatable, and for preserving it when intended for keeping; and yet, as we can obtain it at a farthing a pound, or less, we are too apt to regard as a trifling article. Only in countries where there are neither salt mines nor sea water, can the true worth of this treasure be really understood.

Salt, when pure, is *chloride of sodium*, sometimes improperly called *muriate of soda*. Nature has diffused it very abundantly. It forms thick solid beds in many places underground; it is the chief ingredient in large subterranean pools of brine; and it exists largely in sea water. When pure, it is one of the most beautiful of white solid substances, consisting of crystals that would well repay examination under the microscope. Not only is it used in the various domestic ways so familiar to all of us, but it is also the great source from which *soda* is obtained.

In England, our great stores of salt are obtained chiefly from Cheshire and Worcestershire, the former especially. Vast beds exist near the river Weaver and its principal tributaries, under or not far from the towns of Northwich, Nantwich, Middlewich, and Winsford. It was somewhat less than a century ago that, in searching for coal, rock-salt was found near Northwich; the value of the product led to successful examinations elsewhere. There is one vast bed of reddish salt near Northwich, twenty yards in thickness, and another forty yards; both so hard as to require blasting with gunpowder, in order to extricate the salt for bringing up to the surface. Smaller beds exist in other spots. Besides this, there are pools of brine of intense saltness; supposed to have been formed by underground streams flowing over beds of rock salt, and becoming saturated in their passage.

Salt is prepared in three ways—from the rock-salt, from the brine, or from a mixture of both. Practically they differ, but in principle the three plans are alike; for they consist mainly of evaporating and drying. The rock-salt is dissolved in water to make brine, or is mixed with brine pumped up from the underground springs, or the natural brine alone is used. The liquid is exposed, in very large shallow vessels, to the action of the heat, which drives off the water in the form of steam, and leaves the salt as a sediment. This salt, in a particular state of crystallization or granulation, is ladled into square boxes, where it solidifies; and the high temperature of a heated room finally dries the rectangular masses extricated from the boxes.

In districts less bountifully supplied with salt mines, salt is often obtained by evaporating sea water. The water is collected in shallow receptacles. In rude countries, it is evaporated merely by the heat of the sun; but this process is tedious and imperfect, and artificial heat is now more generally employed.

SODA.—Soda, so largely used in the arts, was in former days obtained from an Italian sea-weed called *barilla*, and also from a Scotch sea-weed called *kelp*. Those were days when a very heavy excise duty pressed on salt; but when that duty was removed, and the salt rendered cheap in the market, it was found that soda could be prepared from this substance more economically than from any other.

The making of soda from common salt consists mainly in driving off the chlorine. To effect this, the salt is first mixed with sulphuric acid in a leaden pan, exposed to heat in a furnace. Chlorine from the salt, and hydrogen from the acid, combine to form *muriatic-acid gas*. This product, in the early days of the manufacture, was a troublesome nuisance to the soda-makers; but now a method is adopted of condensing the gas into a liquid, and selling it as *muriatic acid* or *spirit of salt*. The salt in the furnace, deprived of its chlorine, is a pasty mass. This is mixed with lime and coal in a powdered state, and thrown into the *balling furnace*. Here complicated chemical changes take place. The mixture, boiled and stirred in the furnace, changes to a darkish-coloured substance, which is allowed to flow out into shallow iron trays; this substance is *ball soda, crude soda*, or *British barilla*. It still comprises much that has to be got rid of. By dissolving in tanks of water, carbonate of soda is dissolved out of the substance, and the rest subsides to the bottom. The carbonate, by evaporation, and by a little further treatment in a furnace, becomes a yellowish earthy-looking substance—the *soda ash* or *soda salt*, so largely used by glass-makers, soap-makers, and other manufacturers.

POTASH.—This is another very important alkali, obtained chiefly by the burning of vegetable substances. The potash of the manufactories and shops is not pure potash, or oxide of potassium, but a combination of potash with some other substances; while *pearlash* is carbonate of potash. Crude potash is made in North America in the following manner. Certain plants are burned in pits, and the ashes collected. These ashes are steeped in water until all the alkali has been soaked out of them. The liquid is evaporated to dryness, and slightly calcined; in which state it constitutes crude potash. Different plants, and different parts of the same plant, yield very different proportions of this substance; and the alkali is itself vitiated by different kinds and quantities of impurities. By further processes, it can be brought to the state of a nearly pure carbonate of potash. A peculiar method of treatment leads to the production of *pearlash*.

SOAP MANUFACTURE.—This very useful substance owes its usefulness to the fact that, although oil or grease will not combine with water, they may be made to do so if an alkali be present. In washing hands or garments, the greasy particles which are always more or less present resist the action of clean cold water used alone; but if a little alkali be added, this combines with the grease, the two together become soluble in water, and are then easily washed off. Herein is the whole philosophy of the subject. The soap-maker takes the trouble off our hands. He makes a solid compound of fat or oil and alkali, soluble in water, and fitted to remove greasy particles by combining with and rendering them also soluble. Every laundress conducts a chemical process in each of her washings, although she does not dignify it with such a title.

Different kinds of fat and of alkali are used in soap-making. *Mottled* soap is made of soda, tallow, and that miscellaneous compound known as 'kitchen-stuff.' *White* or *curd* soap is without kitchen-stuff; and the tallow and alkali are selected with more care. *Yellow* soap consists of palm oil, resin, and alkali.

Soft soap contains oil instead of tallow, and potash instead of soda; the composition being such that the soap is always in a soft or pasty state.

In making mottled soap, which is perhaps the kind most largely used in England, the processes are thus conducted. The tallow, principally brought from Russia in casks, requires very little preparation. The kitchen-stuff is melted, strained, and made as pure as is practicable; but it is only used in the inferior kinds of soap. The soda is dissolved in water, to form a *ley* or *lye*. This lye, the fat, and a little salt, are put into a boiler and heated by steam, being kept well stirred all the time. After a certain amount of boiling, it is found that the soda of the ley has combined with the tallow, leaving the spent ley at the bottom; this spent ley is pumped out, and fresh added, until the tallow has combined with as much alkali as its natural affinity will permit. The mixture is now *soap*, in a thick or viscid state.

When the soap is thus far made, it is ladled into buckets or pails, and poured into large square vessels of wood or iron. When the soap has become cold and solid, the vessel or frame is removed piecemeal, leaving the mass standing up on one edge. The soap is cut into *slabs* and the slabs into *bars*, by means of wires.

For *curd* soap, the processes are nearly as above, although more carefully conducted. *Yellow* soap, in like manner, differs from the others rather in the ingredients than in the processes. Soft soap has a consistency which renders some of these processes unnecessary. Any kind of oil will do—whale, seal, olive, or linseed—according to the state of the market. When made, the soft soap is poured at once into barrels. The speckled appearance is due to differences in the action of oil and of resin upon the alkali. The *perfumed* or *fancy* soaps have pure white soap for their basis; the perfumer melts this soap, and combines with it any one among a large number of perfumes; thereby obtaining *rose* soap, *cinnamon* soap, *musk* soap, *honey* soap, &c.

Sulphur or Brimstone.—Sulphur is one of the most curious substances with which we are acquainted. It is neither an earth nor a stone, neither a metal nor a compound; while its intense yellow colour places it apart from nearly all other substances. Its two names, *sulphur* and *brimstone*, derived from words meaning fire-salt and burnt-stone, bear relation to the inflammable character of the substance. Sulphur is met with naturally, combined with many other substances; such as iron, copper, lead, antimony, lime, barytes, strontia, magnesia, &c. It can be separated from all these by heat and chemical agents. Nature has also supplied one particular store of sulphur nearly in its pure state—so vast, that our wants can be almost wholly supplied from that source. This is in Sicily, at and near the base of Mount Etna. There is evidently some connexion between volcanic agency and the formation of this substance; for sulphur is found in fissures in the lava of all the volcanic tracts of Sicily, Italy, Iceland, and other countries.

The sulphur on the sides of Etna mostly lies imbedded in tufa, limestone, and other substances, from which it requires to be separated by burning. This would be better done in England than in Sicily; but in order to lessen the expense of freight, the Sicilians do it themselves. The ore is dug out by mining, like any other mineral. It is built up in a large heap, covered with earth and rubbish, and set on fire. The sulphur melts out of the mass, and flows through orifices into troughs: although at first a black pitchy liquid, it cools into a yellow solid. As thus brought to England, it is dirty and impure. To refine it, the brimstone is distilled in large cast-iron stills, and condensed in an iron receiver. This refined sulphur becomes *roll* sulphur when melted and poured into wooden moulds. If it be heated to vapour, and then condensed in a large, cold, dry chamber, it assumes the form of *flower* of sulphur, or sublimed sulphur.

SULPHURIC ACID.—Sulphur in the plain state is used in making matches, gunpowder, and other articles. The most extensive use, however, is for making *sulphuric acid*, or oil of vitriol; one of the cheapest and most powerful of all acids, invaluable in many of the manufacturing arts, especially that of making soda, lately described. The sulphur employed for this purpose has no need to be refined; it is used in the state of crude lumps, as brought from Sicily and elsewhere. It is thrown into a furnace and burned, great precautions being taken to prevent the suffocating fumes from escaping into the furnace-room. The sulphur is all burnt away, and the gaseous products pass upwards into vessels of enormous magnitude, lined with sheet lead to resist the corrosive action of the acid. In these chambers sulphurous acid gas rises; steam and nitrous acid vapour are admitted; there is then formed sulphuric acid, a liquid heavier than water. This liquid collects at the bottom of the chamber, whence it is drawn off into a tank. For some purposes the acid is not strong enough without further concentration. This is done by distilling it in platinum stills—platinum, though very costly, being used, because the corrosive action eats away almost all other kinds of metal. Some years ago, such stills were valued at so high a price as a guinea an ounce—fourfold the value of silver!

Aquafortis.—Muriatic acid, we have shown, is obtained from salt, sulphuric from sulphur; and now we have to show in what way *nitric acid* or *aquafortis* is produced. It consists of oxygen and nitrogen, two very simple gases in themselves, but producing a wonderfully powerful agent when in combination. Chemists have the means of producing it by the direct union of the two elements; but it is more usually obtained by decomposing substances which contain it in combination with other elements. All rain-water contains a little of it; so do most kinds of chalk, many kinds of soil after heavy rain, and numerous other easily-obtained substances. How to separate the nitric acid from the other constituents of these substances, is a question for the skill of the manufacturer to settle. As usually conducted at the present day, crude *saltpetre* (presently to be noticed) is the chief agent. This salt is put into large iron cylinders, together with sulphuric acid; and when the mixture is heated to a certain degree, vapour passes off through a still into another vessel, where it cools down to a liquid, which is *nitric acid.* On a large scale, nitrate of soda is employed instead of saltpetre.

This excessively acrid liquid is colourless and transparent. The aquafortis of the shops is not precisely the pure nitric acid of the chemist, for it contains certain impurities; but the one as well as the other possesses very powerful properties. Its uses in the arts are chiefly of a threefold character—to form the important class of salts called *nitrates*, by combination with other bodies; to yield up oxygen or nitrogen by decomposition, as an aid to the formation of other substances; and to bite, eat away, or corrode metals or other bodies which, for particular purposes, are exposed to its action.

SALTPETRE.—*Nitre* and *nitrate of potash* are only other names for *saltpetre.* This last name, implying 'stone-salt' or 'salt of stone,' was given because the substance is often met with in or upon stone and brick walls. Nitre can be made by the chemist from nitric acid and potash; but for manufacturing purposes it is obtained in an easier way. Nitre, as a white flowery substance, is seen on the ground after the rainy season, in many parts of the tropical zone, as in India and Egypt. It is found on the rocky walls of caverns in certain places. The flowery nitre, which is in reality nitre combined with other substances, is dissolved in water and evaporated to produce what is called *rough nitre* or *crude saltpetre.* The plaster of old walls frequently becomes coated with nitre, from some chemical action produced in certain ingredients of the plaster. The rough nitre requires to be purified before it will be fit for most manufacturing purposes. This purifying consists in dissolving in water, heating and stirring, clarifying, skimming, drawing off without disturbing the sediment, cooling, and crystallizing. The crystals thus obtained consist of nearly pure nitre or saltpetre.

GUNPOWDER.—This extraordinary substance is a compound of charcoal, sulphur, and saltpetre. A monk, named Berthold Schwartz, described the mode of compounding it five hundred years ago; but it is now known that the Chinese and the Hindoos were acquainted with the composition of gunpowder at a much earlier period. Each of the three ingredients produces a particular part of the explosive action of this substance. The saltpetre, when heated, gives forth oxygen gas readily; the charcoal and the sulphur combine with this oxygen; heat is diffused through the mass; and the solid substances are converted into several gases, chiefly carbonic-acid gas, carbonic oxide, sulphurous acid gas, and nitrogen. These gases occupy an enormous bulk in comparison with that of the substances from which they were derived —supposed to be at least two thousandfold; and the instantaneous driving away of the air on every side, to make room for this expansion, leads to the destruction of surrounding objects with terrific violence. In *gunnery*, the gunpowder behind the ball can find room for its expansion only by one or other of two modes—bursting the gun, or driving out the ball; and the arrangements are planned to produce the latter of these results. The sulphur, though it does not produce the explosion, gives suddenness and intensity to it.

Great care is observed in all the processes of gunpowder-making. The proportions of ingredients, though not uniform, are near about six parts by weight of saltpetre, one of sulphur, and one of charcoal. English military powder has a little more charcoal than sulphur; but powder for blasting has them in about equal quantities. There are also slow-burning and quick-burning kinds of powder for fireworks, depending on the proportion of the ingredients.

In making gunpowder, the saltpetre is dissolved, boiled, filtered, and crystallized, to free it from all impurities. The charcoal is carefully made of alder, willow, or dog-wood, burned in iron retorts. The sulphur is refined and sublimed to the greatest degree of purity. At the gunpowder mills, such as those at Waltham Abbey, the greatest precautions are taken to prevent explosion. Iron is excluded as much as possible from the buildings; iron tools and vessels, iron nails in shoes—everything that could lead to the striking of a spark—are sedulously guarded against. And in winter weather, or in dark hours generally, equal precautions are taken against accidents from the use of artificial lights. Even with all this scrupulous attention, however, explosions sometimes occur, bringing ruin and death in their train.

The several ingredients, when refined and prepared, are weighed in due proportion, and mixed in a barrel. The mixture is slightly wetted with water, and ground under very heavy vertical stones rolling on a bed-stone. The mixture thus becomes a damp stiff paste, called *mill-cake*. This mill-cake is sent to the *corning-house*, to be brought to the state of small corns or grains. This is effected by pressing it by hydraulic power into a thin layer called *press-cake;* crushing or breaking this cake into small pieces; and corning or graining. To effect this last-named process, the small pieces are placed upon parchment sieves pierced with small circular holes; and rollers of very hard wood are made to roll over the fragments, crush them still smaller, and press them in such a way that they are forced through the perforations. The gunpowder, thus *corned*, is then *dusted*; that is, it is sifted through fine hair sieves, to separate the dust or powder from the grains. The grains or corns are then put into a sort of drum or cylinder, and rotated until they rub off all each other's edges and become rounded; they are by the same process polished or glazed. After this the gunpowder is carefully dried, in a room heated by steam or hot air.

GUN-COTTON.—This very singular substance has not yet come much into use as a substitute for gunpowder. Nitric acid, when mixed with any woody or vegetable fibrous substance, acts in a remarkable way upon it, rendering it very inflammable, and in some cases explosive. Common cotton wool is found to be a useful form of fibre for this purpose. A mixture of nitric and sulphuric acids is made; the cotton is well soaked in it, pressed to expel all superfluous acid, washed with clean water, and dried. The substance thus obtained, *gun-cotton*, is still white wool in appearance, though heavier and harsher than before. It is more wonderfully explosive even than gunpowder. Indeed it explodes too rapidly for useful purposes; and as it is expensive to make, and dangerous to have anything to do with, it is not at present much in demand.

ALUM AND ALUMINIUM.—It would strike most persons as a marvel, to be told that the crystallized substance, *alum*, has pure *clay*, dull opaque clay, for its basis; and still more a marvel, that this clay has its basis in the brilliant white metal, *aluminium*, now coming into use for various purposes. Such is nevertheless the relation between the three substances. Alum is made in two or three different ways; and sometimes, but very rarely, it is met with naturally formed. Common alum is a compound of sulphuric acid, alumina, and potash, or a *sulphate* of alumina and potash. In the alum works near Whitby, and other places, there are strata of earth called *alum-stone, bituminous shale,* or *clay slate,* all of which contain some of the elements of alum. They are sometimes obtained by mining near the sea-shore; sometimes they occur as intermediate strata in coal-mines; and sometimes they can be scraped off the roofs of the passages of coal-mines in a powdery state. When the alum ore is dug up, it is steeped for some time in water containing a little sulphate of alumina and iron, until all the soluble matter is dissolved out of it. This solution, when drawn off from the sediment, is boiled, and exposed in large coolers. Some of the ingredients crystallize into sulphate of iron or green copperas; the remaining ingredients are boiled again, potash is added to them, and these crystallize into *alum.* This alum is at first crude and rough; but it becomes purified by further boiling, evaporating, and crystallizing.

If soda or ammonia be added instead of potash, the combination is still alum, though of a slightly different kind. If hard alum-stone be used in the first instance instead of the powdery substance, it requires to be broken and calcined before it will dissolve.

Alum is also largely made, at some of our great chemical works, in a wholly different way. Cornish clay is ground, calcined, and washed, to bring it to the state of nearly pure alumina. To it is added sulphuric acid, with which it combines rapidly. When diluted, and the uncombined particles of clay have subsided, the liquid is pumped up into leaden cisterns; sulphate of potash is added; and after a few more processes, crystallized alum is produced.

It is from this very same alumina, or purified clay, that the white metal *Aluminium* is now produced, by a complicated series of processes. The operation has not yet become a cheap one; but the supply of material is practically inexhaustible; and quicker and more economical processes will doubtless be discovered.

5. Paints, Colours, and Dyes.

It is a very pleasing department of chemistry that takes note of the production of *paints, colours,* and *dyes,* for the use of the artist, the house-painter, the paper-stainer, the glass-stainer, the calico-printer, the dyer, and other handicraftsmen in art and manufactures. Some of these chemicals combine with the substance to which they are applied, as in the case with fast-colours in dyeing; whereas others, while more or less adhesive, remain on the surface only. Some are applied as liquids, for dyeing, &c.; some are mixed with oil; some with size; some with a kind of paste. The actual processes of making are chiefly grinding, melting, dissolving, filtering, &c., which need not be more particularly described. It will be more interesting to notice the sources whence the substances are obtained. Although this chapter purports to relate to substances of mineral origin only, it will be convenient to treat of animal and vegetable dyes and colours as well as mineral.

Animal Dyes and Colours.—The number of substances used by the dyer is considerable. The substances, too, are very diversified, derived from all the three kingdoms of nature, and existing in all the three states of solid, liquid, and gaseous. They nearly all act in the same way, however; they enter into the minute pores of the fabric which is to be dyed, and then combine with it in such a way as to become insoluble: if not rendered insoluble they would wash out, and would not in effect be dyes. This affords one test of the skill of the dyer: so to select his drugs that, while a particular colour shall be produced, the dye shall permanently combine with the cloth or other fabric. There is also this matter to be considered—that the dye does not always present, as a liquid, the same shade or tint of colour, sometimes not even the same colour, as it will present when applied to cotton, wool, or silk.

The chief animal dyes, stains, and colours, are the following. *Cochineal* is a very remarkable substance. It is not merely obtained from an animal; it is *the* animal itself, in a dried state. The cochineal insect, found chiefly in Mexico, feeds upon particular plants, which seem to infuse its whole body with colour. At certain seasons the female insects only are selected, killed, and dried for sale. In this state they appear like brownish grains, about as large as peppercorns. Their inner substance, when dissolved, gives the beautiful carmine colour, obtainable from no other source. In dyeing *scarlet*, carmine is combined with muriate of tin, the two together producing this tint. Being extremely valuable in proportion to the bulk (six or eight shillings per pound), cochineal is often used as a substitute for money between Mexican and other merchants; it is sent as a remittance from one to another, each merchant knowing that he can at any time obtain a ready sale for it in the market.

Lac is sometimes spoken of as if it were an animal substance; but, although produced by a puncture made by an insect in the trunk of certain trees, it is really a gum or resin. There are several kinds of trees treated in this way, in the East Indies; principally fig-trees. At certain seasons the exuded sap is collected by the natives in the state of a thick juice; and it comes to market under the designations of *stick lac*, *seed lac*, and *shell lac*, according to the form given to it. For many purposes, lac is used as a gum or resin, and in making sealing-wax, or varnish; but for other purposes it is a colour or a dye. The Hindoos prepare a scarlet dye, which they use very extensively, by treating stick lac with alum, and thereby drawing a colouring substance out of it, to which the names of *lac dye* and *lac lake* are given.

Sepia is an intensely black liquid, obtained from the extraordinary animal called the *cuttle-fish*. The liquid is often ejected from the living animal, either to favour escape by discolouring the water, and rendering him invisible, or as a means of offensive warfare. It was used by the ancients as ink. A more remarkable fact is, that the black fluid has been found in fossil specimens of the cuttle-fish, or some similar animal, where it had remained for unnumbered ages. Cuvier, the great naturalist, made a drawing of a fossil sepia or cuttle-fish, with ink obtained from the fossil itself; and Chantrey the sculptor made an artistic sketch with the same liquid. Sepia is obtained for the use of artists (it is too scarce and costly to be used in dyeing) by collecting the black fluid from a bladder within the fish, drying it, and carefully preparing it into cakes and other forms. Although originally black, it becomes when used a brown pigment.

Blood, it might be thought, would be a cheap and abundant source of red colour; but the colouring substance constitutes only one-eighth part of the whole mass, and thus soon changes to a kind of dirty brown.

VEGETABLE DYES AND COLOURS.—The vegetable substances used as dyes and colours are far more numerous than the animal. They may be classified in many different ways; but perhaps the most useful is according to the tints.

The principal *red* dyes and colours are *madder*, *Brazil wood*, *Sapan wood*, *Nicaragua wood*, *logwood*, *sandalwood*, *safflower*, *St. John's wort*, and *alkanet root.* Some of these, as the names denote, are wood, the actual woody portion of plants, containing naturally a coloured substance which can be extracted from them; others are flowers; madder is a dye contained in the root of a particular plant; Brazil wood, by various modes of preparation, yields the several colours called crimson, lake, Berlin red, and purple-lake.

The *blue* and *violet* kinds are produced from *indigo*, *woad*, and several other plants. Indigo, the most valuable of them all, is a blue substance obtained from every part of the indigo plant, by steeping, scalding, evaporating, and other processes. Woad, an inferior blue colour, is obtained in a similar way from the woad plant. *Sicilian blue*, *litmus*, *turnsole*, *orchil*, and *cudbear*, are produced from certain kinds of lichen or moss.

The *yellow* vegetable colours are mainly derived from *weld*, *quercitron*, *fustic*, *hickory*, *arnatto*, *turmeric*, *French berries*, *Persian berries*, *saw wort*, *heath*, *dyers' broom*, *saffron*, and *rhubarb*. Weld is obtained from the steepings of the weld plant; quercitron from the bark of an American timber tree; fustic from the yellow wood of a species of mulberry tree; hickory from the bark, green leaves, and nut rinds of the hickory tree; arnatto from the pulpy seed-pod of an American plant; turmeric from the wood of an Asiatic tree; French berries and Persian berries from the unripe fruit of certain trees; saw-wort from the leaves of the plant so named; heath and dyers' broom from plants well known on our commons and hills; saffron from the flowers of the *crocus sativus.*

Those vegetable colours which are placed among the *fawns* and *drabs* are obtained from *sumach, walnut peel, birch,* and *henna.* Sumach is derived from the shoots of the *rhus coriaria;* walnut-peel from the well-known fruit; birch dye from the bark of the birch-tree; and henna (in the east, where it is used for staining the skin and the nails) from the leaves of the Egyptian privet.

The *black* vegetable colours and dyes are principally *gall nuts* and *valonia.* Gall nuts are an excrescence on the bark of a species of oak, the *quercus infectoria.* The acorn cups of many plants yield a similar black dye; especially those of a tree growing abundantly in Greece and Asia Minor; they came to England under the name of *valonia,* and are sought after as being cheaper than nut-galls.

Green and *brown* vegetable dyes and colours are few in number. Those tints are generally produced, if from vegetable substances, by combinations of two or more among those already adverted to.

Among dyeing and colouring drugs may perhaps be included the *tanning* drugs, the use of which is noticed in the Second Chapter. Many of the dye-drugs described in this section are also used for tanning; but the chief kinds are *oak-bark*, obtained from various species of oak; *catechu* or *terra-japonica*, obtained from the wood of the *acacia catechu*; *mangrove*, from the bark of the mangrove tree; and *mimosa*, from the bark of an Australian tree.

MINERAL DYES AND COLOURS.—The minerals employed to produce colour, although not so numerous as the vegetable sources, are much more so than those of animal origin. In most cases, the mineral does not itself possess the colour, nor would it produce the colour if used alone; the result is brought about by various combinations, involving a good deal of chemical nicety. Hence a dyer and a colourman ought to be chemists, or ought at least to be familiar with one particular department of chemical science. Some mineral colours are earths; some oxides, some salts, some acids, and some alkalies. Metals are not in themselves colouring substances; but several of them become so when in combination with other bodies. If, as in the case of vegetable colours, we classify those of mineral origin according to the colours produced, the following may be named as the chief among them:

To produce *yellow* mineral colours and dyes, recourse is had to *chrome yellow*, or chromate of lead; *chrome orange*, midway between yellow and red, and differing a little in chemical constitution from the chrome just named; *orpiment* or *king's yellow*, a chemical compound of sulphur and arsenic; and various oxides of iron with other metals, which form the group of *ochres*—such as yellow ochre, stone ochre, gold ochre, gold yellow, yellow sienna, Chinese yellow, &c. All these yellows appear to the eye like earthy substances; but for some purposes the colour can be extracted from them in a state of greater purity.

Red mineral colours comprise the following as the principal. *Vermilion* or *Chinese red*, a compound of sulphur and mercury; *chrome cinnabar*, or *yellow vermilion*, one among many chromates of lead; *red lead*, *Venetian red*, *minium*, *litharge*, varieties of oxide of lead: *oxide of iron*, presenting various shades from light red to dark brownish-red, and producing the colours known by the diversified names of *Armenian bole*, *Berlin red*, *colcothar*, *English red*, *red ochre*, *burnt ochre*, *red earth*, *terra di sienna*, *mineral purple*, *stone red*, *Indian red*, &c. The old and new red sandstones of the geologists owe their colour chiefly to the contained iron. Red enamel colours, suitable for enamel-painters and glass-stainers, are produced from some of the salts of gold and copper.

Blue mineral colours are very important. One is *cobalt*, which, together with *Saxony blue*, *smalt*, or *king's blue*, is prepared from the oxide of cobalt, combined with other substances. *Copper blue*, and some other kinds, are chiefly carbonate of copper.

The beautiful colour, *Prussian blue*, is one of the salts of iron. *Ultramarine, azure blue*, or *lapis-lazuli*, one of the most costly of all mineral colours, is prepared from the mineral called lapis-lazuli.

Green mineral colours are few in number, though many different names are given to them. *Brunswick*, *Scheele's* and *Schweinfurth* greens are combinations of arsenic and copper. Oxides of copper and of chromium will combine to form green; and various mixtures of blue and yellow will do the same.

Brown mineral colours comprise few except *raw umber, burnt umber*, and *Sienna brown*, which are oxides of iron and other metals, and sometimes take rank among the ochres.

Black mineral colours are chiefly *black lead* and *charcoal*, prepared in various ways. Others are yielded by certain mineral substances when in combination with vegetable dyes.

White mineral colours are much more numerous than those of vegetable origin; indeed, scarcely any vegetable white is permanent. *White lead* or *flake white; zinc white*, as a substitute for white lead; *chalk*, or carbonate of lime; *gypsum*, or *plaster of Paris*, which is a sulphate of lime; *sulphate of barytes; steatite*—these are the chief white mineral pigments employed in the arts. In many operations, described briefly in former chapters, white is produced, not by adding anything, but by simply removing colour already in existence; such, for instance, as in the whitening of calico, cambric, muslin, linen, and other woven textile goods, by bleaching with chlorine or other chemical agents.

The Magenta Class of Colours.—We have purposely left to the last a few words concerning those very beautiful colours of the *magenta* or *aniline* class, which are the latest results of chemical research into mineral colours, and which have recently come into such great favour. It is in every sense an interesting inquiry; for not only are the colours highly beautiful in themselves, but they are all produced from a substance that is about one of the last to which we should feel disposed to attribute the power of producing anything beautiful. This is *gas-tar*. Reference to a former chapter will remind the reader that this tar is produced during the manufacture of common street-gas at the several gas-works. At first it was a terrible nuisance to the gas-makers; it cost them great trouble to separate it from the gas; and when separated, they did not know what to do with it. It was in every one's way. At this juncture, however, chemistry stepped in and solved the difficulty, as it has done in many similar cases. A distinguished man has well said that "dirt is only something useful in the wrong place." Nothing whatever is absolutely useless: even dirt, rubbish, or waste possesses value if we only apply it in the proper place and at the proper time. As there is a time for all things, so is there a place for all things; and science is continually correcting our daily proceedings in this matter.

Coal-tar, we have said, produces beautiful colours. The matter is thus managed. The coal-tar is subjected to a chemical process, by which *aniline* is obtained from it. This aniline is a colourless oily substance, which is obtained also from various plants; the makers produce it in preference from coal-tar because of the cheapness and abundant supply of that material. The coal is distilled in such a way as to produce *heavy oil* and *light oil*. The heavy oil is usefully employed as a preservative for wood, and also as a medicament in the treatment of ulcerated wounds. The light oil is *coal-tar naphtha*, whence is obtained *benzine*, *aniline*, and a number of other chemical substances. Benzine is employed to dissolve gutta-percha, to make varnish, to dissolve greasy substances, and to clean gloves and textile goods; it may also be employed instead of oil for lamps. We thus see that coal-tar, the despised residue of former days, is really a very valuable substance, yielding other substances useful both in the manufacturing arts and in medicine.

Without noticing further the other products from coal-tar, we will fix our attention upon benzine. When treated in a particular way with aquafortis, this substance yields a yellowish liquid so pleasantly fragrant as to be a welcome scent for perfumery and toilet soaps; and when this yellowish liquid, called *nitro-benzine*, is further exposed to the action of hydrogen gas, it produces the colourless oily liquid *aniline*. From aniline, by various modes of treatment depending on the kind of result intended to be produced, are obtained those beautiful colours known by the names of *Magenta, Mauve, Aniline purple, Violine, Roseine, Solferina, Emeraldine, Azuline,* &c. The rich purple of one colour, the intense crimson of another, the peculiar bronze of a third, the fuchsia-tint of a fourth, &c., are universally admired. They have all a peculiar kind of lustre, not easily described in words, but very apparent when compared with the effects of ordinary colours. Cotton fabrics, such as muslin and calico, do not take these magenta or coal-tar dyes so readily as silk and wool; the dyer's art is needed to bring about the union by indirect means. A celebrated French chemist, in speaking of these very valuable colours, says—"Coal has not yet been transformed into diamonds; but we can extract from it a violet colour equal in value to gold itself;" and another says that the relative value of the coal and its beautiful produce may be thus declared: "Whilst the coal employed to obtain it would hardly sell at one farthing per pound, a similar weight of aniline dye is worth sixty or eighty pounds sterling." This, however, was in the infancy of the manufacture; dyers could not afford to use such substances until the price had been greatly reduced by improved processes.

It may not be unfitting to mention here that *guano* —a substance still more disagreeable and even offensive than coal-tar—has in a similar way been made to yield beautiful colours available to the dyer.

This manure, which we are in the habit of believing is only known to farmers and those who sell to them, produces a number of curious and beautiful substances by chemical action. Among them is *murexide*, the brilliant colours of which have been thus clearly described:—"It consists of small quadrangular crystalline plates, which reflect light of a green metallic lustre, like the wing-cases of a golden beetle. Two of the prismatic sides of a single crystal of murexide reflect this green metallic light; whilst the other two reflect only a dull brown light. When seen by transmitted light—in other words, when looked through—these little crystals appear like so many garnets of the finest claret tint. When pulverised, they furnish a red powder, which, under the burnisher, becomes of a brilliant metallic green."—And all this from the unsightly and ill-odoured guano! In the dyer's hands, the murexide is made to yield an almost endless series of carmine, purple, orange, and yellow tints, very brilliant and beautiful.

Minerals and Chemicals—how inexhaustible is this group! Some of the more important have only been mentioned; but the reader will have seen that even this selected number is considerable; and that the substances themselves, their origin and their preparation, are full of interest.

CONCLUSION.

One useful lesson may be derived from this small work, and in a still greater degree from works in which more ample space permits more detailed treatment. It is, that man's industry, strictly speaking, *produces* nothing; he only modifies that which the bounty of Providence places at his disposal.

Let us consider this matter a little. By what means, and out of what materials, do we fabricate our *metal* goods, for instance? It is impossible not to perceive, on fair consideration, that Nature supplies all the substances on which our ingenuity is exercised. Every atom of the metal is contained in the ore; we only extricate it by driving off other substances. And when it has become pure, we change its *form* by various means, but *produce* nothing. We do not even produce heat by kindling the fuel in the furnace; all the elements of heat are there, in a latent or quiescent state; we merely apply the spark, and the chemistry of nature does the rest. Nor do we any the more produce light; the hydrogen and the carbon are in the substances employed, the oxygen to feed the combustion is in the atmosphere; we place these substances in a position to act upon each other, and bring some other hot substance in contact with them—all the real *production* that follows is the result of natural forces. If it be said that the glass-maker produces glass, the assertion can only be accepted in a general conversational way. The sand and the alkali are placed together by him in a kiln; the coals are placed by him in a furnace; a light is so placed by him that it may kindle paper or wood, and the wood kindle the coal—but all that follows is beyond his grasp. Forces, powers, properties, or by whatever other name we may designate them, are possessed by these substances, enabling them to *produce* glass, when the conditions are favourable; and it is the business of the glass-maker to bring about these conditions. He places the proper substances and agencies together, in due relations and due proportions; but the production that follows is altogether beyond his power.

Nor is it any the more true to say that the farmer produces corn; although it is a very convenient expression as popularly understood. He loosens the soil in such a way that air and moisture may act upon it; he places the seed beneath the surface at such a depth that the moistened soil may envelope it; he so chooses the time of sowing that the sunshine of summer may nourish and warm the young shoots. But the *growing*, the *producing*, is due to a Greater Artificer than he. The production of fleecy wool on the back of a sheep, of silk in the cocoon of a little worm, of cotton in the seed-pod of a plant, of flax in the stem-fibres of another plant, of wood in the trunks of forest-trees, of sap and gum in the bark, of oil in the nuts, of nutritious farina in the seeds, of grateful juices in the fruit.—What has man to do with all this? He simply places together the materials, the tools with which Nature works.

Let it not be supposed that these observations are intended to lower the dignity of human industry. Just the contrary. True dignity, in this as in other matters, is generally consistent with seeming to be what we really are. Man is a helper, a labourer; but Nature is the master artificer. Man fetches and carries, places side by side, weighs and adjusts, tests and purifies, the various substances of which all the things around us are made; but there is always a moment in each operation, when he must hold his hand, and let the real work be accomplished by a higher power than his. But, unless these preliminary operations of selecting, placing, weighing, adjusting, testing, purifying, and the like, are properly conducted, the work will not be done according to our need, because the natural forces are not placed in the proper conditions for attaining the desired end. That man *creates* nothing, we are all ready enough to admit—at least, in a material sense; what are called the *creations of genius* do not come into consideration here. A tree weighing a thousand pounds has grown up from a little seed weighing one grain; but still all the carbon, oxygen, hydrogen, nitrogen, &c., of which it consists, were previously in existence—in the air, the earth, and the waters. That man *produces* nothing, although not so readily assented to, is equally true. A mass of sugar weighing a thousand pounds is brought to its familiar form by a multitude of processes to which the sugar-cane is subjected; but all the elements of sugar are of natural origin, like the elements of the tree. The farmer in the one case, the sugar-boiler in another, is the labourer that puts this and that together—places, cuts, trims, varies, adjusts, protects. He is not only a carrier and a labourer, but a watchman also, attending to the tools and materials with which Nature works; and the more intelligent and industrious he is, the better will the work be done; but, nevertheless, the real work of producing is due to an Invisible Hand.

THE END.

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